ENGINEERING GEOLOGICAL EVALUATION OF RESERVOIR SLOPES

Ph.D. THESIS

by

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DEPARTMENT OF EARTH SCIENCES
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE-247667 (INDIA)

DECEMBER, 2014

ENGINEERING GEOLOGICAL EVALUATION OF RESERVOIR SLOPES

A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree

of

DOCTOR OF PHILOSOPHY

in

EARTH SCIENCES

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ROORKEE

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"ENGINEERING GEOLOGICAL EVALUATION OF RESERVOIR SLOPES"** in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the Department of Earth Sciences of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during a period from December, 2009 to December, 2014 under the supervision of **Dr. R. Anbalagan**, Professor, Department of Earth Sciences and **Dr. M. N. Viladkar**, Professor, Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other Institute.

(SUJATA PARIDA)

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

(R. ANBALAGAN) Supervisor

(M. N. VILADKAR) Supervisor

Dated:

The Ph. D. Viva-Voce Examination of **Ms. Sujata Parida**, Research Scholar, has been held on . . . .

Chairman, SRC

Signature of External Examiner

This is to certify that the student has made all the corrections in the thesis.

Signature of Supervisor (s)

Head of the Department

Dated:

ABSTRACT

Koteshwar dam project is a 400 MW hydro electric project being executed on the river Bhagirathi, a tributary of Ganga in Tehri district of Uttarakhand. The project is located about 22 km downstream of Tehri dam and the reservoir extending to 17 km upstream and nearly up to the steel girder bridge which is located close to the Tehri dam. One of the major structures involved in such projects is the dam behind which the reservoir is formed. In the event of failure of any slope around the periphery of the reservoir and the consequent landslide that can occur, a large chunk of rock mass can collapse in to the reservoir body and generate waves, which travel towards the dam and can give a big impact on the body of dam and damage it. It becomes therefore essential to ensure the stability of hill slopes all around the periphery of the reservoir.

In the Himalayas, subtle variation in lithology and local changes in the orientation of rock discontinuities can make rock sliding extremely varied. Due to this variability, rock slope failures in some domains are so inevitable and certain that practical remedial measures are sometimes quite ineffective and extremely costly. An attempt has been made in the present study to discuss in detail the geotechnical investigation conducted at the site of Koteshwar reservoir, field and other studies undertaken for studying the stability of all the hill slopes around the periphery of the reservoir. Field studies included i) collection of all the geological data related to rock mass characterization of the slope material all around the periphery of the reservoir along Bhagirathi river, ii) conducting scan line survey at some typical slope sections and iii) collections of representive samples of rock and debris material forming the various slopes. The reason behind the rock slope failure is when the shear stress acting along a critical failure surface in a rock slope exceeds the shear strength of the slope mass in that slope.

As far as rock mass classification systems is concerned the properties of discontinuities are the main input parameters in most of the classification schemes. The CSIR classification system of Rock Mass Rating (RMR) has been used for classification of jointed rock masses. Slope Mass Rating (SMR) technique for stability assessment of rock slopes, is primarily based on the application of $(RMR)_{basic}$ and the orientation of discontinuities.

Entire test data was analyzed to assign rock mass rating at various rock slope sections identified and to classify all the debris/talus samples at debris/talus slope sites. Debris/talus slopes were then analyzed using the software packages-SARC and SAST for possible circular failure or a talus slide type of failure. Stability studies were carried out for computations of the factors of safety in static and seismic conditions for dry, partially saturated and fully saturated conditions of the slope mass. For all the unstable slopes, an attempt has been made to suggest the remedial measures, which in most of the cases, are in the form of re-profiling of the slopes using the method of benching and cutting. For rock slopes, possible mode of failure for every slope was identified using stereo plots prepared for every rock slope on basis of the geological data collected at the site. Kinematic analysis of rock slopes using Hoek and Bray charts was carried out for getting a priory idea about the condition of the rock slope. Similarly, Slope Mass Rating (SMR) system was also employed for obtaining the idea about the rock slope stability. Subsequently, detail kinematic analysis of rock slope was carried out using the software packages like SASP for plane wedge type of slide and SASW for three dimensional wedge failure. For all the unstable rock slopes, an attempt has been made to suggest the remedial measures in the form of cable anchors.

The main objective of the research work in this study is to identify the unstable slopes around the periphery of the reservoir and study the stability aspects of unstable slopes of Koteshwar dam reservoir which has been taken as a case study in the present research. The stability of slopes in the reservoir area is very important for the safe functioning of the dam/ barrage. Unstable slopes in the rim area of the reservoir may lead to slope failures during the operation of the reservoir.

On the basis of the entire study, it was observed that two slope sections in the left bank and five slope sections on the right bank of the Koteshwar reservoir are in critical condition. Attempt was also made to predict the possible height of wave which would be generated due to un-avoidable landslide and the corresponding wave height at the dam location when this wave travels upstream towards the dam. The values of maximum wave height generated at the location of these slope sections range from 0.7 m to 4.1 m. When these waves travel to the dam axis, the wave height left out varies from 0.0 m to 1.3 m. It is therefore clear that this wave height is not a matter of concern. This data is useful while adopting the preventive/ remedial measures.

ACKNOWLEDGEMENT

It is with great pleasure for me to pay gratitude to people who have helped and encouraged me during the difficult and challenging time of this study, without which I would have not come so far. First of all, I would acknowledge Indian Institute of Technology Roorkee (IIT Roorkee) for giving me this opportunity to this highly reputed education programme.

Before thanking God, I would like to give all my gratitude to my supervisors; Dr. R. Anbalagan, Professor, Department of Earth Sciences, Indian Institute of Technology Roorkee and Dr. M. N. Viladkar, Professor, Department of Civil Engineering, Indian Institute of Technology Roorkee for their valuable guidance, constant encouragement and keeping my spirit high and enriching my mind to complete the journey of research. Working under their supervision was a confidence-building experience. They freely gave their time and provided strategic and knowledgeable support, which I required to complete this task. I am indebted for their overall guidance. I highly appreciate their careful thoughts, constructive suggestions and patience. It has been a great pleasure and a privilege for me to be their student.

I sincerely thank to Indian Government especially to **Ministry of Human Resource Development** for providing me a sufficient grant for research work due to which I could pursue my doctoral programme without any economical burden.

I sincerely express my gratitude to Dr. R. K. Goel, Chief Scientist, Central Institute of Mining and Fuel Research, Roorkee and Dr. Priti Maheshwari, Associate Professor, Department of Civil Engineering, IIT Roorkee for their kind help and suggestions during this period of research.

I would like to express my sincere appreciation and thanks to Prof. G. J. Chakrapani and Prof. M. Israil (Chairman, SRC), Department of Earth Sciences, IIT Roorkee for their fruitful advice and valuable cooperation in academic work.

I am grateful to Prof. P. K. Gupta (former Head), Prof. A. K. Saraf (former Head) and Prof. D. C. Srivastava, Head of the Department, Department of Earth Sciences, IIT Roorkee for their help, constant encouragement and cooperation, which gave me strength for carrying out this research work.

I am also immensely grateful to Dr. Pitambar Pati (Bhaina) and his wife, Niharika for providing a homely environment in Roorkee with lots of affection and care.

Unrestricted and continued encouragement imparted by Prof. A. K. Sen is heartily acknowledged. I am also grateful to all other teaching faculty members and staffs of Department of Earth Sciences, IIT Roorkee, from whom I have learnt and got benefited immensely during my stay. A warm thank goes to departmental staff, Mr. A. R. J. G. Nair (Nair ji), Mr. Kamesh Gupta and Rishiraj ji for giving me a valuable support and patience for research.

I owe special thanks to respected (Late) Mrs. Anbalagan and Mrs. Viladkar who have been a constant source of encouragement.

I am in depth of words to express my feelings and heartiest thanks to my friend and colleague Dr. Rohan Kumar, for his effective suggestions which helped me a lot for completion of this research. I would like to offer my deepest thanks to my loving juniors; Varinder, Gaurav, Bipin, and Neethu, who gave me continual support to come out from depression and helped me to maintain a productive, healthy and fun loving environment in lab.

Thanks are also due to my juniors, for whom, I have no words appropriate enough to express my feelings; Suman, Arun, Debashish, Debi, Subrat, Sunita, Simranjeet and many others.

There are many fascinating and wonderful people without their support I would have never made it this far. Very few people are there in this world who are loved and regarded just for their harmless goodness. I extend my special thanks to my friends; Lali, Anjali, Asmita, Mandira, Pushpa and Chinmoy for being there to stand with me for all difficulties and funny moments at IIT Roorkee. I owe a lot of thanks to these people and will never forget their support and the joy, they brought in my life. With them I never felt that I am so far away from my home. The fun we had at Kasturba Bhawan, IIT Roorkee can never be out of my memory.

The Koteshwar Hydro Elecrtic Project Authorities, especially Mr. V. K. Gupta, Mr. A. K. Chamoli and Mr. Sandeep Rallan deserve full praise and thanks for providing all the logistic support during the field visits.

Finally the love of my life my loving father Mr. Karunakar Parida and mother Mrs. Sushama Parida thank you for your constant support and encouragement to complete this course. Your love and faith are my strengths without which I would not have reached this far. No words to express my debt and my love for you. Bless me for success all time in future so that I am able to fulfill your dream. The present work is dedicated to my loving parents.

Behind every successful person there stands another person telling that you are right or wrong - Dr. Bijay Kumar Das, my husband, who not only encouraged me but spared me from all homely responsibilities. Thanks are due to his for the sacrifices and patience that he has shown adequately. Thanks for always guiding and being there for me.

I am heartily indebted for the caring smiles and cries of my twenty months old son Moon (Sai Shashwat) who gave me immense strength in the final phase of this work.

Lastly, but not the least, I express my greatest gratitude to **Almighty** for giving me strength to work through all these years.

Dated: **SUJATA PARIDA**

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CHAPTER – I

INTRODUCTION

1.1 INTRODUCTION

A hydroelectric project involves the construction of either a dam or a barrage for creation of storage behind the body of dam in the form of a reservoir. This gives rise to a hydraulic head which is used for the generation of electricity. The reservoir usually runs into few kilometers and is surrounded by hills on all sides. After the construction of the dam and the creation of reservoir, the portion of the hills below the reservoir water level is submerged and the slope mass gets fully saturated. The shear strength of the slope mass material degrades upon submergence and this affects the stability of the hills drastically. In the event of any major landslide, a large quantum of slope mass can slide into the reservoir giving a big impact on the water body. This impact has the potential of generating waves of significant height. These waves travel towards the dam / barrage and in case the landslide is in close vicinity of dam / barrage, the energy of the waves can be highly damaging to the stability of the dam / barrage structure. It is therefore essential to investigate into the stability aspects of the hill slopes around the periphery of the reservoir, particularly the critical slope sections. In the present study, a case of a reservoir of Koteshwar hydroelectric project has been taken for detail investigation.

1.2 GENERAL SCENARIO OF HYDRO POWER DEVELOPMENT IN INDIA

India was the 7th largest producer of hydroelectric power in 2008 after Norway. In 1947, during independence, the electricity produced in India was 1362 MW. But presently the installed capacity of generation of power has grown to 1,64,509 MW because our country paid considerable attention to power generation. The potential for hydroelectric power in India is one of the greatest in the world. The total installed capacity of the country as on September 30, 2013 was approximately 39,788.40MW which is 17.39% of total electricity generation. While the hydro electric power accounts for 37,086 MW (25%), the major share of power generation was through thermal source, which accounted for 1,06,433 MW (65%), Nuclear is 4,560 MW (2.9%) and Renewable energy sources 16,429 MW (7.7%). The share of small scale hydropower (SHP) is 2,820 MW. The total estimated potential for hydro electric power is about 1,50,000 MW, equivalent to 84,000 MW at 60 % load factor. India holds an enormous hydro electric power potential through its great river systems. The country has been divided into 6 major water resources regions and 35 river basins. The major river basins are the Indus, the Brahmaputra, the Ganga, East flowing Peninsular rivers, Central Indian rivers and West Flowing Peninsular rivers. These rivers drain a total area of about 2,50,000 sq. km. with an average annual flow of about 180 million hectare meters. The Himalayan rivers are perennial, as they are fed during summer by the melting snow and glaciers besides rainfall during monsoon. On the other hand, the peninsular rivers which originate at much lower altitudes are fed only by rainfall and therefore seasonal.

It is very important to develop the hydro power resources of India for energy security. For developing a large scale hydro power project, it takes about ten years from planning to commission. With the hydro power policy announcement in 2008, the hydro power development has been greatly boosted. During 12^{th} plan (2012-2017), it has been proposed to maximize the hydro capacity addition for reducing CO_2 emissions and energy security of India. A shelf of 109 hydro electric schemes aggregating to 30,920 MW has been identified (Saxena and Kumar, 2010).

1.3 HYDRO POWER DEVELOPMENT IN HIMALAYA

The Himalayan eco-system covering 15% of the land area, consists of a comparatively young and dynamic section of the geo-sphere of our country. The Himalaya forms the Northwestern boundary of the Indo-Australian plate. This is a continent to continent collision boundary and has produced some of the highest mountain ranges and deepest valleys on any of the continental plate boundary. The Himalaya is the critical determinant of the Indian sub-continental climate. In the winters, they serve as an effective barrier to the intensely cold continental air blowing southward into India. In the monsoon months, the Himalaya forces the rain bearing winds from the south to pour heavy rain over them and provides water in abundance to its rivers. In the higher mountains, snowfall tends to conserve some of the rain and feed the Himalayan Rivers during summer by melting snow and glaciers.

The enormous water resource coupled with steep slope gradients provide favorable conditions for development of economically viable power generation at cheap. Majority of the hydroelectric potential lies in the Himalaya. In order to harness the enormous untapped water resources of Himalaya, a number of schemes have already been implemented. Many more are under planning and construction. The Bhagirathi river, a major tributary of Ganga, is considered as the source stream of the Gangas in Hindu mythology and culture. It holds a vast hydro power and irrigation potential. The river Bhagirathi runs through the state of Uttarakhand. The headwaters of the river are formed at Goumukh, at the foot of the Gangotri glacier. Bhagirathi river, with a total length of 217 km up to Devprayag, has an average slope of 12.5m per km. As on March 2011, installed capacity of 1,422 MW has been developed and 3,449 MW (13,620 MU) is under development. The various schemes operating or in planning and construction stages in the Bhagirathi valleys are listed in Table 1.1.

Table 1.1 Hydro Power Development in Bhagirathi Valley

S. No.	Project Name	Type of Project	Installed Capacity (MW)	Status
1	Maneri Bhali Hydro Electric Scheme (Stage-I)	ROR	90	Completed
2	Maneri Bhali Hydro Electric Scheme (Stage-II)	ROR	304	Under Construction
3	Pala Maneri Hydro Electric Scheme	ROR	416	Under Construction
4	Tehri Dam Project Stage-I	S	1000	Under Construction
5	Tehri Dam Project Stage-II	PSS	1000	Under Investigation
6	Bhaironghati Hydro Electric Scheme (Stage-I)	ROR	47.60	Under Investigation
7	Bhaironghati Hydro Electric Scheme (Stage-II)	ROR	240	Under Investigation
8	Loharinag Pala Hydro Electric Scheme	ROR	520	Under Construction
9	Bhilangana Hydro Electric Scheme	-	18.90	Under Investigation
10	Koteshwar Dam Project	ROR	400	Under Investigation

1.4 GEOLOGY OF LESSER HIMALAYA

On the basis of regional tectonic framework, the entire Himalayan arc can be subdivided into four major tectonic zones separated by a series of major thrusts. These zones from South to North are named as:-

i) Lesser Himalaya or Southern Himalaya between Higher Himalayan zone and Sub-Himalayan Siwalik zone.
ii) Higher Himalaya or Great Himalaya including the Higher Himalayan Crystalline and Tethys Himalaya.
iii) Trans Himalaya.
iv) Shiwaliks.

The project area is situated in the Lesser Himalayan terrain.

Lesser Himalaya

The bounded region between Main Central Thrust (MCT) in the north and Main Boundary Thrust (MBT) to the south is named as Lesser Himalaya. The Lesser Himalayan rocks consist of Precambrian, Lower Paleozoic and Tertiary sediments and low grade meta sediments. The thickness of Lesser Himalayan domain is about 1,300 m and the general elevation of mountains varies from 1,500 m to 3,000 m. The Lesser Himalayan zone is also characterized by numerous klippe and nappes of high-grade metamorphic rocks.

1.5 ENGINEERING GEOLOGICAL PROBLEMS OF HYDROPOWER DEVELOPMENT IN HIMALAYA

In spite of Himalaya's great potential for hydro power, much of this is still unharnessed due to a number of complex factors – the geotechnical problems of the tectonically active and fragile terrain being one of the important factors. The geotechnical problems faced during hydro power development in the Himalayan region are of many types which are as follows:

i) Foundation problems,
ii) Slope stability problems,
iii) Problems of underground excavations including tunnels, shafts and caverns,
iv) Availability of construction material,

v) Seepage problems, and
vi) Seismicity.

1.6 PROFILE OF KOTESHWAR HYDRO ELECTRIC PROJECT

Koteshwar project is a 400 MW hydro electric project being executed on the river Bhagirathi, a tributary of Ganga in Tehri district of Uttarakhand. The project is located about 22 km downstream of Tehri dam and the reservoir extends up to 17 km upstream and nearly up to the steel girder bridge (Fig. 1.1) which is located close to the Tehri dam.

The Koteshwar Project regulates the water released from Tehri Reservoir for irrigation and other purposes. The reservoir created by Koteshwar Dam shall also function as a balancing reservoir for Tehri Pumped Storage Plant (PSP). Koteshwar Hydroelectric Project will facilitate the functioning of Tehri Power Complex as a major peaking station in the northern grid and it will function as the pre-requisite lower reservoir for Tehri PSP. The reservoir extends over a distance of about 17 kms and the draw-down conditions of the reservoir water may induce instability of hill slopes. It is therefore essential to study the stability conditions of slopes all around the periphery of the reservoir.

1.6.1 Location and Accessibility

The study area lies in Tehri district of Garhwal division of Uttarakhand (Fig. 1.1). The highway from Rishikesh to Gangotri via Tehri, Dharasu and Uttarkashi is the main artery of transportation. It is a much frequent pilgrim root. The nearest airport is at Dehradun. There are some metalled and some unmetalled roads providing access to higher and inner parts which bifurcate from Bhaironghati along Jadhganga River. Geographically, the study area is enclosed in between the latitude 30°16′00” to 30°23′00” and longitude 78°28′30” to 78°30′30” having a variation in altitude from 3000 m to 5500 m.

1.6.2 Physiography

The Koteshwar reservoir extends over a length of more than 17 km in Bhagirathi valley. The Bhagirathi river flows roughly in the south direction from downstream of Tehri dam. The valley is fairly narrow with V-shape profile. Though the valley is nearly straight in the initial stretch of about 8 km, it takes two S-shaped loops afterwards and before the dam site. The valley slopes are typically different on both the banks. While the right bank generally has moderate slopes of the order of 35°-45° in the upper levels, the slopes become steeper in the lower levels with an average slope angle of 50°. On the other hand, the left bank slopes are consistently steep to very steep. The slopes are nearly vertical in many places. While rocks constitute the left bank slopes in general except at few locations, the right bank slopes have overburden debris cover in many parts of the reservoir area. However, rocks are seen commonly in lower parts close to river bed on right bank. The slopes on left and right banks extend to more than 100 m from the river bed.

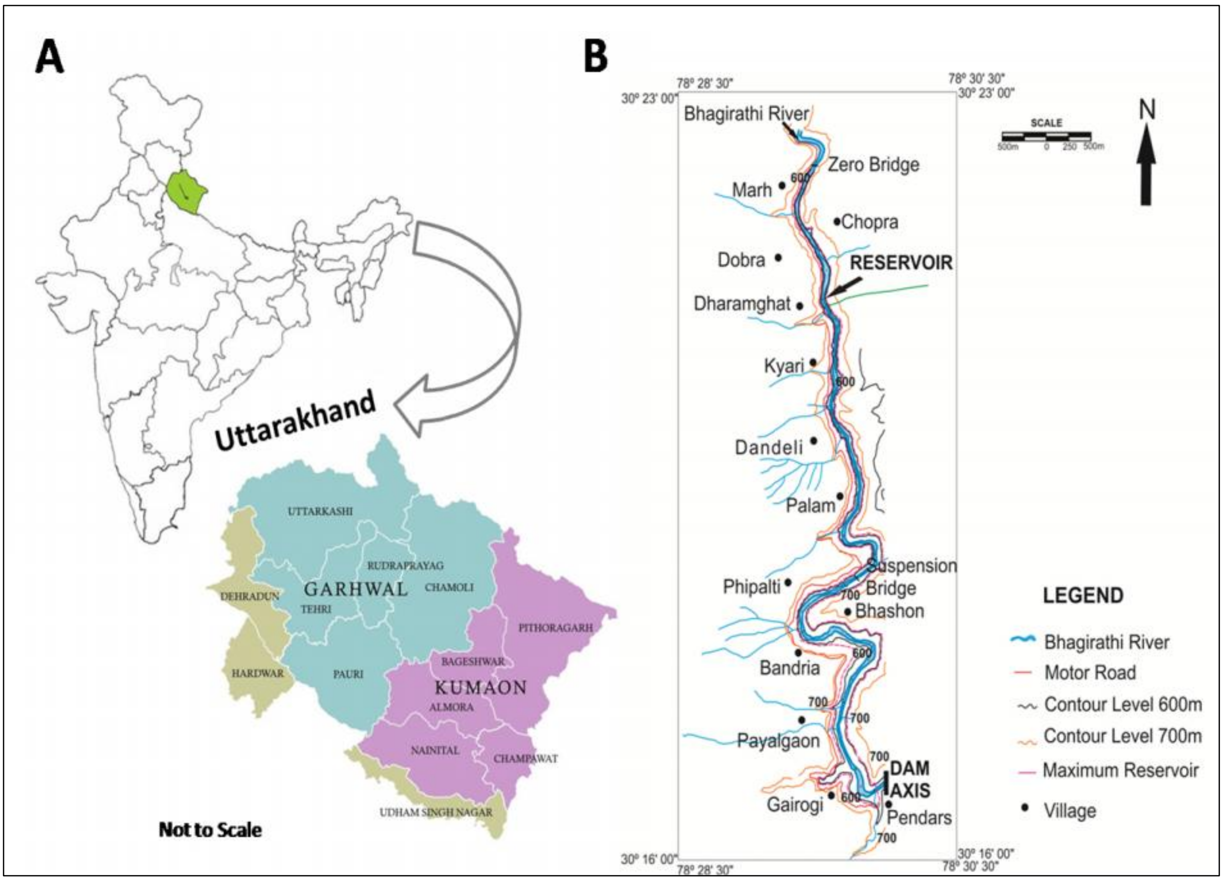


Fig. 1.1 A - Location of Koteshwar Hydro Electric Project, B – Area of Study

1.6.3 Drainage

The left bank has very few drainage courses (streams) joining the river Bhagirathi. The drainages running in westerly direction seem to be structurally controlled as they are nearly parallel to each other except a few. These stream are generally first order streams with only few of them showing second order branches. The streams on right bank commonly have second order streams though many third order streams can also be seen. They do not show any preferred direction in the upper levels. However, they seem to be parallel to each other in the lower levels, The streams on the right bank flow towards east direction.

In view of the steep hill slopes on left bank, most of the human activities are concentrated on the right bank. Approaches are not available for inspection of left bank slopes in many parts due to steep valley faces. On the left bank, only two villages can be seen close to the river – one located in the initial reach, namely the Chopra Village located about a kilometre downstream of the steel girder bridge (Fig. 1.1). The other one is located in the middle of the reservoir area just above the old girder bridge, namely Bhashon. However, many villages are located on the right bank like Dobra, Kyari, Dandeli, Palam, Phipalti, Gairogi, Bandria, etc. This is primarily because of the fact that extensive agricultural lands are available for supporting the life on the right bank. The only approach road to Koteshwar dam is also located on the right bank. This all weather metalled road nearly follows the river flow up to Koteshwar dam.

1.6.4 Climate

The area of study falls in the Lesser Himalayan zone, which is characterized by the tropical monsoon climate. Long humid summers and cold dry winters are the characteristics of the area. The area receives substantial amount of rainfall, as the South-West monsoon changes its direction to North-West along the NW-SE trending Lesser Himalayan range. Thus, it loses most of the moisture in the process, in the form of rains while moving over the Lesser Himalayan ranges. In the study area, maximum rainfall occurs between mid June to mid September. However, the normal annual rainfall in the area is about 1650 mm. During winter season, the higher peaks receive snow, while low lying areas receive moderate rains between mid December and the month of January.

The average temperature, in the study area remains between 20^0C to 30^0C. The maximum temperature (35^0C) is attained during the months of May-June and a minimum (5^0C) during the months of December-January.

1.6.5 Flora and Fauna

The natural vegetation follows a climate altitudinal zonation. The vegetation is characteristic of the Sub-Tropical (below 1200 m) to Temperate zone (1200-1800 m). Some of the important species in the area are Sal (*Shorea robusta*), Banj (*Quercus incana*), Oak (*Quercus himalayansis*), Chir (*Pinus longifolia*), Deodar (*Cederus deodara*), etc.

The reservoir areas are comparatively covered by vegetation, while the valley slopes are generally devoid of vegetation cover. Small patches of shrubs, bushes, wild grasses and thorns are often seen on the valley slopes. On the gentler valley slopes, terraced cultivated fields are present.

The important crops cultivated in the area are wheat, paddy, mustard and maize. The vegetables raised on the terraced fields are potato, tomato, onion, ginger, chilli, spinach (*Spinacea oleracea*) etc.

The wild life in the area comprises of fox, jackal, monkeys etc. Among the domestic animals, cows, buffaloes, mules, donkeys, dogs, goats, ships, oxen are the most common.

1.6.6 Seismicity

The study area falls in Zone IV of the Seismic zoning map of India, prepared by the Bureau of Indian Standards (BIS: 1893-2002, Part I). The study area lies NE of the MBT and as the tectonic feature dips northward, the thrust plane also lies beneath the site. Earthquakes of magnitude 7.0 or more were reported in this area.

The seismic activity within the Koteshwar hydro electric project is high and recent earthquake of maximum magnitude 6.8 has occurred in the area. Noteworthy earthquakes in this region are the Chamoli earthquake of magnitude 6.8 on 27th March 1999 and the 6.6 magnitude earthquake of Uttarkashi which occurred on 20th October, 1991. Due to these earthquakes some poorly built houses in the adjoining villages were damaged, causing minor cracks on the walls of the houses. In view of the above fact, stability analyses for slopes, in the study area, have been carried out, incorporating the horizontal acceleration of 0.1g induced by the earthquake.

1.7 GENERAL LAYOUT OF KOTESHWAR PROJECT

The Koteshwar Hydro Electric Project has a 97.5 m high concrete gravity Dam constructed along with a Surface Power House of 400 MW capacity (4 units of 100 MW each) and a Surface Switchyard. The layout of the project is shown in Fig. 1.2 and the dam section is shown in Plate 1.1.

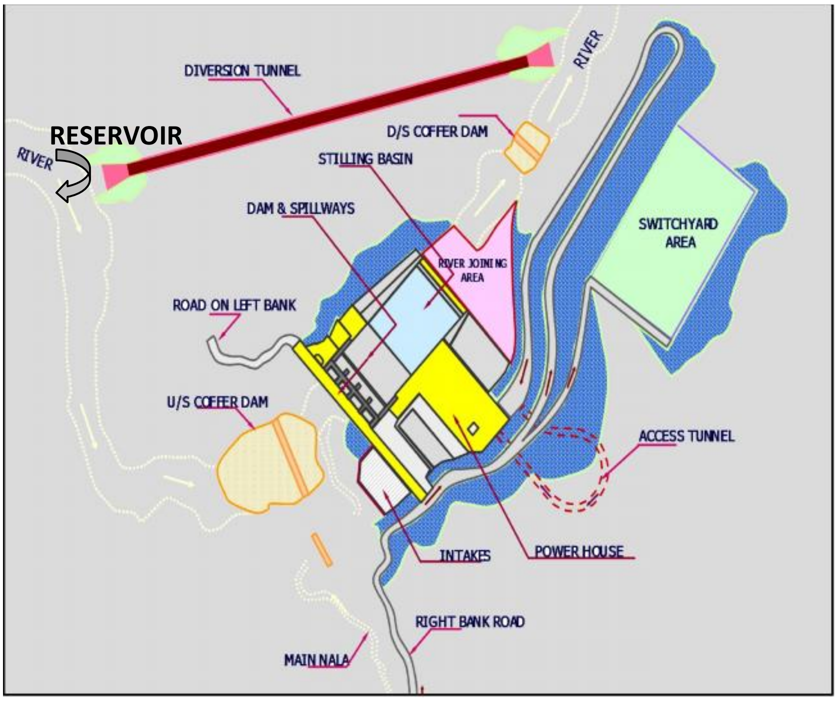


Fig. 1.2 Plan showing various components of Koteshwar Hydroelectric Project

Plate 1.1 Proposed Koteshwar Dam

Salient Features

The Salient Features of the Koteshwar dam project are given below

Hydrology	
Catchment Area	7,691 sq. km. at dam site
Snow Catchment	2,328 sq. km.
Design Flood	13,240 cumecs
Annual Run off	8.14 km^3
Annual normal water flow	258.0 cumecs
Storage Reservoir	
Full Reservoir Level (FRL)	EL. 612.5 m
Maximum Flood Level (MFL)	EL. 615.0 m
Minimum Draw Down Level (MDDL)	EL. 598.5 m
Gross Storage upto FRL	88.9 MCM
Live Storage Capacity	35.0 MCM
Diversion Tunnel	
Size and Type	8.0 m diameter Horse shoe type
Length	593.0 m
Discharge	1180 cumecs
Dam	
Type	Concrete Gravity
Maximum Height above deepest foundation level	97.5 m
Elevation of top of dam	EL 618.5 m
Crest Length	300.50 m
Length of non-over-flow section	196.50 m
Spillway	
Discharge Capacity at FRL (612.5 M)	9,140 cumecs
Discharge Capacity at MFL (615.0 M)	13,240 cumecs
Number of bays	4
Bay width	18 m

Crest Elevation	594.50 m
Type of Service gates	Radial
Size of gates	18 m × 16 m
Power Intake	
Location	Right bank integrated into water retaining structure
Intake Sill Level	582.5 m
Number and size of Penstocks	4 nos., 6.2 m diameter
Type of service gate	Fixed wheel
Power House	
Type	Surface at toe of dam
Location	Right Bank
Number of Units	4
Rated Unit Capacity	100 MW
Installed Capacity	400 MW
Type of Turbine	Vertical shaft Francis type
Maximum head	75.0 m
Minimum head	58.0 m
Rated head	69.0 m
Max. Flow through each unit at rated head	161 cumecs
Switch Yard	
Type Outdoor on surface	400 KV
Size	215.5 m × 136 m
Power Generation	
Annual Energy in 50% dependable year	1366 MU
Annual Energy in 90% dependable year	1234 MU

1.8 IDENTIFICATION OF PROBLEM

The primary aim of the research work presented in this study is to identify the unstable slopes around the periphery of the reservoir and study the stability aspects of unstable slopes.

The most important consideration in developing and maintaining a reservoir is its ability to hold the water without endangering the stability of the rim area. Koteshwar dam reservoir, which is a part of Tehri hydro-electric project in the state of Uttarakhand, has been taken here as a case study. The stability of slopes in the reservoir area is very important for the safe functioning of the dam/ barrage. Unstable slopes in the rim area of the reservoir may lead to slope failures during the operation of the reservoir. In the event of such failures, it can lead to the generation of waves, which then travel towards the dam. These waves may cause a big impact on the body of dam or barrage and may be responsible for their damage. It becomes therefore essential to ensure the stability of hill slopes all around the periphery of the reservoir.

1.9 OVERVIEW OF METHODS OF SLOPE STABILITY ANALYSIS

The following methodology was adopted for the stability analysis.

1.9.1 Detailed geological mapping, preparation of geological sections of potentially unstable rock slopes and rock mass characterization

On basis of the initial reconnaissance survey, it was identified that the slopes around the periphery of Koteshwar dam reservoir are comprised of jointed rock mass or debris / talus like material or the river borne material. Based on the mapping of the reservoir area on a scale of 1:1000, potentially unstable slopes were chosen on both the banks of the reservoir. Stability analysis and other related studies were carried out for these locations.

This was followed by the geological and geomorphological study of the project area. Detail geotechnical field investigations were then undertaken for collection of the data related to rock mass characteristics at various slope sections. Using all the field data, geological maps were prepared for the project area on a scale of 1:2,50,000 and for the reservoir area on a scale of 1:25,000.

On the basis of field investigations of rock mass characteristics including its discontinuities at locations of all sections under consideration, estimation of corresponding Rock Mass Rating (RMR) and Slope Mass Rating (SMR) was carried out for understanding the rock mass quality.

Stereo-plots were prepared for all slope sections under consideration, using the data of characteristics of various discontinuities at each section. Such plots help in the kinematic analysis of rock slopes so as to identify the possible mode of failure at each slope section.

1.9.2 Stability analysis at various slope sections

a) Estimation of strength parameters

For the stability analysis of various slope sections, it is essential to estimate first the shear strength parameters of slope mass material. As stated earlier, the slope mass material is comprised of either jointed rock mass or debris or talus material. To determine the shear strength parameters of jointed rock mass, shear strength of critical rock joints was estimated by the project authorities using Barton and Bandis (1990) model and then the strength parameters of rock mass were estimated. For the shear strength parameters of debris / talus material, sufficient quantity of samples were collected by the project authorities from various debris slope locations on both banks of the reservoir. Direct shear tests were then conducted for obtaining values of shear strength parameters such as, cohesion, c (t/m^2) and angle of internal friction, Φ^0 of the debris material.

b) Stability analyses of rock slopes

The stability analyses of rock slopes were carried out by using Computer Program SASP in which the failure mode is in the form of a plane wedge failure (Singh and Goel, 2002). For rock slopes in which three dimensional wedge failure was expected, stability analysis was carried out using program SASW (Singh and Goel, 2002). The stability studies were carried out for computations of the factors of safety in dry and saturated states and under both static and dynamic conditions. Accordingly, one slope section in left bank and six sections in the right bank were analyzed using SASP and three slope sections in right bank were analyzed using SASW.

c) Stability analyses of debris slopes

The stability analyses of debris slopes was carried out by using Computer Program SARC in which the failure surface has been assumed as circular which can be deep seated (Singh and Goel, 2002). Stability analysis of talus slopes was carried out using program SAST

(Singh and Goel, 2002). The thickness of talus deposits is much smaller compared to that of debris slopes. The stability studies were carried out for computations of the factors of safety in dry and saturated states and under both static and dynamic conditions (Hoek and Bray, 1981). Accordingly, three debris slope sections in left bank and two sections in right bank were analyzed using SARC and one slope section in left bank and nine slope sections in right bank were analyzed using SAST.

1.9.3 Prediction of Wave Height

Prediction of wave height at locations of unstable sections and at the dam/barrage axis was carried out using computer program: WAVE. Computations have been carried out for one critical rock slope in left bank and four sections in right bank of the reservoir. The program gives the values of the weight of sliding wedge, mean depth of water in the reservoir and the distance of landslide from the dam body along with the maximum wave height generated at the location of landslide and the wave height at the location of dam after attenuation over the distance.

1.9.4 Remedial Measures

Attempt has also been made to suggest remedial measures at critical slope sections around the periphery of the reservoir.

1.10 ORGANISATION OF THESIS

The thesis has been organized in eight main chapters along with an introduction and a concluding chapter. Introduction of the work has been given in the present **CHAPTER – I**.

The review of literature pertaining to slope stability analysis by using different methods like deterministic, probabilistic and numerical methods is presented in **CHAPTER – II**.

CHAPTER – III covers geological setting in three parts viz. regional, in and around project area and along the reservoir area.

The geotechnical studies of the Reservoir Rim area for identifying the potentially unstable slopes and rock mass characterizations in the reservoir area have been discussed in **CHAPTER – IV**.

CHAPTER – V deals with the estimation of strength parameters for debris slopes and rock slopes.

CHAPTER – VI focuses on the kinematic analysis of rock slopes and identification of mode of failure.

CHAPTER – VII presents the stability analyses of debris slopes by using Computer Program SARC/SAST.

CHAPTER – VIII focuses on the stability analysis of rock slopes using limit equilibrium method using the Computer Program SASP/SASW.

CHAPTER – IX evaluates the height of the water waves, generated by the possible slides, in the reservoir.

CHAPTER – X includes the discussion of the results and the conclusions drawn from these results.

CHAPTER – II

REVIEW OF LITERATURE

2.1 REVIEW OF REGIONAL GEOLOGY

The present study has been focused on the stability study of the slopes along the rim of the reservoir of Koteshwar Hydro Electric Project of Uttarakhand state, India. The main geological formations belonging to the Chandpur Formation of rocks comprises of phyllites. Physiographically the areas lie in a region of tectonic or folded and overthrust mountain chain with strata structurally marked by complex folds, reverse faults, overthrusts and nappes of great dimensions (Krishnan 1982). The area is traversed by many faults and main central thrust (MCT) is one of them which are responsible for the crushing and shearing of rocks. Every year due to heavy rainfall, landslides get triggered causing casualties and several incidences are reported from different parts along the major communication route in this area. Slope instability cause significant problems in mountainous areas. In recent years many studies have been carried out related to slope stability problems in Himalayan region. Several approaches have been presented, including the mountain risk approach of Deoja et al. (1991), landslide hazard evaluation factor (Anbalagan, 1992; Gupta and Anbalagan, 1997), GIS based rating techniques (Sarkar and Kanungo, 2004), deterministic techniques (Joshi et al., 2000). North India and particularly the Himalayan belt have experienced many strong to moderate earthquakes since eighteenth century (Rao and Rathod, 2014). The Slope failure along the banks of the reservoir are mostly shallow debris slides, talus slide, rock slides and rock falls (Sarkar et al. 2005). Gupta (1996) described methods for evaluation of geoenvironmental hazards by preparing landslide hazard zonation map with reference to degradation of hill slopes in Uttarakhand Himalayan region. Reddy et al. (2013) describe the development of a green and sustainable strategy for the remediation of a contaminated site located in Chicago to comply the applicable federal and state environmental regulations. Weathering has presumably altered and broken down the upper part of the bedrock in the region by chemical decomposition and physical disintegration (Bhasin et al., 2002).

2.2 REVIEW OF EARLIER WORK

2.2.1 Limit Equilibrium Approach

Over the decades, using the limit equilibrium approaches majority of the slope stability problem was addressed. Limit equilibrium approach is a conventional, simple and widely accepted approach to the practicing engineer. However, these classical techniques have limitations in handling material variation, varying geometry, etc., with large number of assumptions. Numerical techniques appear to be a better alternative to simulate the practical slope stability problem. To solve complex problems number of researchers applied different numerical techniques (continuum and discontinuum).

Many research articles have been published since the publication of the first method of analysis by Fellenius (1936) that were either related to slope stability or involved slope stability analysis subjects. Among the available methods of analysis the limit equilibrium method of slices is also an important one (Matsui and San, 1992). Limit equilibrium method of slices is the most commonly used method among others due to its simplicity and ease of use Alkasawneh et al. (2008), Anbalagan and Parida (2013). Bishop's method can be used for circular slip surfaces (Bishop, 1955). Bhasin et al. (1995) used a comprehensive engineering geological assessment of low strength anisotropic rocks at the site of a major hydroelectric power project in the Himalayan Region in India. Sheng-hong et al. (2007) used the limit equilibrium method for the analysis of the stability of rock slopes for some hydropower projects.

2.2.2 Numerical Methods

The classical conventional techniques for rock slope stability analysis have limitations in handling material variation, varying geometry, complex boundary condition, etc. Over and above there are a large number of assumptions for these techniques. Numerical techniques represent a powerful alternative approach for rock slope stability analysis and require fewer assumptions, especially regarding the failure mechanism. Wide spectrums of numerical slope stability techniques have become available in recent times. These techniques can be broadly classified into three approaches such as continuum, discontinuum and hybrid. The continuum approach is the most popular and widely used one. In cases of rock slopes, the continuum approach is only applicable if the slope can be justified as an homogeneous medium which is very often not the case. The finite element method is one of the important numerical techniques. In order to find out the factor of safety (FOS) that is in accordance with the conventional limit equilibrium methods in conception, Griffiths and Lane (1999) combined the finite element method (FEM) with the strength reduction technique (Matsui and San,

1992) to determine the FOS. Gurocak et al. (2008) performed finite element analysis of stable and unstable slopes and good correlations were found with the conventional limit equilibrium approaches. Hammah et al. (2004) examined the difficulties of straightforward application of the method to generalized Hoek–Brown (GHB) criterion as a material model in shear strength reduction (SSR) analysis using FEM and also suggested a solution approach that uses equivalent Mohr– Coulomb envelope in place of the Hoek–Brown failure criterion. Latha and Garaga (2010) performed the seismic slope stability analysis of a 350-m-high slope using the equivalent continuum approach in FLAC (fast Lagrangian analysis of continua) along with the generalized Hoek–Brown failure criterion. Kanungo et al. (2013) have attempted 2D finite element plain strain modelling of two debris slopes and one potential rock slide using PHASE2 software along a highly vulnerable road stretch of Chamoli-Badrinath National Highway (NH-58) in Garhwal Himalayas, India.

Many researchers performed the stability analysis using discontinuum approach where the discontinuities are directly incorporated into the numerical model. Zhang et al. (1997) carried out studies on the dynamic behavior of a 120 m high rock slope of the Three Gorges shiplock using distinct element method (DEM). Bhasin and Kayania (2004) performed static and dynamic rock slope stability analysis using a numerical discontinuum modelling technique for a 700 m high rock slope in western Norway. Pal et al. (2012) used the distinct element code (UDEC), which incorporates the strength and deformability properties of the joints and intact rock for stability analysis of Surabhi landslide, Dehradun, India. As reported in this work, the joint shear strength parameters were assumed based on the type of rock that exists in the study area. Also the number of joints represented in the model is reduced as compared to those present in the field. Singh et al. (2002) carried out an extensive experimental study and tested more than 80 block specimens of a jointed mass of model material under uniaxial compression.

The finite element approach may be valuable if awkward geometries or material variation are encountered which are difficult to solve using conventional methods. Several commercial FE packages are available which handles the complexity of the calculation. The graphical capabilities of FE programs also allow better understanding of the mechanisms of failure. Researchers like Smith and Hobbs (1974) applied FE method for slope stability analysis and obtained good agreement with slip circle solutions. Rathod and Rao (2012) attempted to understand the reasons for the failure and assess the stability of the existing constructed slopes using limit equilibrium and FEM solutions and also to propose modified design for rebuilding the slopes. The advantages of a finite element approach for slope stability analysis over conventional limit equilibrium method can be summarized as follows: (1) no assumption needs to be made in advance about the shape or location of the failure surface. Failure occurs ‘‘naturally’’ through the zone within the soil mass in which the soil shear strength is unable to resist the applied shear stresses; (2) since there is no concept of slice in the FE approach, there is no need for assumptions about slice forces. The FE method preserves global equilibrium until ‘‘failure’’ is reached; and (3) the FE method is able to monitor progressive failure up to and including global failure.

2.3 REVIEW OF DETERMINISTIC AND PROBABILISTIC APPROACHES

In the past many researchers have applied different techniques of slope stability analysis by using different methods. These methods are classified into three groups: deterministic, probabilistic and the numerical methods. Two prominent works regarding the usage of deterministic model for carrying out slope stability assessment have been carried out by Sharma et al. (1994), Anbalagan and Chakraborty (2008) and Singh et al. (2008) by considering geotechnical parameters on local scale. Gokceoglu et al. (1996), Luzi et al. (2000), Park et al. (2001), Pathak et al. (2004), Suchomel et al. (2010) and Kainthola (2013), Dahal et al. (2014) have considered the slope stability problem in a probabilistic framework. The use of a probabilistic framework can be significant improvement over the deterministic framework but its role may be limited to handling only some of the main uncertainties (Chowdhury and Flentje, 2003).

Landslide hazard assessment in terms of landslide susceptibility zonation (LSZ) on both macro- and meso-scales of an area becomes important whereby the area may be divided into near-homogeneous domains and ranked according to the degrees of potential hazard due to mass movements (Varnes 1984). Several approaches for LSZ mapping on macroscale have been proposed. These approaches can be grouped into two broad categories; qualitative and quantitative. These LSZ approaches have been reviewed in detail by Varnes (1984), van Westen (1994), Mantovani, et al. (1996), Aleotti and Chowdhury (1999), Guzzetti et al. (1999)

and Saha et al. (2005). However, these landslide hazard mapping techniques may not be suitable for large-scale mapping where stability assessment of different slopes (rock and debris slopes) is intended. Evaluation of slope stability at first instance needs consideration of historic record of landslide.

Hasegawa et al. (2009) suggests that large-scale landslides are the major cause of slope failure during monsoon in the Lesser Himalaya of Nepal. A comparative analysis of landslide contributing parameters due to rainfall in the Lesser Himalaya was carried out by Dahal et al. (2009). Kanungo et al. (2010) attempted rock slope stability assessment technique using finite element based modelling for Indian Himalayas. The major reasons for the slope instability in the Lesser Himalayan terrain are the steep topography, unfavorable lithology, structural discontinuities in addition to nature of soil (Gupta and Anbalagan 1997; Kumar and Anbalagan 2013). Kanungo et al. (2013) used limit equilibrium approach and finite element approach for the stability assessment of debris slide in Garhwal Himalayas.

In the Himalayas, slight differences in lithology and local changes in the orientation of discontinuities in rock can make rock sliding very diverse. Because of this variation, rock slope failures in some areas are so inevitable and certain that some of the treatments are sometimes quite ineffective and very expensive. So rock slope stability needs detailed assessment of the rock type, structural and topographic condition (Ghosh et al., 2014). Usually the slide along the rocky surface occurs when the shear stress acting along critical failure surface in rock slope exceeds the shear strength of the mass of the slope in this direction . In such cases, the main factor that regulates the stability of rock slopes is the variation trends of the directional anisotropy of the planar structural discontinuities (such as, bedding, foliation, joint and fault) in rocks (Romana, 1985; Hack et al., 2003). Reddy et al. (2009, 2011) performed laboratory investigation to determine the geotechnical properties of synthetic municipal solid waste. Anbalagan et al. (2007) analyzed the slope instability condition of a peculiar landslide prone slope along a road corridor in north Himalaya by utilizing the circular failure charts (CFC) of Hoek and Bray for the computation of factor of safety (FOS) on the basis of the site specific geotechnical parameters. Using advanced 3D modeling of cut slopes on the basis of physic mechanical conditions for the estimation of factor of safety Singh et al. (2008) carried out slope stability characterization of cut slopes along a road corridor in

Rudraprayag (Uttarakhand, India). Das et al. (2012) attempted geotechnical-based slope stability probability classification (SSPC) methodology for the deterministic landslide susceptibility assessment. Heuristic methods based on landslide hazard zonation and GIS based approaches were extensively applied in the Uttarakhand Himalaya region (Anbalagan 1992; Pachauri and Pant 1992; Gupta et al. 1999; Sarkar and Kanungo 2004). Kannan et al. (2014) attempted to assess and compare the reliability of geospatial-based landslide hazard zonation maps in Bodi-Bodimettu Ghat section as a case study. Saranathan et al. (2010) prepared a landslide hazard zonation in Yercaud Ghat section, and Kannan et al. (2011) generated macro landslide hazard zonation in Bodi-Bodimettu Ghat section. Gupta and Anbalagan (1995) produced landslide hazard zonation mapping of Tehri Pratapnagar area, Garhwal Himalayas.

Based on field data there are various rock mass classification systems which are proposed in the literature. In most of the classification schemes the main input parameters which are considered, are the properties of discontinuities. The CSIR classification system of Rock Mass Rating (Bieniawski, 1974) has been used for classification of jointed rock masses. Slope Mass Rating (SMR) technique, developed by Romana (1985) for stability assessment of rock slopes, is primarily based on the application of $(RMR)_{basic}$ and the orientation of discontinuities. This technique is suitable for preliminary assessment of slope stability in jointed rocks, including the very soft or heavily jointed rock masses. In this SMR approach, adjustment rating for joints, depending on the orientation of joints in relation to the slope, has been introduced by Romana (1985). Later modified SMR approach was established by Anbalagan et al. (1992) to account for the wedge failure along with planar and toppling failures (BIS, 1997).

Kinematic analysis, which is purely geometric, examines which mode of slope failure is possible in a given jointed rock mass situation (Yoon et al., 2002). Angular relationships between discontinuities and slope surfaces are applied to determine the potential modes of failures Kliche (1999), Anbalagan et al. (2013). Numerous studies have been presented (Markland, 1972; Goodman, 1976; Hoek and Bray, 1981; Matherson, 1988) for predicting the modes of failure utilizing the stereographic projection technique.

2.4 CRITICAL COMMENTS

A perusal of substantial literature indicates some technical gaps particularly related to the stability of reservoir slopes. Problem of stability of reservoir slopes assumes importance, especially in hydro-electric projects which encompass dam / barrage as a very important structure which is constructed to create a reservoir or water head so that water under pressure can be taken through head race tunnels to underground power house for generating power. If the slopes around the periphery of the reservoir are not stable, any major landslide in the close proximity of the dam / barrage can led to generation of waves which when travel to the dam body can be detrimental to the stability of the dam itself.

Stability analyses were carried out by many research workers for various slope conditions. Problem of reservoir slope stability is somewhat different because reservoir slopes around the periphery of the reservoir get partly/fully submerged due to reservoir filling. Saturation of slopes degrades their shear strength parameters which govern the shear strength of slope mass. The behavior of such a submerged slope becomes further critical under seismic conditions. However, the literature review suggests that this has not been done earlier.

In the present study, an attempt has been made to carry out the stability analysis of slopes around the periphery of Koteshwar reservoir for dry / submerged and static / seismic loadings. Attempt has also been made to compute the volume of slope material, which may get detached due to slope failure and slide into the reservoir water body. Due to the sliding of such large quantum of unstable material, waves will be generated and the fast travelling waves will hit the dam or the barrage and damage these structures. Attempt has therefore also been made to compute the corresponding wave height and check if it would adversely affect the stability of the dam/barrage. This aspect has also not been paid any attention so far.

CHAPTER – III

GEOLOGICAL SETTING OF STUDY AREA

3.1 GEOLOGICAL SETTING

The Himalaya has drawn the attention of a large number of investigators for over a century that endeavored to work out the structural and tectonic patterns in this region. The results of these investigations have added to the knowledge and understanding of the complex geology of the Himalayan terrain.

The Himalaya is broadly divided into four principal East – West trending linear tectonic belts (Fig. 3.1) on the basis of their characteristic geologic attributes (Shankar et al., 1989, Kumar et al., 1989). The Karakorum Belt is the northern most (Table 2.1) which is followed in the south by the Ophiolitic melange and the plutonic zone of the Indus – Shyok Belt, followed in the south by the Main Himalayan Belt which has been further sub divided into two viz., Lesser Himalaya and the Higher Himalaya. The Frontal Fold Belt is the southernmost belt which consists essentially of the Tertiary of the foreland basin.

On the basis of lithological assemblages, grade of metamorphism, limited radiometric data, emplacement of granites, presence of diagnostic sedimentary structures and unconformities, eleven different stacks of sedimentary cycles have been identified (Shankar et al., 1989).

A brief description of each belt is given below:

3.1.1 Frontal Fold Belt (FFB)

It is the southernmost tectonic belt and is made up essentially of Tertiary and Quaternary sediments, consisting the Subathu, the Murree and the Shiwalik Group of rocks overlain by alluvium. The former three sequences rest on the Proterozoic basement. This belt is separated from the Main Himalayan Belt by tectonic surface known as Murree thrust in Jammu region, Krol thrust in the Eastern and Western part of Himachal Pradesh and Uttarakhand respectively, and the Main Boundary Thrust (MBT) in parts of Garhwal and Kumaun in Uttarakhand, Bhutan and Arunachal Pradesh (Kumar et al., 1989).

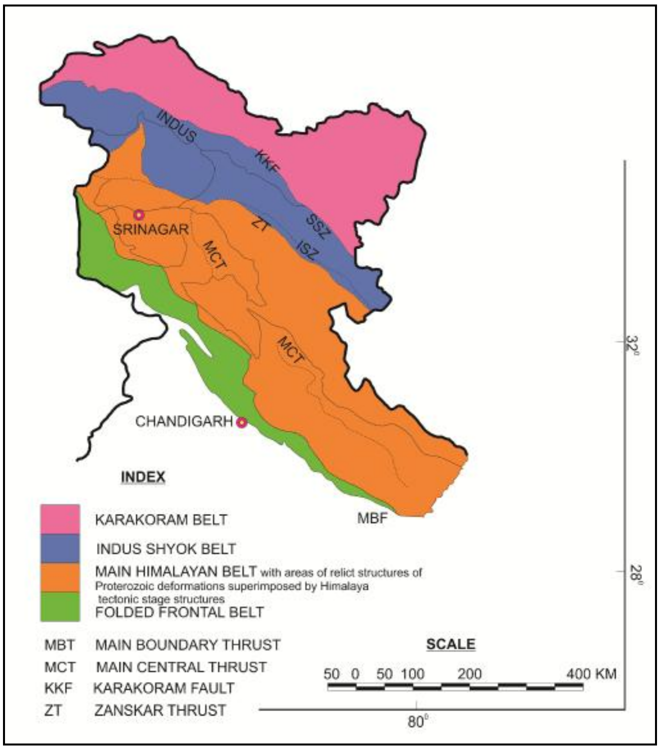


Fig. 3.1 Map of The Western Himalaya showing Tectonic Litho-stratigraphic Belts (after Kumar et al., 1989)

Table 3.1 The Himalayan Tectonic Belts (Kumar et al., 1989)

North

Karakoram Belt (KB)

--------------------Shyok Suture--------------------

Indus Shyok Belt (ISB) and Lohit Complex Belt (LCB)

-------Indus – Tsangpo / Tidding Suture--------

Main Himalayan Belt (MHB)

--------------Main Boundary Thrust---------------

Frontal Fold Belt (FFB)

South

3.1.2 Main Himalayan Belt

The Main Himalayan Belt, which is the most complex tectonic belt, occurs between the Frontal Fold Belt in the south and the Indus Shyok Belt in the north. It abuts in the east against the Lohit Complex along the Tidding Suture, whereas in the west it continues up to Pakistan. This belt itself can be divided into two zones (Shankar et al., 1989) – Lesser Himalayan Zone and the Higher Himalayan Zone.

Lesser Himalayan Zone

The Lesser Himalayan Zone, 2000-3000 m high, consists the late Precambrian-Eocene rocks. The Murree, the Krol Thrust and the Main Boundary Thrust (MBT) mark the southern boundary with the Frontal Folded Belt whereas, the Main Central Thrust (MCT) separates it from the Higher Himalaya.

Higher Himalayan Zone

The Higher Himalayan Zone represents a zone of greatest vertical uplift. The Main Central Thrust (MCT) marks the boundary between the Lesser and the Higher Himalaya whereas, the Indus Suture Zone (ISZ) marks the upper boundary. This zone is characterized by the presence of low to high grade metamorphic rocks.

3.1.3 Indus Shyok Belt

The Indus Shyok Belt is sandwiched between the Karakoram Belt in the north and the Main Himalayan Belt in the south. This belt comprises of early to late Cretaceous - Tertiary Sediments and associated ultramafic, mafic, intermediate and acid magmatic rocks. However, imprints of earlier geologic history are also known in parts of this belt. This belt can also be divided into three zones (Kumar et al., 1989) i.e.

i) Zone I – Indus Suture Zone

ii) Zone II – Ladakh Granitoid with Indus Group and Khardung Volcanics

iii) Zone III – Shyok Suture Zone

3.1.4 Karakoram Belt

It is the northernmost litho-tectonic belt. The Karakoram fault marks its southern boundary.

3.2 REGIONAL GEOLOGY

The present study area (Tehri – Koteshwar area) lies in Lesser Kumaun Himalaya of Uttarakhand. The Lesser Himalayan terrain is characterized by fascinating geological setting. The regional geology of Tehri – Koteshwar area is discussed below:

A number of research workers in the past carried out regional geological studies and the stratigraphy of various units are well established. Kumar and Daundiyal (1976) worked on the stratigraphy and structure of 'Garhwal Synform' on a regional scale. Though a number of research workers extensively worked in this part of the area, the work of Valdiya (1980) is followed for regional description of the Tehri – Koteshwar area.

Stratigraphy

The rocks exposed in Tehri – Koteshwar area lies in the Inner as well as Outer Himalaya. The Inner Lesser Himalaya is represented by the rocks of Rautgara Formation of Damtha Group, Deoban Formation of Tejam Group and Berinag Formation of Jaunsar Group. On the other hand, the rocks exposed in the Outer Lesser Himalaya belong to Chandpur and Nagthat Formations of Jaunsar Group and Blaini, Krol and Tal Formations of Mussoorie Group. The stratigraphic succession of the study area is shown in Table 3.2 and the distribution of different Formations belonging to the various Groups is shown in Fig. 3.2 and Fig. 3.3.

3.2.1 Rautgara Formation

The rocks of Rautgara Formation are exposed in two places - to the north and northwest of the town: Pratap Nagar. In the extreme northern side, it is separated by Berinag Thrust from the Berinag and Deoban Formations. The southern extension is delimited by North Almora Thrust (NAT), separating it from Chandpur Formation. The Rautgara Formation consists of purple, pink and white coloured, well jointed, medium grained quartzites interbedded with medium grained, grey and dark green sublitharenites and minor slates as well as metavolcanics. Some litho units of Rautgara Formation show ripple marks indicating deposition in shallow water conditions (Valdiya, 1980).

3.2.2 Deoban Formation

The rocks of Deoban Formation exposed in the area are sandwiched between the Rautgara and the Berinag Formations with a thrust contact. The Deoban rocks mostly occupy the higher portion of the area which consists of fine grained dolomitic limestone showing colour variation from white, pale pink and bluish grey with minor phyllitic intercalations.

Table 3.2 Stratigraphic Succession of Study Area (after Valdiya, 1980)

Group	Inner Lesser Himalaya	Outer Lesser Himalaya	Age	Rock Type
	Formations			
Mussoorie		Krol	Cambrian	Limestone intercalated with slates and siltstone
		Blaini	Neoproterozoic	Quartzite, limestone, slates, phyllites and conglomerate
Jaunsar	Berinag	Nagthat	Mesoproterozoic	Weathered quartzite intercalated with slate
		Chandpur	Mesoproterozoic	Low grade lustrous phyllites
Tejam	Deoban	Mandhali	Mesoproterozoic	Dolomitic limestone with phyllitic intercalations
Damtha	Rautgara		Mesoproterozoic (>1300 my)	Quartzite, slate, metavolcanic rocks

3.2.3 Chandpur Formation

The Chandpur Formation is present mostly along the Bhagirathi river course in Tehri area. The rocks are delimited on the northern side by North Almora Thrust (NAT), which trend roughly northwest - southeast and dips towards southwest. The rocks of Chandpur Formation are low grade metamorphosed lustrous and shiny phyllites. The phyllites are olive green, grey and greyish brown coloured and often interbedded with meta-siltstones and fine grained wakes. The Koteshwar reservoir extends over the phyllites of Chandpur Formation and the slope stability of the reservoir is governed by the conditions of these rocks.

3.2.4 Nagthat Formation

The rocks of Nagthat Formation are exposed in the central and southwestern part of the study area with northwest - southeast trend. Due to the presence of folds like anticlines and synclines, and with subsequent erosion, these rocks are repeated very often in the area. The northern end of the formation is restricted by the Chandpur Formation. Further, it is repeated twice due to the presence of folding. The Nagthat Formation consists of white, purple and green coloured quartzites with subordinate intercalations of grey and olive green slates and siltstones.

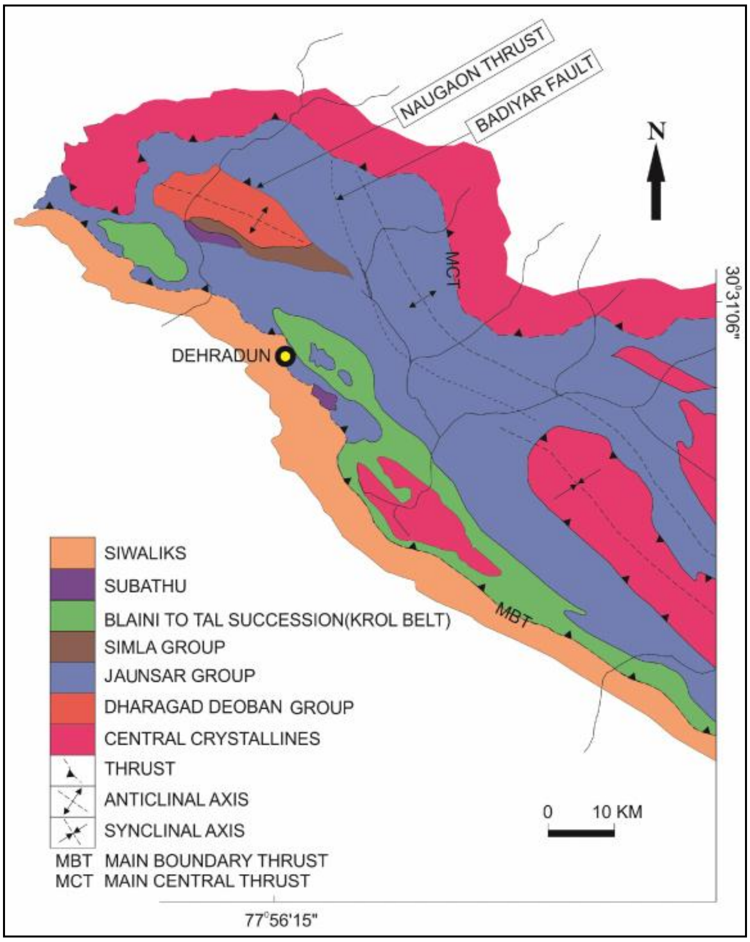


Fig. 3.2 Geological Map of Deoban Belt and it's Adjoining Area (after Ganesan and Verma, 1981)

3.2.5 Berinag Formation

The rocks of Berinag Formation are exposed in northeastern part of Tehri area. The Berinag Formation is separated by Berinag thrust. It consists of white, purple and green coloured quartzites.

3.2.6 Blaini Formation

The Blaini Formation is seen in central and western part of the study area. The rocks are repeated twice due to folding. The Formation consists of quartzites, limestones, slates, phyllites and conglomerates with sub-rounded to well rounded clasts of cobble to pebble size.

3.2.7 Krol Formation

The Krol Formation is exposed in the southwestern region delimited by Tal and Blaini Formations. The Formation mainly comprises of limestones with intercalations of grey and greenish grey slates and siltstones.

3.2.8 Tal Formation

Rocks of Tal Formation are exposed in the southwestern corner of the study area. The Formation mainly comprises white and grey coloured limestone with intercalations of pale quartzites and grey slates.

3.3 STRUCTURE

A number of major as well as minor structures have been observed in the study area. Major structural features include North Almora Thrust (NAT) and Berinag thrust, which are seen in the northern region. The south-easterly dipping North Almora Thrust separates the Chandpur phyllites from Rautgara Formation. The north-easterly dipping Berinag Thrust also called locally as Pratap Nagar Thrust (Valdiya, 1980), separates the Rautgara Formation from the Berinag Formation. A number of anticlines and synclines in the central and southwestern regions, which together form a part of Mussoorie syncline (Valdiya, 1980) have been observed. The axial trend of the fold is NW-SE direction. In addition, a local fault has been observed in the southwest of Chamba town. The minor structure includes bedding planes, joints, foliations, small scale folds, and small scale faults.

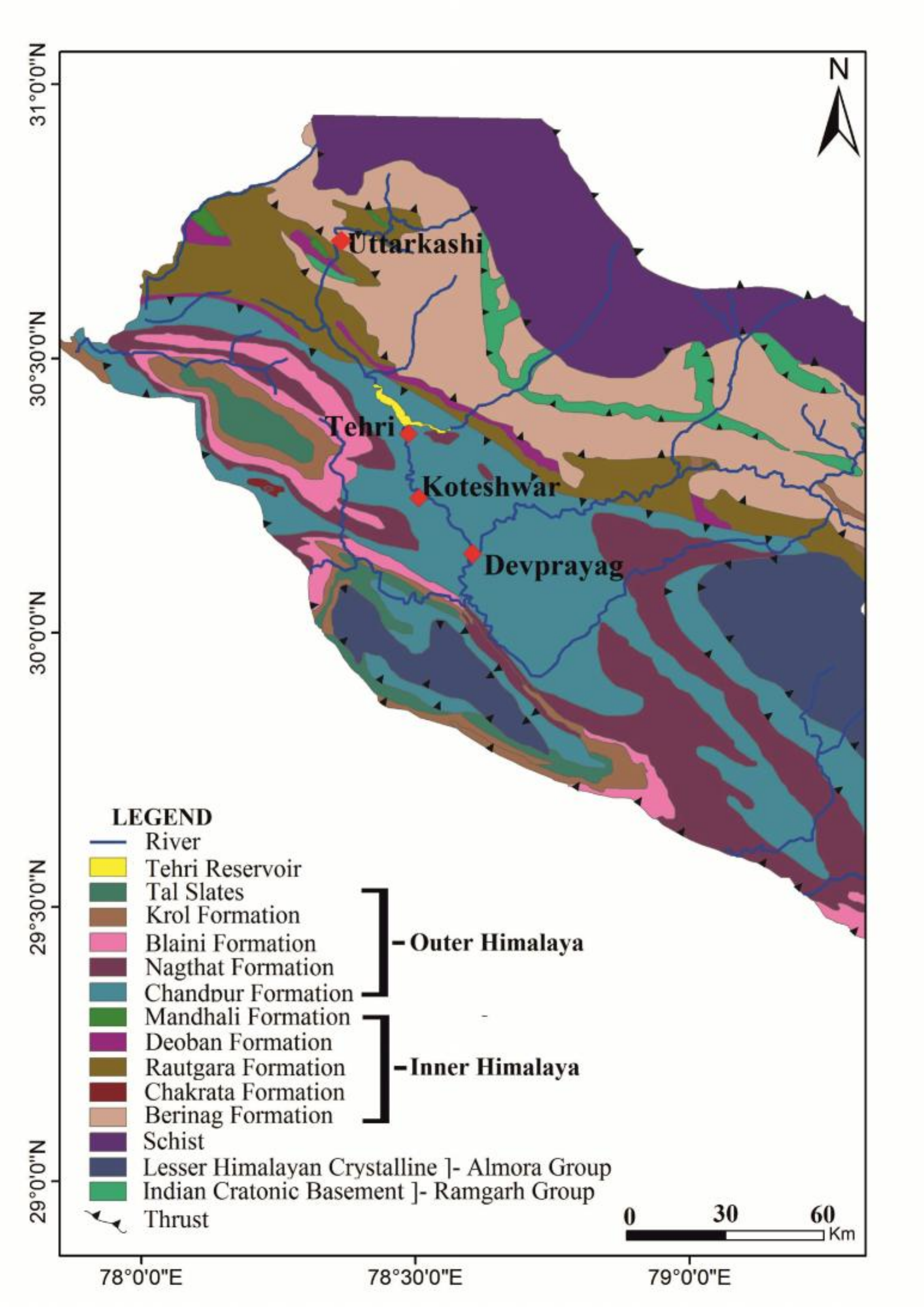


Fig. 3.3 Regional Geological Map of Tehri - Koteshwar Area (Modified after Valdiya, 1980).

3.4 GEOLOGY OF KOTESHWAR DAM RESERVOIR

The Bhagirathi river which runs in the southerly direction has cut through the rocks of Chandpur Formation, which mainly occupy entire reservoir area of Koteshwar dam. In general, the left bank slopes are steep with many escarpments. The valley slopes are marked by the presence of barren rock exposures. In the initial reach of about a kilometer, phyllite rocks are exposed on the steep to very steep slopes. Close to village Chopra, two dump-fills are observed within a short span of less than half a kilometer. These dumps extend up to the top road level for a height of about 80m. The dump fills consist of excavated loose fill materials disposed on the left bank slope. They are presently seen to have steep slopes of the order of more than 50^0. Gabion walls are under construction to protect the downstream dump in the toe area. A pumping unit is located just in front of the downstream dump within the river bed itself close to the right bank.

Further downstream of the dump, a small patch of agricultural field is seen over the river borne materials. The entire stretch of left bank further downstream up to the dam site has steep rock slopes. However, just above the old steel girder bridge, agricultural fields are seen with the reservoir slope and further above also. This area extends over a distance of less than a kilometer along the river course. The rock slopes are often seen to be controlled by the steeply dipping joints. At places, patches of river borne material are seen to be present at higher levels. The major geological discontinuity namely, foliation dips into the hill. The joints are generally discontinuous and have short strike continuity. As such, they are not very important from the general slope stability point of view. Hence the left bank rock slopes are generally stable in nature.

As compared to the left bank, which is steep with many escarpments, the right bank has moderate to steep slopes, which are in many places controlled by the foliation of the rocks. Though the slope is fairly steep at many locations close to the river bed (>40˚). Further above slopes become flat and particularly above the road, the valley has moderate slopes (30˚- 40˚). The right bank slopes are mostly occupied by landslide debris around the rim of the proposed reservoir (El 613 m). The rock exposures are seen in small patches mostly at the road level and close to the river bed level. Above the road level, the slopes mostly have debris on the slope.

The river erosion in the Geologic past had resulted in the removal of toe support of the foliation controlled slopes. This had resulted in a series of landslides in the past, the debris of which is seen commonly on the slope around the rim of the reservoir. The thickness of debris at places is more (>20 m) at higher elevations above the road. However, the thickness around the road and below it is generally of the order of around 3 -10 m. River Borne Materials (RBM) are seen at few locations – one is located on right bank opposite to Bhashon Village, where agricultural fields are seen. This area has now been submerged as it is located below El 613 m. Another RBM patch is located close to village Palam, where a private quarry is located at present. This area is located just around the MRL and hence part of this area will be inundated when the reservoir is full. A large deposit of RBM is located near village Gairogi, where THDCIL has a major quarry and a crushing plant.

The approach road to Koteshwar dam passes though the right bank above the maximum level of the reservoir. It mainly passes through the debris on the northern part of the area. Rock exposures are encountered at many places on the southern part of the area close to the dam.

3.4.1 General Slope conditions based on Slope Facet Maps

The reservoir area of Koteshwar dam extends in the North – South direction in an elongated, linear fashion with the river flowing consistently towards south. A number of streams approaching both the banks join the river and form deep depressions along the stream course particularly on right bank, which also has formed number of spurs and gullies trending roughly east-west. Due to change in local slope directions, the entire study area has been divided into a number of slope facets, each facet marking the smallest unit of mapping from the slope stability point of view. A slope facet is a part of hill slope having nearly consistent slope angle and direction and is delimited by ridges, spurs, gullies, streams and rivers. Stability conditions remain more or less same within a slope facet, but may differ as compared to adjoining facets. The slope facet map (Fig 3.4) shows the distribution of facets in the study area. The facet numbering starts from zero bridge on the northern side, where as the tail reaches of the reservoir are present on the southern side with numbers increasing towards the south and continue up to the dam site. There are 17 slope facets on the left bank and 39 on the right bank of the reservoir.

During field visits, individual slopes were studied and data related to geology and stability conditions were collected. The geological map of the reservoir area is shown in two parts-one is lithological map showing the distribution of rock types, overburden debris and RBM (Fig 3.5) and the other is the structural map which shows the distribution pattern of joints and foliations in the study area (Fig 3.6).

The field data collected facet wise is presented in the Appendix – I, II which shows the details of slope parameter and geology. The following sections discuss about more details of slope parameter, geology and other conditions of different facets.

3.4.2 Left Bank

The left bank facets are mostly located on rocks with steep slope gradients towards east. In all, 17 slope facets from L1 to L17 have been identified from zero bridge towards the dam. Details of the individual facets are discussed below. For description purpose, the facets showing more or less similar character have been clubbed.

Slope Facets: L1, L2 and L3

These slope facets are located on the left bank of the river just downstream of the steel girder bridge. The slope facets are generally steep and occupied by phyllite rocks exposure. The unmetalled road located on this bank starts from the steel bridge and extends up to the end of the facet L3, where Chopra village is located on the slopes above the road. There are two muck dumps present within these facets. These are the presently identified two sites, where the excavated muck is being dumped. The dumped muck might have attained a thickness of the order of 30-40 m above the rock slopes and extend over a height of 70-80 m. The mucks extend up to the existing road level with a steep slope towards west. The road cut section has exposed phyllites on the hill slopes. Further above, the phyllites with thin debris cover are present. Since the reservoir water may extend to a height of 20-25 m above the river bed, the reservoir operation may have damaged the stability of muck dumps. At other locations, phyllite rocks are present below the level of the road. The attitude of the geological discontinuities and other details are presented in Appendix – I, II .

Slope Facet: L4

The slope facet L4 has a moderate to steep slope of the order of 40˚. It is typical slope on the left bank where RBM is present at lower levels close to the river bed. The rock exposures can be seen close to the river bed to a height of about 2 m or so and further above, these exposures are generally concealed by RBM and debris on a fairly steep slope (≈40˚). The RBM is present just above the rock exposure and extends to a height of about 10 m. Further above the debris blanket slope, agriculture is being practiced. The debris slope extends to a height of more than 50 m. On higher levels, RBM can be seen again. The MRL extends to a height above the level of lower RBM and goes up to the toe of the debris.

Slope Facets: L5 to L11 and L13 to L17

All these slope facets are mostly located on rock slopes with thin debris overburden at places particularly in top levels. The valley faces are generally steep with a slope angle of more than 60˚ though at places they are nearly vertical. The most predominant discontinuity, namely the foliation dips into the hill. The two sets of joints observed in the rocks do not have longer strike continuity. Because of these structural advantages, the slopes are generally stable in nature. The other details are given in detail in Appendix I,II.

Slope Facet: L12

This slope facet is located in the area of old steel girder bridge, which has been replaced by another new girder bridge. The Bhashon village is located within this facet on the left bank. This village is very important because this is the only other village on the left bank apart from Chopra village. All the other villages are located on the right bank only. Here the Bhagirathi river flows roughly towards east and then takes an acute turn in the vicinity of the village to the southwest direction. Though the rocks are present at lower levels and extend nearly up to MRL and further above. Thin overburden of more than a meter is seen on the slope close to and above MRL. A number of houses are observed on the debris slope on the left bank.

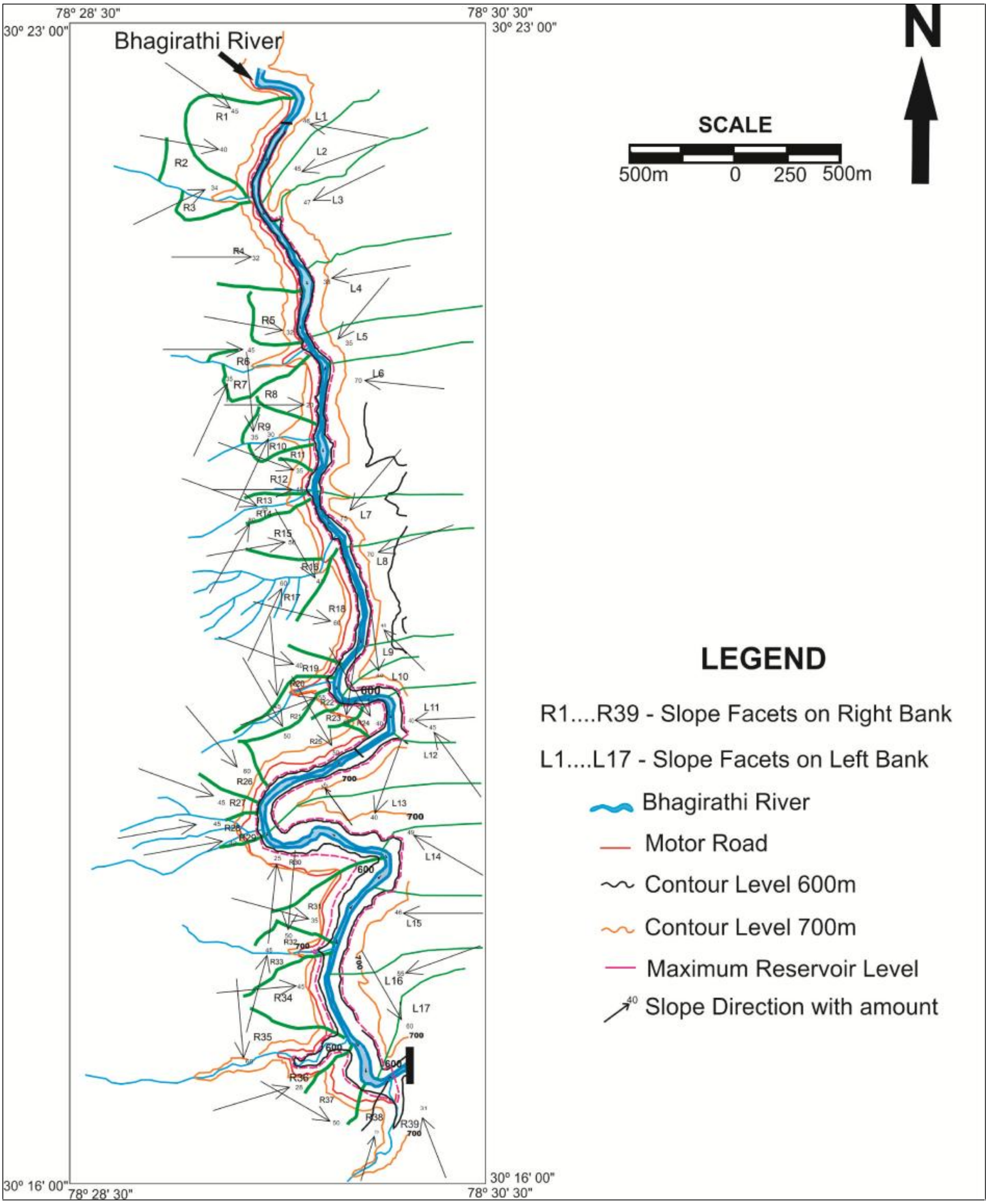


Fig. 3.4 Slope Facet Map showing Direction of Slopes around Reservoir Area

3.4.3 Right Bank

The right bank slopes have moderate to steep slopes with debris occupying major part of the slope. The rocks are seen at places along the road although they are generally exposed close to the river bed level. Based on the topography of the bank, 39 slope facets from R1 to R39 have been identified from zero bridge towards the dam. The only access road to Koteshwar dam from Zero bridge is located on this bank. The 18 km long road cuts across the right bank slope facets and runs roughly in the south direction nearly parallel to the river course. The general gradient of the road increases towards the dam (south). The data related to the attitude of the geological discontinuities and other details collected facet wise is presented in Appendix – I,II whereas general conditions including geology and other slope conditions are discussed below:

Slope Facets: R1, R2 and R3

These slope facets are located close to the Zero Bridge. The Marh stream joining the Bhagirathi River can be seen on this bank marking the boundary between facets R2 and R3. These facets have moderate debris overburden above the rock varying from about a meter to more than 5 m at places. The rocks present below the debris show three sets of discontinuities including the foliation. It is important to note that the difference between maximum reservoir level and the road is less than 15 m in these facets. Moreover the general slope angle is also fairly steep, of the order of about 45˚. In view of the possible instability of slopes of these facets, the road may face problems of instability as discussed in subsequent sections.

Slope Facet: R4

It is a fairly big slope facet, where the road is mostly located on rocks. Debris materials are seen above the road level. Thin debris cover can be seen below the road also extending up to the river bed level. Rock exposures can be seen at the road level and below it. A part of the facet on the northern side close to facet R3 has debris cover, where talus failure can be expected.

Slope Facets: R5 to R14

These facets are mostly small to moderate size. Due to presence of a number of local streams, the area has been divided into many small facets. The slopes above and below the road are moderate to steep in nature and vary from 20˚ to 45˚. The debris materials are found blanketing the slopes above and below the road. The debris extends up to the lower slopes leaving a gap between the river bed and the level of debris which is occupied by the rock exposures. The MRL mostly ends at the toe of the debris, which has a shallow depth 3 to 6 m in the area. Three sets of discontinuities were observed in the area in addition to slope attitude which have been mentioned in Appendix – I,II . The probable mode of failure of these slopes is Talus failure due to shallow thickness of the debris.

Slope Facets: R15 to R17

These slope facets have moderate slopes below the road and steep slopes above. The slopes have phyllite rock exposures both above and below the road. The rock exposures can be seen close to river level also. In view of the fact that moderate slopes are present below the road with apparently stable rock exposures, the draw down conditions may not cause any damage to the slopes.

Slope Facet: R18

It is a fairly big facet with varying geological and slope conditions. On the northern side, the slope has rocks with debris cover below the road. On the southern side of the facet, river borne materials are present about 40 m below the road and extend nearly down up to the river bed. It is a thick deposit and excavated for using as aggregates by private firms. The village Palam is located on this facet above RBM and close to the road level. The draw down conditions of the reservoir water may cause internal erosion of RBM and cause instability. However, the road is located much above the MRL and hence damage to the road is not expected.

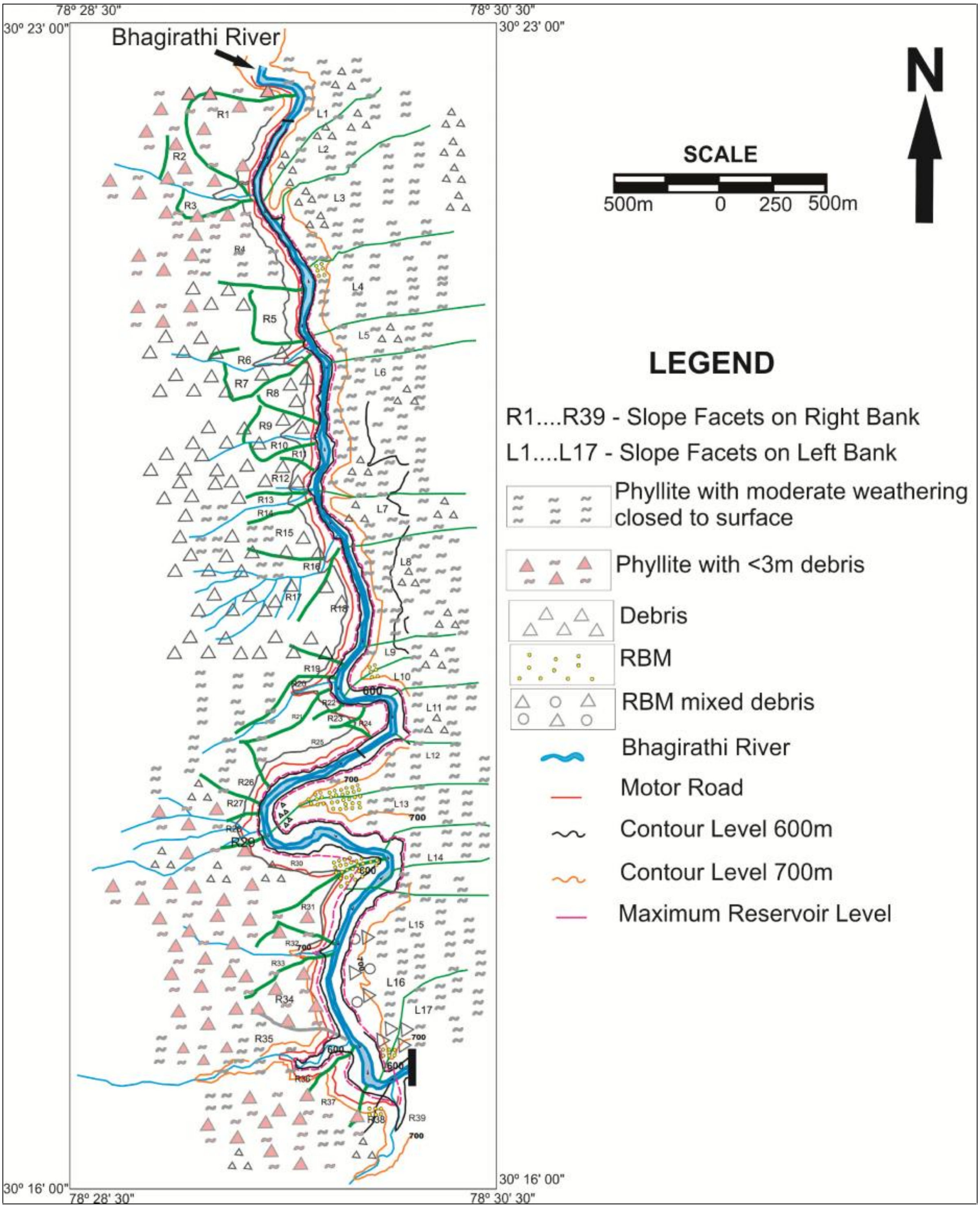


Fig. 3.5 Lithological Map of Koteshwar Reservoir Area.

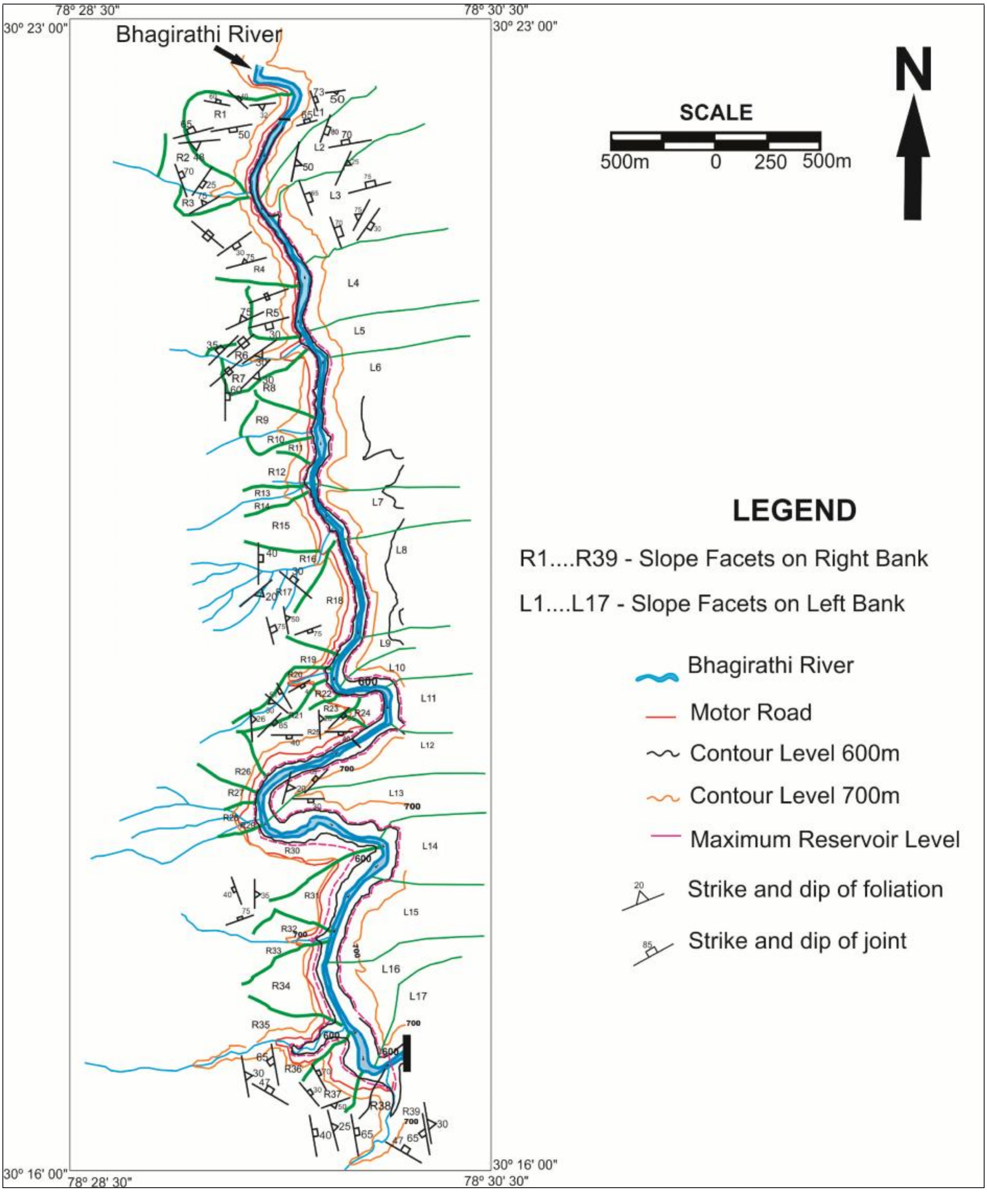


Fig. 3.6 Map showing Structural Details of Koteshwar Reservoir Area

Slope Facets: R19 to R25

These facets are located on the acute turn of the river flow, where the river takes S-shaped loop. Except R25, all other facets are small in size. Rocks are exposed in all the facets above the road level with very thin debris present in small pockets. The thickness of debris is more below the road in facet No. 24. In place of an old girder bridge, a new bridge has been constructed with approach roads. The attitudes of geological discontinuities observed in these facets are presented in Appendix – I, II .

Slope Facets: R26 to R29

These small slope facets are bounded by minor streams located at close intervals. The facets are located on inward curve of the river Bhagirathi. The past bank erosion had resulted in the formation of debris, which are observed on the slope as a whole. The thickness is more above the road and intermittent rock exposures could be seen below the road within the debris. However, since the level difference between the road and MRL is more than 50 m, the slope appears to be stable and not likely to be affected by the operation of the reservoir.

Slope Facets: R30 to R36

These slope facets are safely located on the right bank and have intermittent rock exposures with thin debris overburden cover. The river takes an acute turns within these facets and the slopes are just stable in dry condition whereas they may be unstable in saturated condition. The river takes the first turn between the slope facets R30 and R31. Massive 40 m thick RBM deposit is observed at the bend close to the river level. These materials are being excavated by THDCIL for aggregate purpose. The excavated benches are progressing towards the road side. The road takes an acute U-shaped hair pin bend within the facets R35 and R36.

Slope Facet: R37

This slope facet is located on phyllite rocks with thin debris cover. Since the slope below the road is moderately steep (≈50˚), the rock materials may get over saturated due to the presence of reservoir water at the toe. In case of failure of the slope materials, the road may also get damaged. The road cut slope adjoining the road and below the Shiva temple is already in an unstable condition due to local instability.

Slope Facets: R38 to R39

This facet is located close to the dam site on which the administrative office building is also located. Further below the road, the slope is very steep (nearly vertical). Since debris materials are present on the steep slope face, their shear strength parameters may be high due to natural cementing of these materials. The entire slope is blanketed by the debris. Once the reservoir is filled up to the MRL, the seepage water may lubricate the materials, erode the delicate bonding of the cement and cause the slope failures. This may affect the road the damage may as well extend further up to the slope above. The RBM deposit is present above the road. The administrative building of THDCIL is located further above on the RBM. In case if the road sinks and the RBM also fails, the stability of the foundation of the office building may be in peril.

CHAPTER – IV

GEOTECHNICAL STUDIES OF KOTESHWAR DAM RESERVOIR

4.1. FIELD INVESTIGATIONS AND SCANLINE SURVEY

Based on the mapping of the Koteshwar dam reservoir area and using the slope facet concept, some important slope sections, which may be considered as representatives of the slope pattern of the area, were chosen on both the banks. The locations of all these sections are shown in Fig. 4.1. Using Total Station, slope profiles of the chosen sections were observed on 1:1000 scale. In order to study the stability and other related issues of the reservoir rim area, the stability studies of slopes all along the left and right banks of the reservoir were carried out in detail using these sections. The slopes, in general, are comprised of both debris and the rock mass. Out of a total of 22 slopes, 17 slopes on the right bank and 5 slopes on the left bank of the reservoir were visually identified for detailed analysis. Field visits were undertaken to collect the data related to rock mass characteristics and the mapping of various slopes. These include slope angle, slope direction, number of joint sets, dip amount and dip / strike direction of each joint set, joint aperture, joint roughness, continuity of joints, joint filling material (gouge), joint water condition, condition regarding weathering, foliations etc., if any.

The scan line survey was also undertaken at 39 locations on right bank and 17 locations on the left bank of the reservoir. This scan line survey gives the minute details of various features of rock mass along selected finite lengths of the slope face. The data collected through the scan line survey is presented in Appendix- I for selected locations of left and right bank slopes of the reservoir.

The location, description of the slope profile, geology, structure, details of stability analysis and overall impact due to reservoir filling are discussed in the following sections.

4.1.1 Right Bank Slope Sections

Slope Section: RBS1

The slope section RBS1 is located on the right bank near the Zero Bridge at a distance of 200 m (Fig. 4.2). The section depicts the nature of slope below and above the road. The slope, on an average, has an angle of 45˚ towards N125˚. The height of the rock slope above the road is 60 m whereas below the road, it is 30 m. The maximum reservoir level (MRL) extending to about 25 m above the river bed is mainly confined to rocks only. The rocks exposed in this area are basically phyllites of Chandpur Formation. The slope mass has two

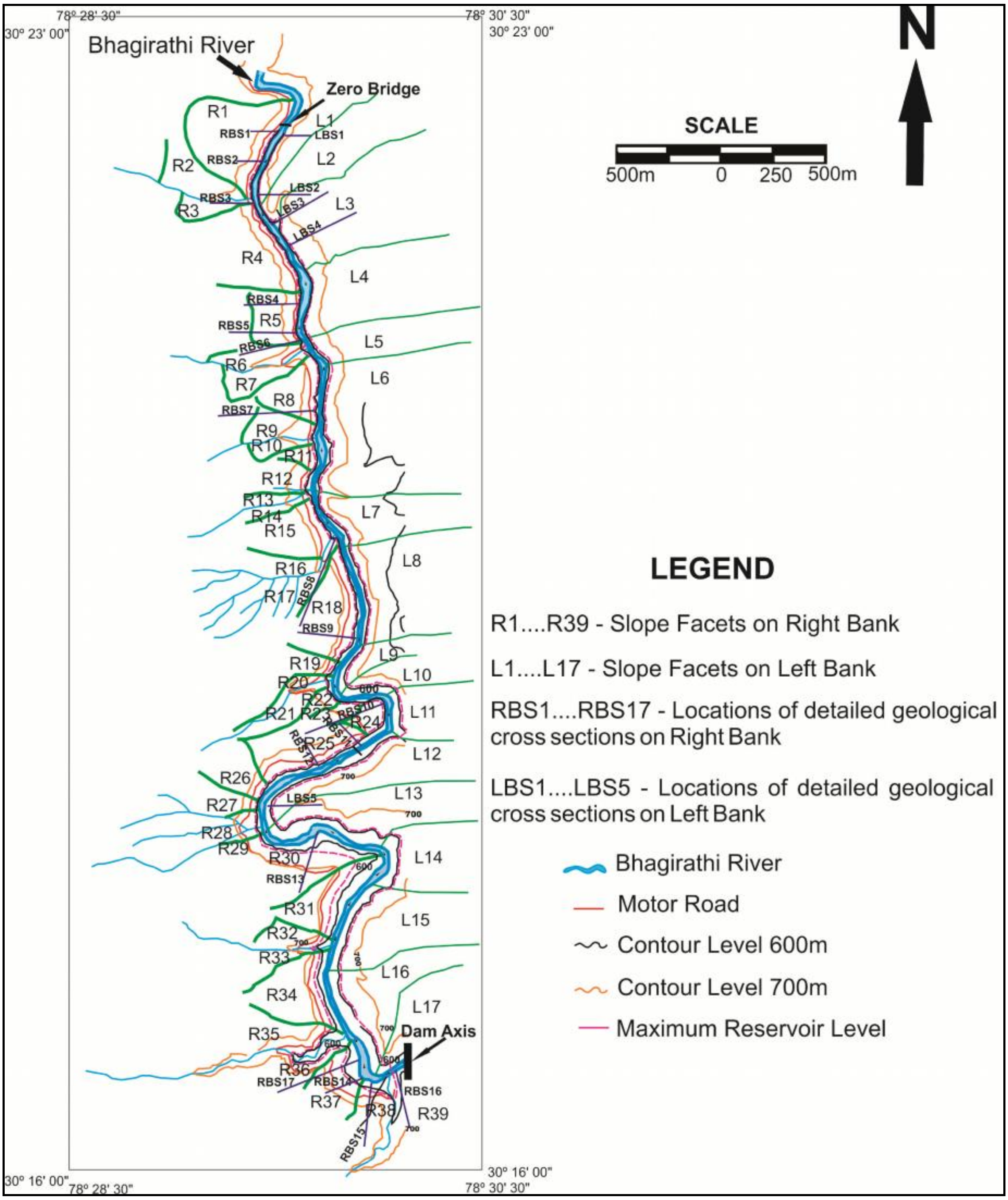


Fig. 4.1 Slope Facet Map showing Locations of Geological Sections

regular joint sets and a foliation joint. The foliation generally dips at an angle of 32^0 towards N 175^0 and the two joint sets namely J1 and J2 are dipping 60^0 towards N40^0 and 40^0 towards

N10^0 respectively. Thin debris cover of less than 3 m thickness can be seen on the slope surface both above and below the road close to the river bed. A view of the slope around section RBS1 is shown in Plate 4.1.

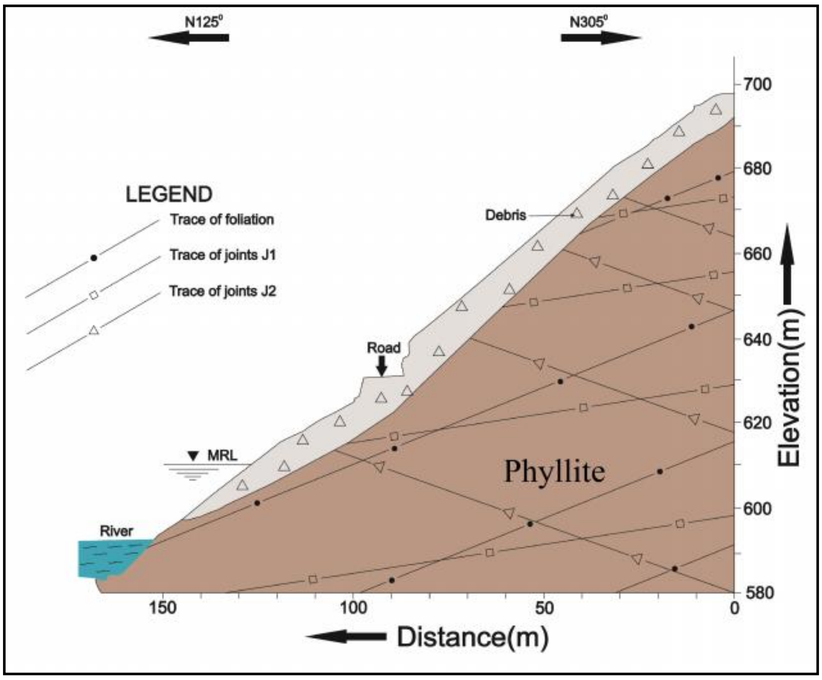


Fig. 4.2 Geological Section of Slope RBS1 at 200 m from Zero Bridge

Plate 4.1 A View of Slope RBS1 at 200 m from Zero Bridge

Slope Section: RBS2

The slope at section RBS2 is located at about 500 m d/s of the Zero Bridge (u/s Marh stream) on the right bank (Fig. 4.3). The section depicts the nature of slope below and above the road. The slope, on an average, has an angle of 40˚ towards N100˚. The slope has a fairly thick overburden cover of about 10 m. The road has been excavated within the debris. Once the reservoir is full, part of the toe material up to a height of about 23 m above the river bed will be submerged. Since the thickness of the debris is about 8 m, Talus failure is the most probable failure at this site. The height of the rock slope above the road is 55 m whereas below the road is 10 m. Phyllites of Chandpur Formation are the only rocks exposed in this area. The foliations, which are strongly developed in addition to other joints, are the predominant geological discontinuity in rocks. The foliation generally dips at an angle of 48^0 towards N 175^0. In addition, there are two sets of joints J1 and J2, which dip at an angle greater than 60^0 towards N345^0 and 50^0 towards N170^0 respectively. A view of the slope around section RBS1 is shown in Plate 4.2.

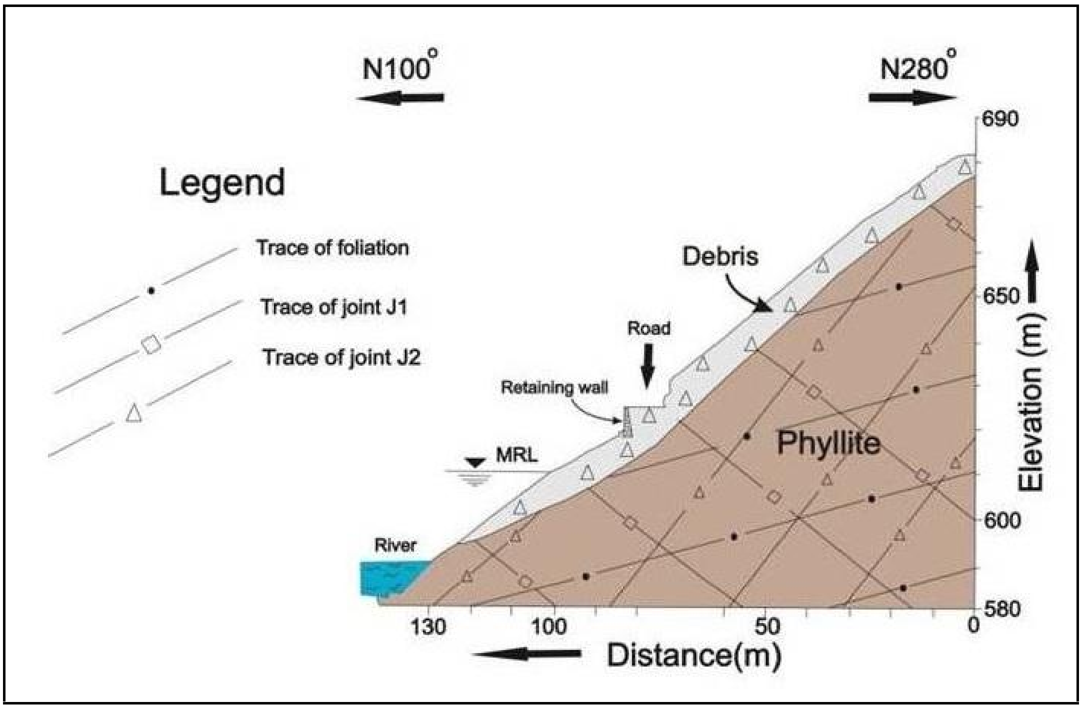


Fig. 4.3 Geological Section of Slope RBS2 at 500 m from Zero Bridge (u/s of Marh Stream)

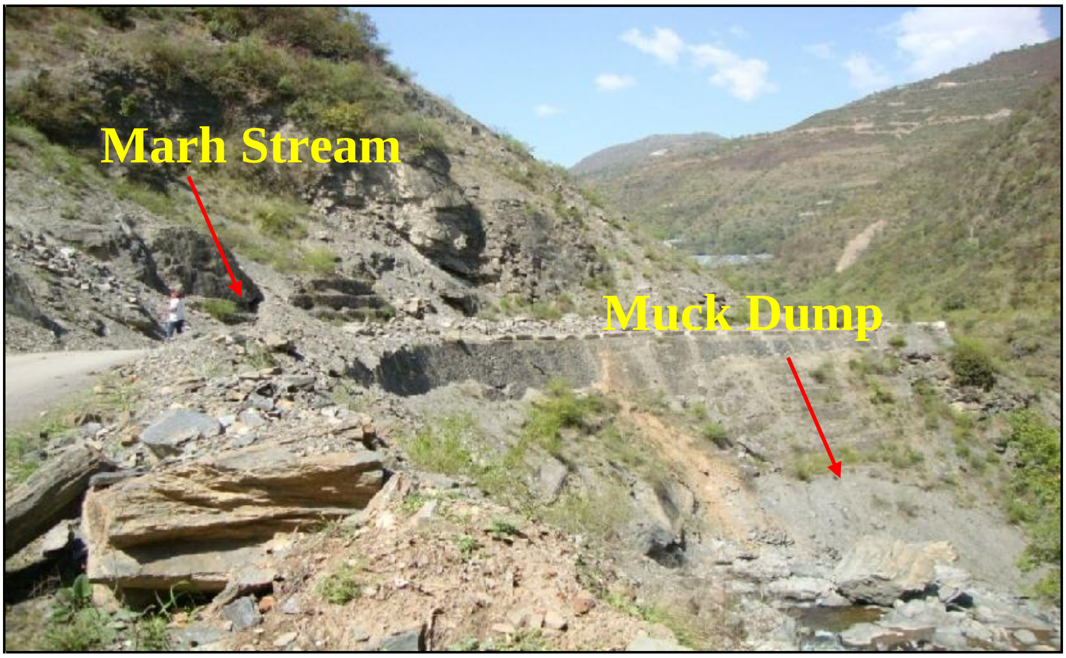


Plate 4.2 A view of Slope RBS2 at 500 m from Zero Bridge (u/s of Marh Stream)

Slope Section: RBS3

The slope section RBS3 is located at a distance of 1 km downstream (d/s) of the Zero Bridge (near pumping unit) on the right bank of the reservoir (Fig. 4.4). Here the road is located on rock exposures. Thin debris can be seen below the road close to the river bed. However, a thin cover of debris (≈ 5 m) is present on the slope surface above the road level. The slope, on an average, has an angle of 34˚ towards N64˚. The height of the rock slope above and below the road is ≈ 30 m. The MRL extending to about 30 m above river bed is mainly confined to phyllite rocks only. The slope mass has two regular joint sets and a foliation joint. The foliation generally dips at an angle of 75^0 towards N 330^0 and the two joint sets, namely J1 and J2 are dipping 70^0 towards $N70^0$ and 25^0 towards $N113^0$ respectively. A view of the slope around section RBS3 is shown in Plate 4.3.

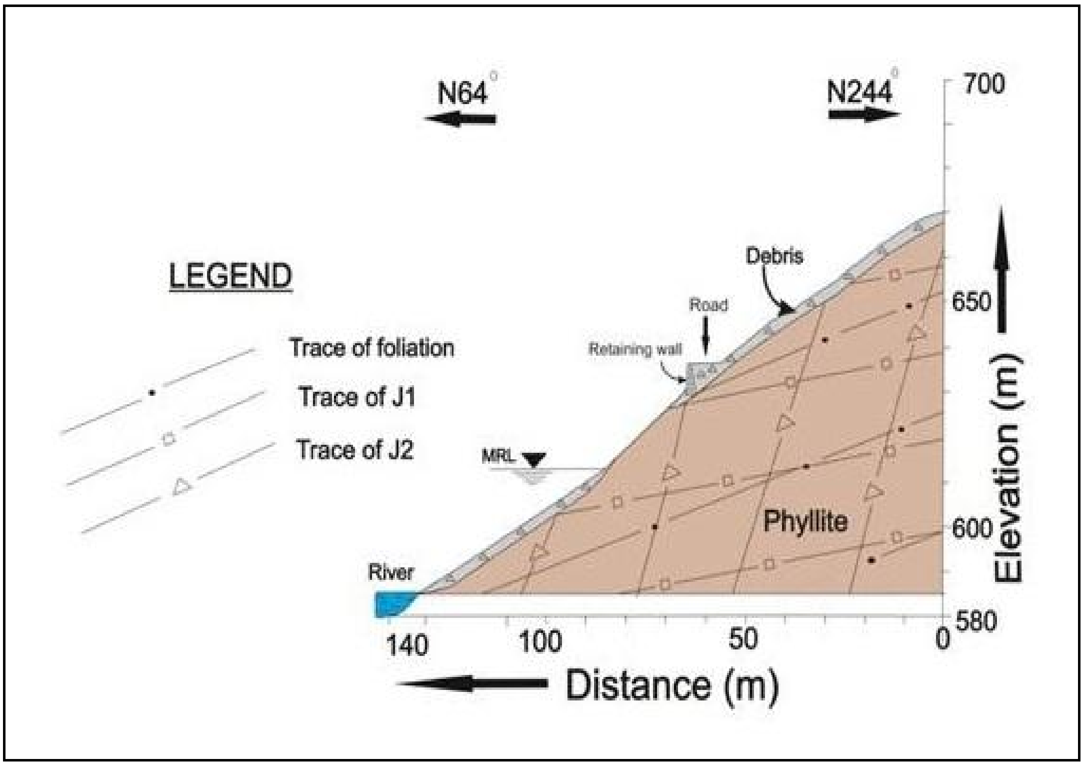


Fig. 4.4 Geological Section of Slope RBS3 Located 1 km from Zero Bridge (near Pumping Unit)

Plate 4.3 A view of Slope RBS3 Located 1 km from Zero Bridge (near Pumping Unit)

Slope Section: RBS4

The slope section RBS4 is located on the right bank below the road 2 km d/s of Zero Bridge (near Dobra village) (Fig. 4.5). A look at the section indicates that the slope angle below and above the road remains more or less the same. The slope on an average has an angle of about 32˚ towards N90˚. The height of the slope above and below the road is 10 m and 30 m respectively. The slope has a moderate overburden cover of about 5 m. The road has been excavated within the debris. Once the reservoir is full, it will submerge a part of the toe material, extending to a height of about 32 m above the river bed. The thickness of the debris is about 5 m. In this slope section, the rocks are present at shallow depth and the foliations are dipping nearly in the same direction as that of the slope but at a lower angle. The area around the section RBS4 has been shown in Plate 4.4.

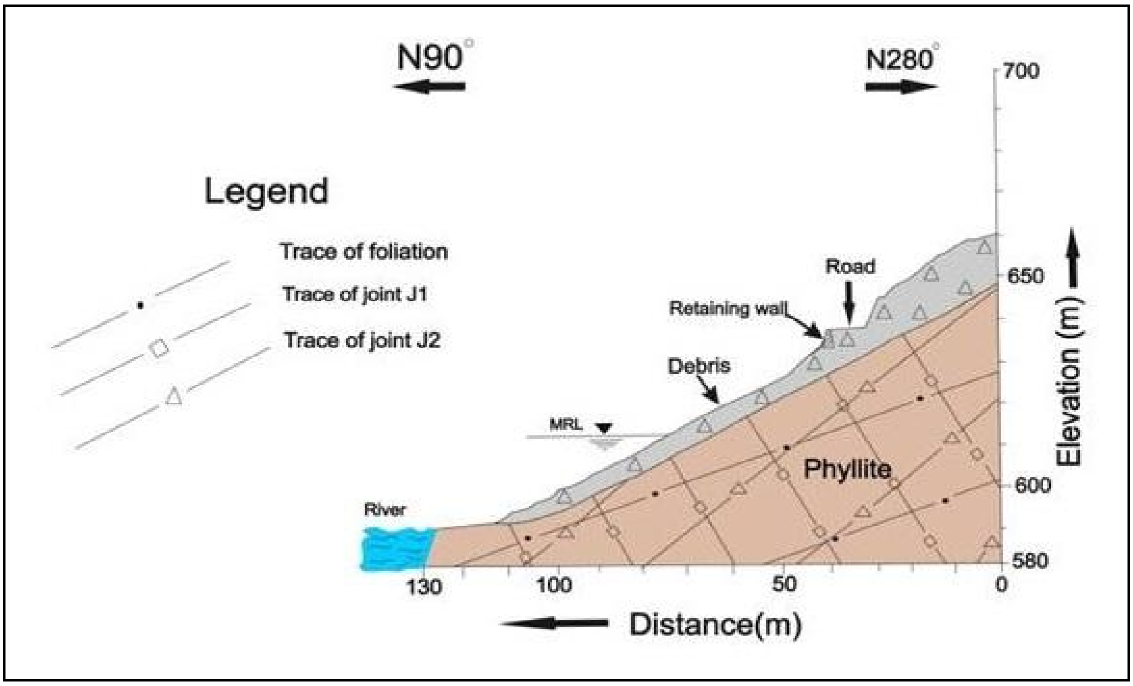


Fig. 4.5 Geological Section of Slope RBS4 Located 2 km from Zero Bridge (u/s of Dobra village)

Plate 4.4 A view of Slope RBS4 Located 2 km from Zero Bridge (u/s of Dobra village)

Slope Section: RBS5

The slope section RBS5 is located on the right bank below the road at 2.3 km away from Zero Bridge (d/s of Dobra village, below Kunjeshwar Mahadev temple) (Fig. 4.6). The slope below the road shows moderate angles with an average of about 32˚ toward N100˚ direction. The slope mass has two regular joint sets and a foliation joint. The foliation generally dips at an angle of 75^0 towards N 335^0 and the two joint sets, namely J1 and J2 are dipping ≈ 90^0 towards $N140^0$ and 30^0 towards $N145^0$ respectively. On an average, the slope has a moderate debris overburden cover of about 6 m, though the general thickness increases upwards. The hard rocks are exposed at lower levels up to the river bed. The road has been excavated within the debris. Once the reservoir is full, the MRL is expected to rise to about 33 m above the river bed and submerge a part of the debris material at the toe. A view of the area around the section RBS5 is shown in Plate 4.5.

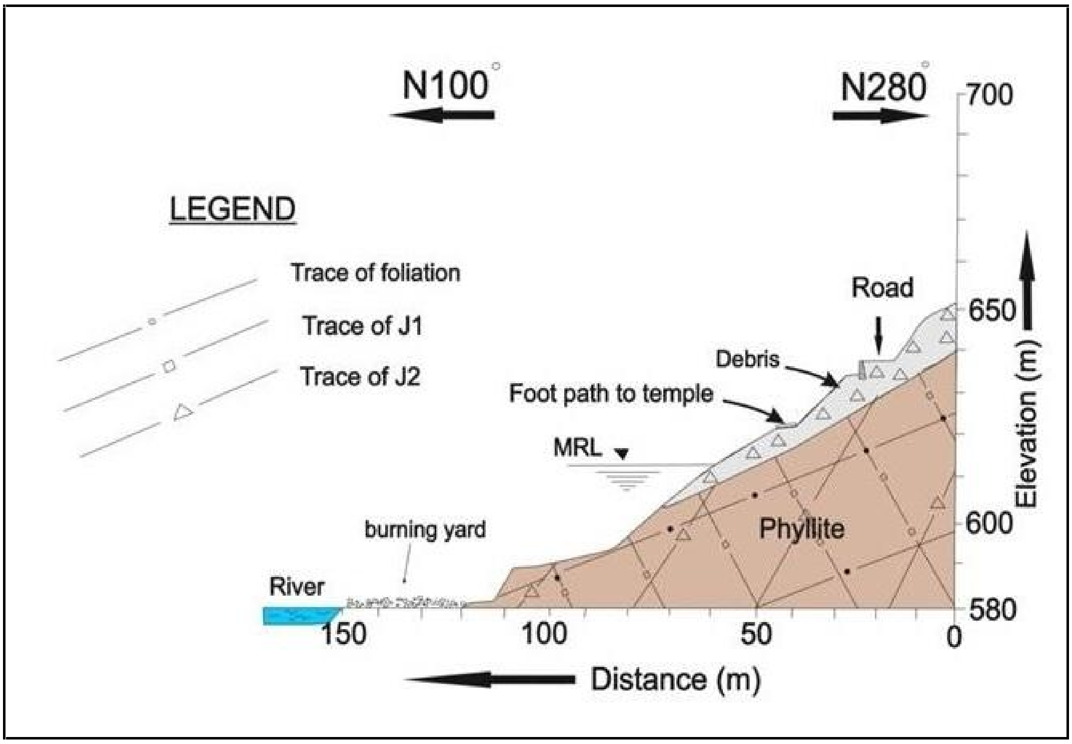


Fig. 4.6 Geological Section of Slope RBS5 Located at 2.3 km away from Zero Bridge (d/s of Dobra village, below Kunjeshwar Mahadev temple)

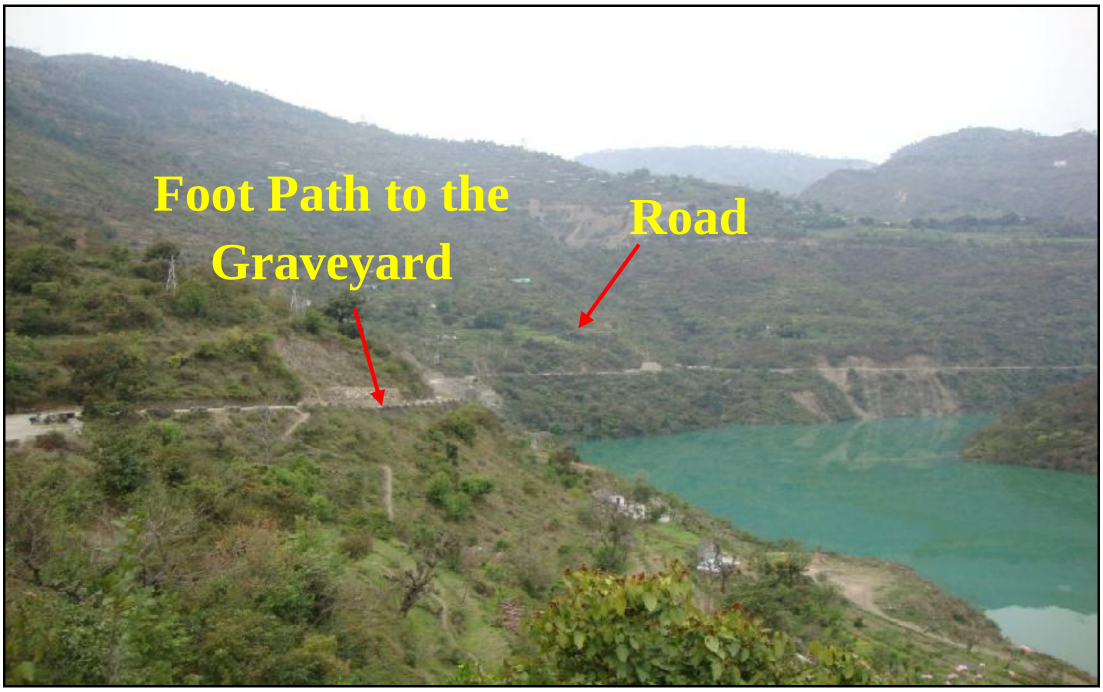


Plate 4.5 A view of Slope RBS5 Located at 2.3 km away from Zero Bridge (d/s of Dobra village, below Kunjeshwar Mahadev temple)

Slope Section: RBS6

The slope section RBS6 is located at 2.7 km away from the Zero Bridge towards the dam site (just upstream of Dharamghat Village) on the right bank below the road (Fig. 4.7). The slope has a fairly steep angle of 45˚ towards N90˚. The foliations are the predominant geological discontinuity in the rocks, which are strongly developed in addition to other joints. The foliations are dipping nearly in the same direction as that of the slope but at a milder angle. The foliation generally dips at an angle of 30^0 towards N 145^0. In addition, there are two sets of joints J1 and J2, with dips of 35^0 towards $N335^0$ and $\approx 90^0$ towards $N140^0$ respectively.

Here, the road is located on debris material with an average thickness of 8 m, which extends down for about few meters and further down, rock exposures can be seen. Moderately thick debris is present at road level and further above, to a considerable height. The rock exposures extend from below the road down to river bed level. The MRL extending about 33 above the river bed is confined to phyllite rocks only. The Plate 4.6 shows the area of the section RBS6.

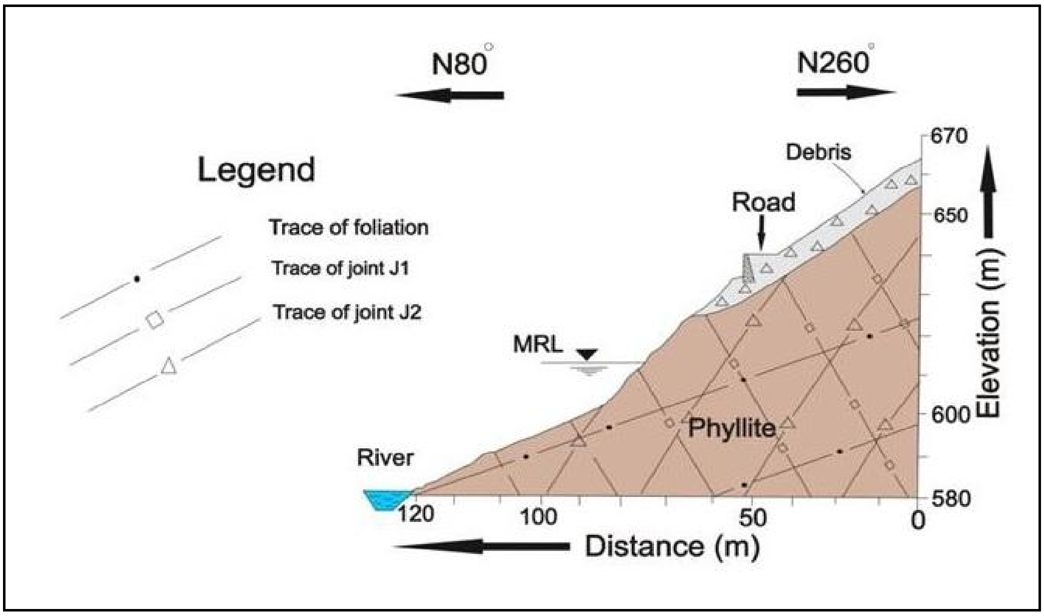


Fig. 4.7 Geological Section of Slope RBS6 located at 2.7 km away from the Zero Bridge towards the dam site (just u/s of Dharamghat Village)

Plate 4.6 A view of Slope RBS6 RBS6 located at 2.7 km away from the Zero Bridge towards the dam site (just u/s of Dharamghat Village)

Slope Section: RBS7

The slope section RBS7 is located at 3.2 km d/s of Zero Bridge on the right bank below the road close to village Kyari (Fig. 4.8). The slope below the road shows gentle angles with an average of about 20˚ towards N90˚ direction. The foliations are the predominant geological discontinuity in the rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 30^0 towards N 135^0. In addition, there are two sets of joints J1 and J2, which are dipping 60^0 towards N270^0 and ≈ 90^0 towards N140^0 respectively.

On an average, the slope has a moderate overburden cover of about 6 m below the road. Above the road level, the thickness of the debris increases. The debris cover in lower levels extends to an elevation of 600 m only. Further down, hard rocks are exposed up to river bed level (El. 576.6 m). The road has been excavated within the debris. Once the reservoir is full, the maximum reservoir level, rising by about 35 m above the river bed, will submerge a part of the debris material at the toe. A view of the area around the section RBS7 is shown in Plate 4.7.

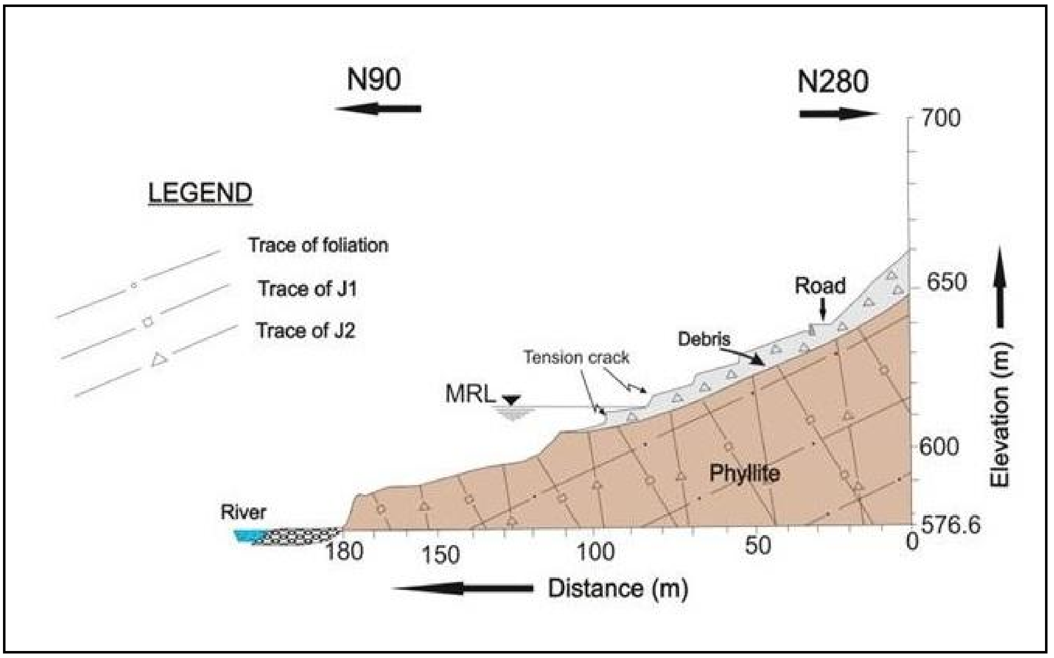


Fig. 4.8 Geological Section of Slope RBS7 Located 3.2 km d/s of Zero Bridge (near Kyari Village)

Plate 4.7 A view of Slope RBS7 Located 3.2 km d/s of Zero Bridge (near Kyari Village)

Slope Section: RBS8

The slope section RBS8 is located on the right bank at 4.7 km d/s of Zero Bridge below the road (close to village Dandeli) (Fig. 4.9). The slope below the road shows gentle angles with an average of about 41˚ toward N150˚ direction. The foliations, which are strongly developed in addition to other joints, are the predominant geological discontinuity in rocks. The foliation generally dips at an angle of 20^0 towards N 140^0. In addition, there are two sets of joints J1 and J2, which are dip at 40^0 towards $N90^0$ and 30^0 towards $N220^0$ respectively. Further above the road, the slope angle increases rapidly. On an average, the slope has a moderate overburden cover of less than 5 m above and below the road. The Plate 4.8 shows the area around section RBS8 indicating the extension of the debris and the rocks. The rocks are present at shallow depth.

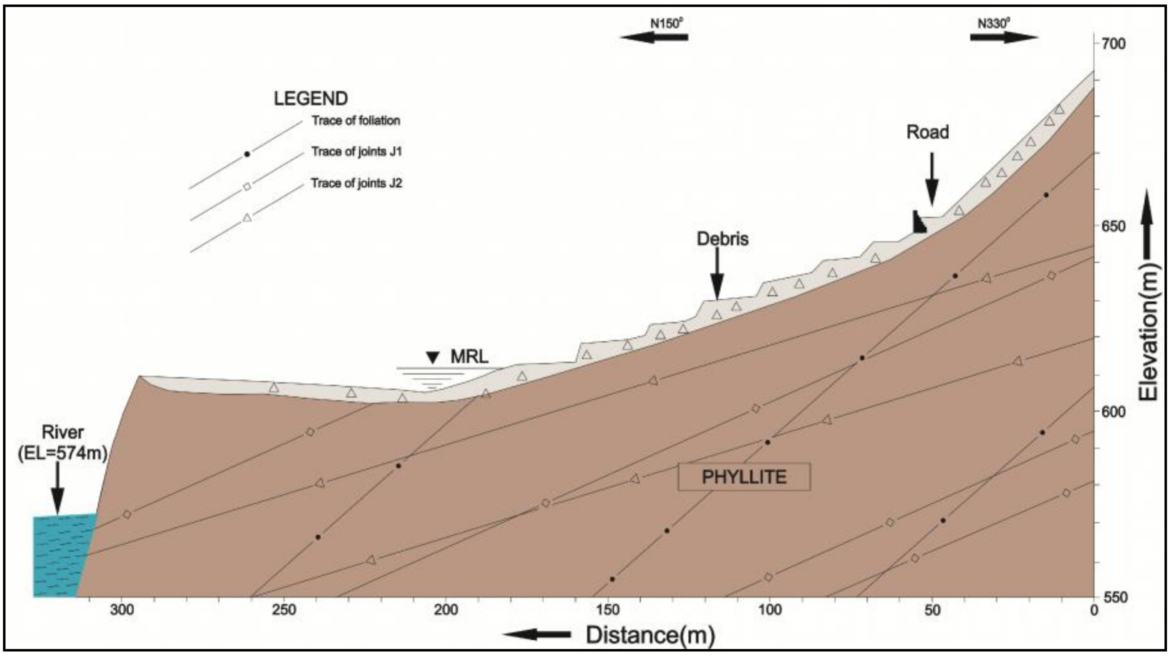


Fig. 4.9 Geological Section of Slope RBS8 Located 4.7 km d/s of Zero Bridge (near Dandeli Village)

Plate 4.8 View of Slope RBS8 Located 4.7 km d/s of Zero Bridge (near Dandeli Village)

Slope Section: RBS9

The slope section RBS9 is located on the right bank at 5.7 km d/s of Zero Bridge below the road (close to village Palam) (Fig. 4.10). The slope below the road shows steep slope angle of 60˚ towards N104˚ up to a height of about 45 m down. The foliations are the predominant geological discontinuity in rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 50^0 towards N 80^0. In addition, there are two sets of joints J1 and J2, which are dipping at 75^0 towards $N175^0$ and 75^0 towards $N160^0$ respectively. Further down, River Borne Material (RBM) is present, where a private quarry was in operation at the time of this survey. The excavated benches are encroaching fast towards the hill slope towards west. The thickness of the RBM is more than 35 m. Rocks are seen exposed below RBM on the near vertical scarp face for more than 10 m up to the river bed level. The road has been excavated within the debris. Once the reservoir is full (El 613m), the MRL rising by about 38 m above the river bed will submerge a part of the RBM at the toe. The Plate 4.9 shows the extension of the debris and RBM at the site.

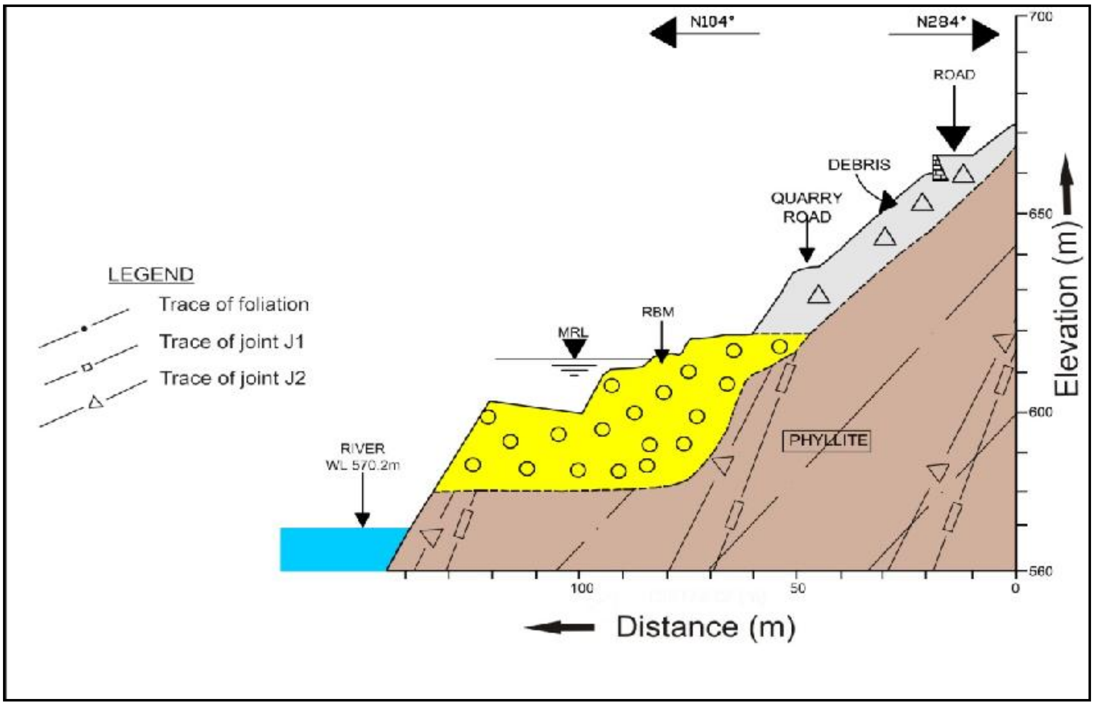


Fig. 4.10 Geological Section of Slope RBS9 Located 5.7 km d/s of Zero Bridge (near Quarry Site below Palam Village)

Plate: 4.9 A View of Slope Slope RBS9 Located 5.7 km d/s of Zero Bridge (near Quarry Site below Palam Village)

Slope Section: RBS10

The slope section RBS10 is located on the right bank at 6.5 km d/s of Zero Bridge below the road (close to village Palam) (Fig. 4.11). The slope below the road shows gentle angles with an average of about 60˚ toward N189˚ direction. Further above the road, the slope angle increases rapidly. The foliations are the predominant geological discontinuity rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 30^0 towards N 220^0. In addition, there are two sets of joints J1 and J2, which are dipping at 51^0 towards N239^0 and 41^0 towards N150^0 respectively. On an average, the slope has a thin overburden cover of less than 5 m below the road. Rocks are exposed further down up to river bed level at shallow depth. The area around the section RBS10 has been shown in Plate 4.10 indicating the extension of rocks and debris in the area.

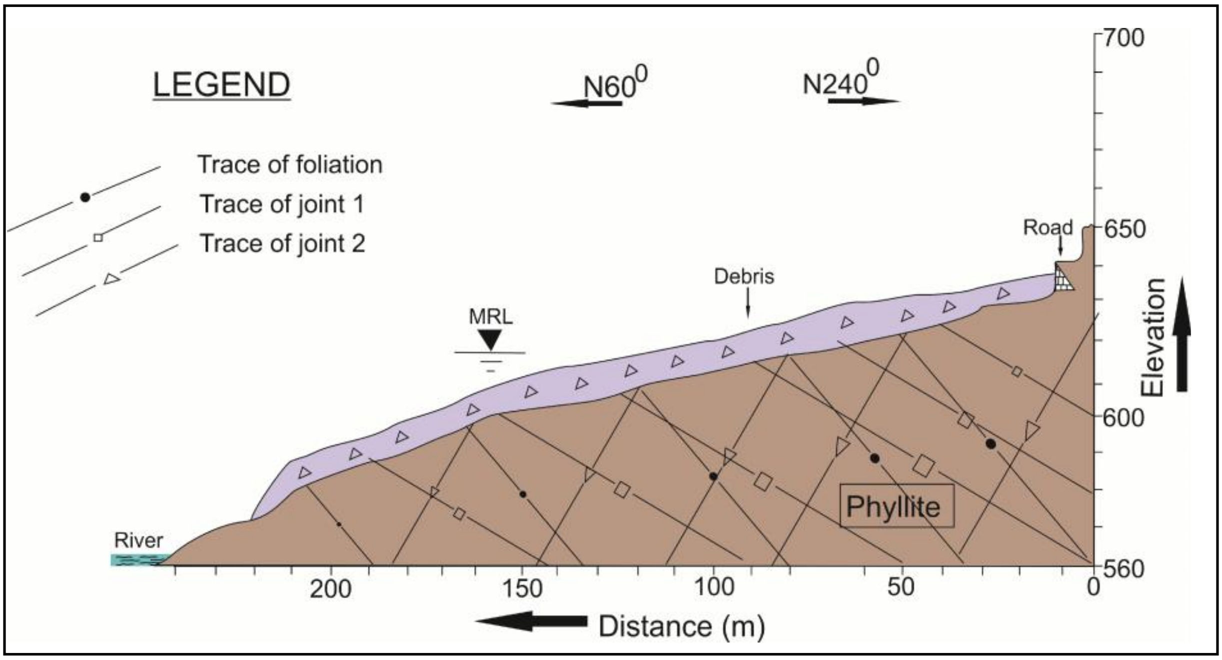


Fig. 4.11 Geological Section of Slope RBS10 Located 6.5 km d/s of Zero Bridge (near Palam Village)

Plate 4.10 A View of Slope RBS10 Located 6.5 km d/s of Zero Bridge (near Palam Village)

Slope Section: RBS11

The slope section RBS11 is located on the right bank at 7.2 km d/s of Zero Bridge below the road (close to village Palam) (Fig. 4.12). The slope below the road shows gentle angles with an average of about 40˚ towards N149˚ direction. The foliations are the predominant geological discontinuity in rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 26^0 towards $N85^0$. In addition, the joint sets, J1 and J2 dip at 40^0 towards $N180^0$ and 85^0 towards $N315^0$ respectively. The slope below the road shows varying slope angles - initially the slope being around 40˚and gets flattened to about 25˚ towards N149˚ direction at lower elevations below El 610 m. On an average, the slope has a fairly thick overburden cover of about 10 m below the road. The debris cover in lower levels extends up to El ± 580 m. Rocks are exposed further down up to river bed level (El ± 561 m). The road has been excavated within the debris. Under full reservoir conditions (El 613 m), the MRL may rise by about 44 m above the river bed and thus may submerge a part of the debris material at the toe. The extension of the debris and the rocks close to river bed level is shown in Plate 4.11.

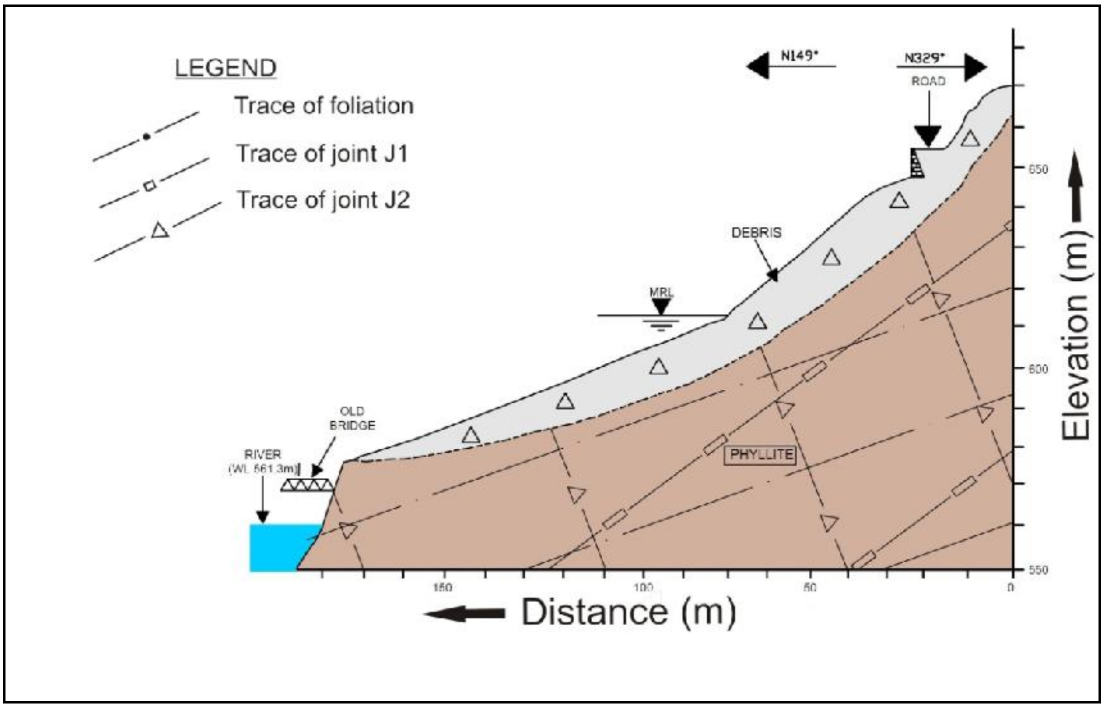


Fig. 4.12 Geological Section of Slope RBS11 Located 7.2 km d/s of Zero Bridge (near Palam village u/s of Iron Bridge)

Plate 4.11 A View of Slope RBS11 Located 7.2 km d/s of Zero Bridge (near Palam village u/s of Iron Bridge)

Slope Section: RBS12

The slope section RBS12 is located on the right bank at 7.7 km d/s of Zero Bridge below the road (near Phipalti village) (Fig. 4.13). The slope below MRL shows varying slope angles, but an average angle of 50˚ has been adopted for the analysis. The foliations are the predominant geological discontinuity in rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 26^0 towards $N85^0$. Moreover, the foliations are dipping nearly in the same direction as that of the slope but at a lower angle. In addition, there are two sets of joints J1 and J2, which are dipping at 40^0 towards $N180^0$ and 85^0 towards $N315^0$ respectively. Since the rocks are present on the slope below MRL, the submergence conditions are likely to affect the rock slopes. The Plate 4.12 shows a view of the area around Section RBS12.

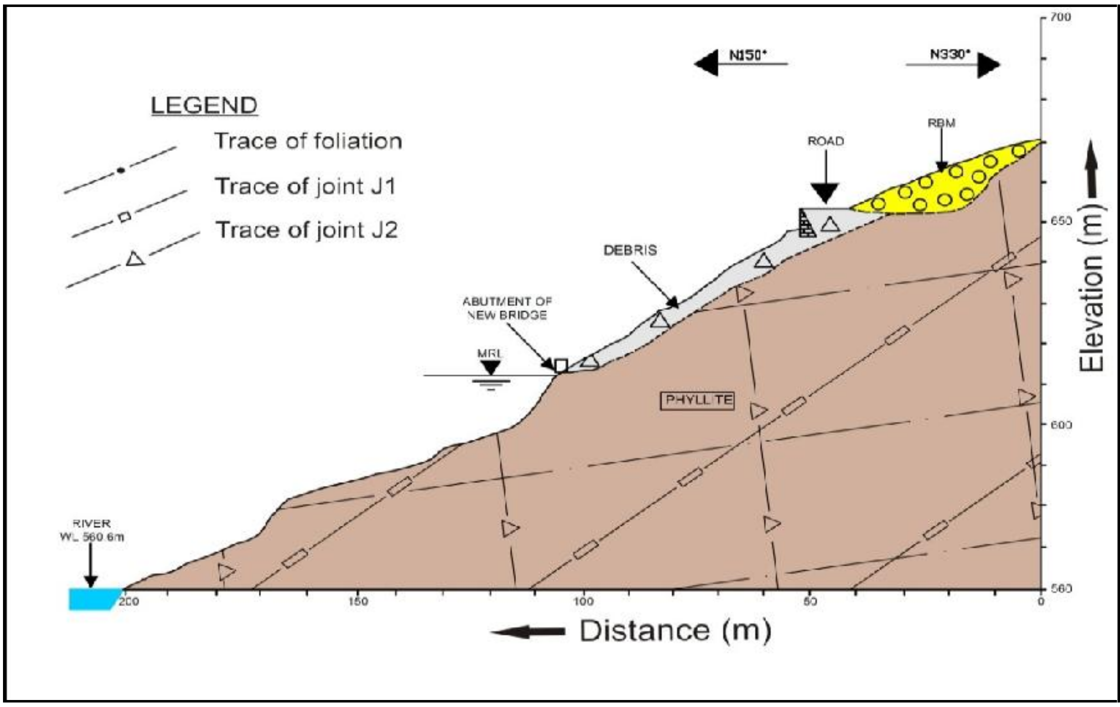


Fig. 4.13 Geological Section of Slope RBS12 Located 7.7 km d/s of Zero Bridge (near Phipalti village)

Plate 4.12 A View of Slope RBS12 Located 7.7 km d/s of Zero Bridge (near Phipalti village)

Slope Section: RBS13

The slope section RBS13 is located on the right bank at 8.5 km d/s of Zero Bridge below the road close to village Bandria (Fig. 4.14). The slope below the road shows moderate angles of 25˚ towards N06˚ direction. The slope below the road has debris cover (< 5 m thick) for more than 40 m. The foliations are the predominant geological discontinuity in rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 35^0 towards $N90^0$. In addition, there are two sets of joints J1 and J2, out of which J1 dips at 40^0 towards $N250^0$ and J2 dips at 75^0 towards $N340^0$ respectively. Further down, river borne materials are present, where THDCIL has established a quarry at present. The excavated benches are encroaching fast towards the hill slope towards south. The thickness of the RBM is more than 40 m. Aerially, the deposit has a width of more than 150 m towards the river. Further down, the rocks are seen obscured by debris materials on a moderately steep slope up to river bed level. The road has been excavated within the debris. Once the reservoir is full (El 613 m), the MRL will rise to 63 m above the river bed and submerge a part of the RBM at the toe. Since the thickness of the RBM is more than 40 m. The area around the section RBS13 has been shown in Plate 4.13 indicating the extension of debris in the area.

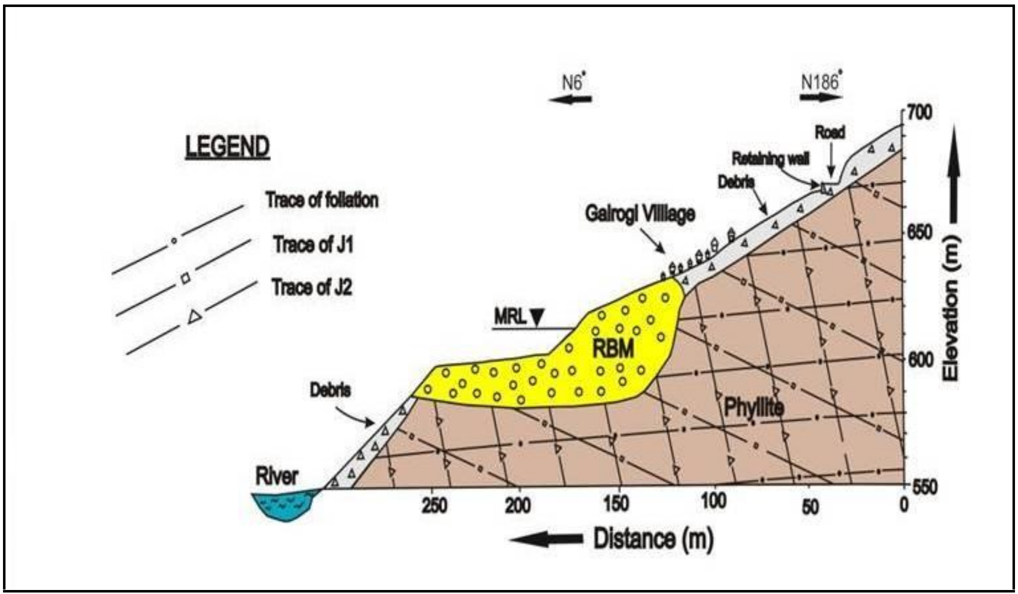


Fig. 4.14 Geological Section of Slope RBS13 Located 8.5 km d/s of Zero Bridge near THDCIL RBM Quarry near Bandria Village

Plate 4.13 A View of Slope RBS13 Located 8.5 km d/s of Zero Bridge near THDCIL RBM Quarry near Bandria Village

Slope Section: RBS14

The slope section RBS14 is located on the right bank at 14 km d/s of Zero Bridge below the road close to village Gairogi (Fig. 4.15). The slope below the road shows gentle angles with an average of about 50˚ toward N120˚ direction. The foliations are the predominant geological discontinuity in rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 50^0 towards $N340^0$. Two sets of joints J1 and J2 were observed which are dipping 30^0 towards $N50^0$ and 70^0 towards $N60^0$ respectively. On an average, the slope has a thin overburden cover of less than 5 m below the road. Rocks are exposed further down up to river bed level at shallow depth. The area around the section RBS14 has been shown in Plate 4.14.

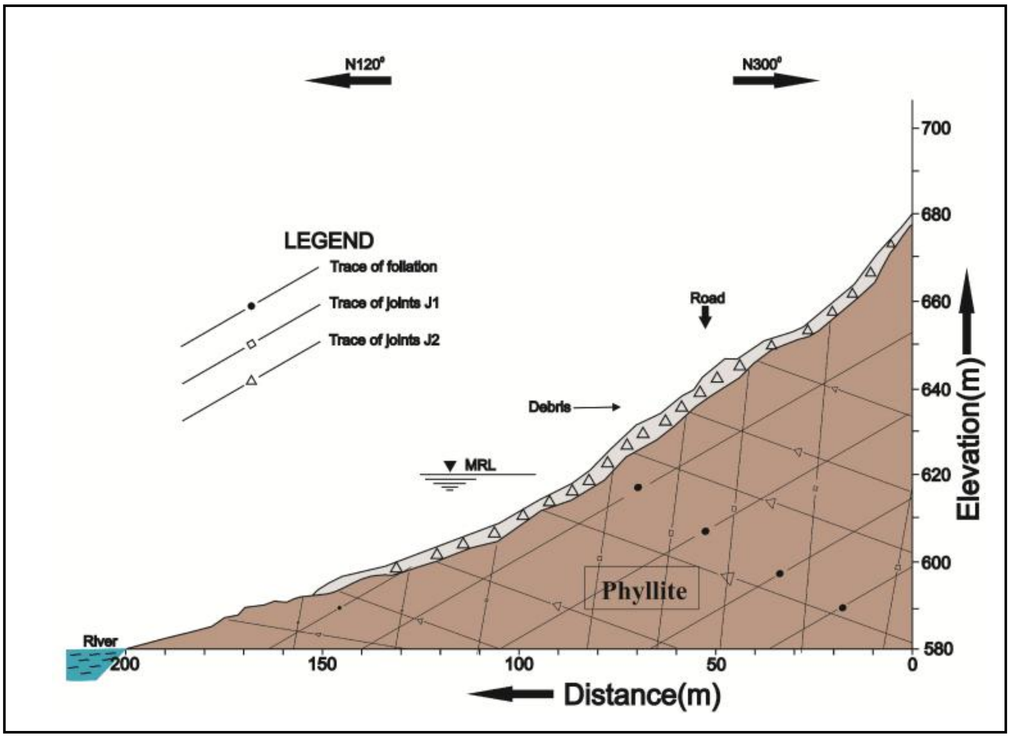


Fig. 4.15 Geological Section of Slope RBS14 Located near THDCIL Guest House

Plate 4.14 A View of Slope RBS14 near THDCIL Guest House

Slope Section: RBS15

The slope section RBS15 is located on the right bank at 14.5 km d/s of Zero Bridge below the road close to village Pendars (Fig. 4.16). The slope below the road has an escarpment slope with angles of 70˚ towards N17˚ direction. This steep slope extends for more than 40 below. The foliations are the predominant geological discontinuity in the rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 25^0 towards $N75^0$. In addition, there are two sets of joints J1 and J2, which are dipping 40^0 towards $N260^0$ and 65^0 towards $N260^0$ respectively. This is unusual for the debris slope to maintain such a steep angle. Though this phenomenon has been observed at many places in Himalaya, these conditions are common on those slopes, where the slope materials are cemented by natural cementing medium deposited by the subsurface water in the geologic past. It is certain that the slope materials are cemented together to attain a steep slope. Further down the slope has moderate angle of less than 25˚ with debris materials getting exposed up to the river bed level. The road is located on the edge of the steep slope. Further above the road, RBM is present with a thickness of 8 m. The THDCIL Administration office is located over the RBM. A view of the area around the section RBS15 is shown in Plate 4.15.

Rocks are not exposed further down up to river bed level (El ± 554m). The road has been excavated within the debris. Under full reservoir conditions (El 613 m), the MRL may rise about 60 m above the river bed. The reservoir may submerge a part of the debris material at the toe level. In order to check the stability conditions with reference to the rock exposures, stability analysis has been carried out. The slope direction and the attitude of the geological discontinuities indicate that the disposition of the geological discontinuities is more favourable to plane mode of failure. The foliations are dipping nearly in the same direction as that of the slope but at a lower angle.

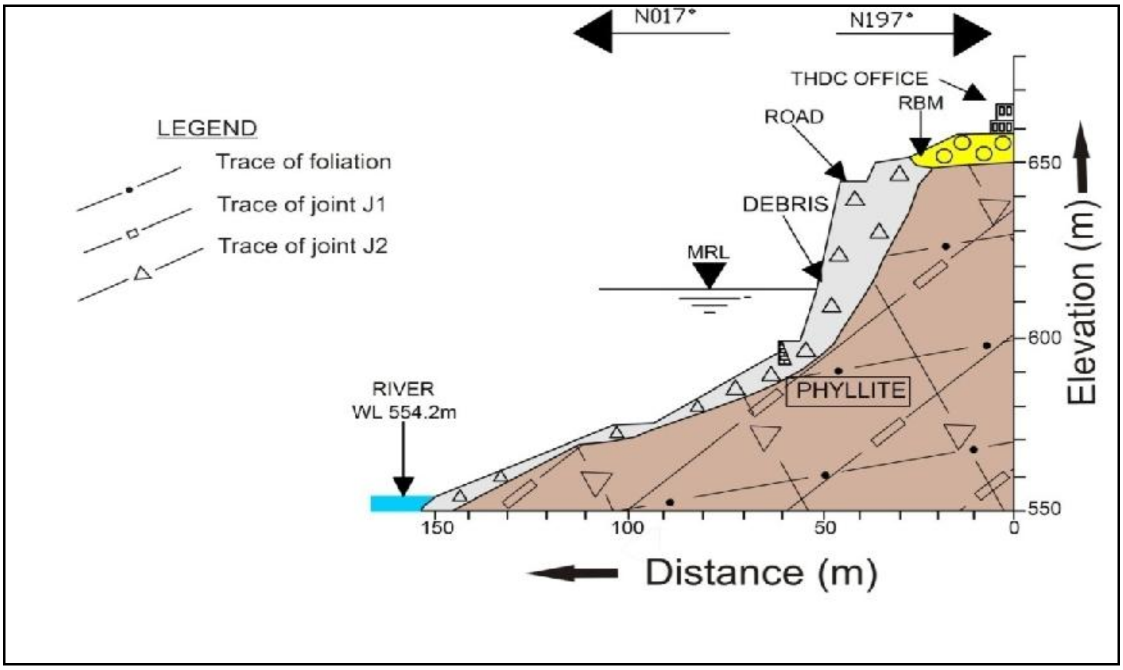


Fig. 4.16 Geological Section of Slope RBS15 located 14.5 km d/s of Zero Bridge (near THDCIL Administrative Building, Pendars village)

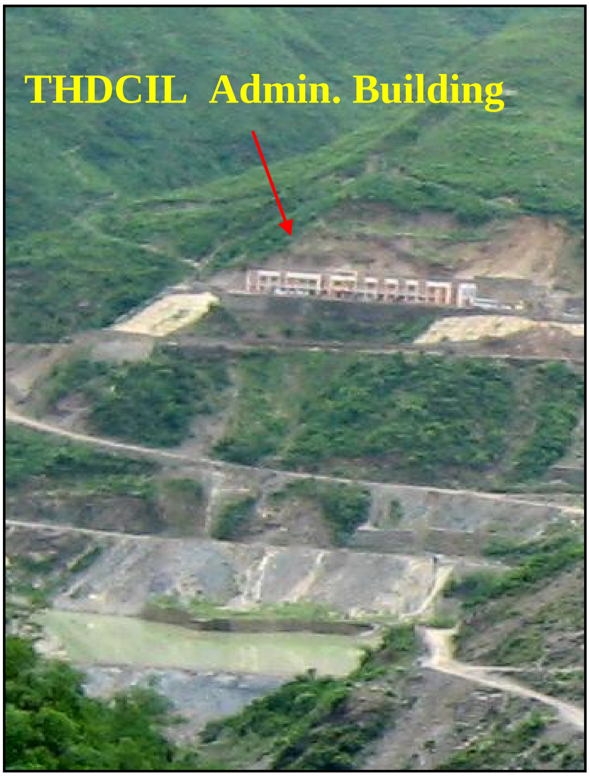


Plate 4.15 A View of Slope RBS15 located 14.5 km d/s of Zero Bridge (near THDCIL Administrative Building, Pendars village)

Slope Section: RBS16

The slope section RBS16 is located on the right bank at 15.5 km d/s of Zero Bridge (u/s of Dam Axis) (Fig. 4.17). The slope below the road shows varying slope angles – initially the slope being about 31˚ and gets flattened to about 5˚ towards N343˚ direction at lower elevations below El 595 m. However, in view of MRL being at El. 613 m, the top slope of 31˚ is more important from standpoint of stability analysis. The foliations are the predominant geological discontinuity in rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 30^0 towards $N80^0$. Two sets of joints were observed, namely J1 and J2, which are dipping 47^0 towards $N25^0$ and 65^0 towards $N260^0$ respectively. On an average, the slope has a fairly thick overburden cover of about 8 m below the road. The overburden consists of a mixture of debris and river borne materials. Rocks are exposed below

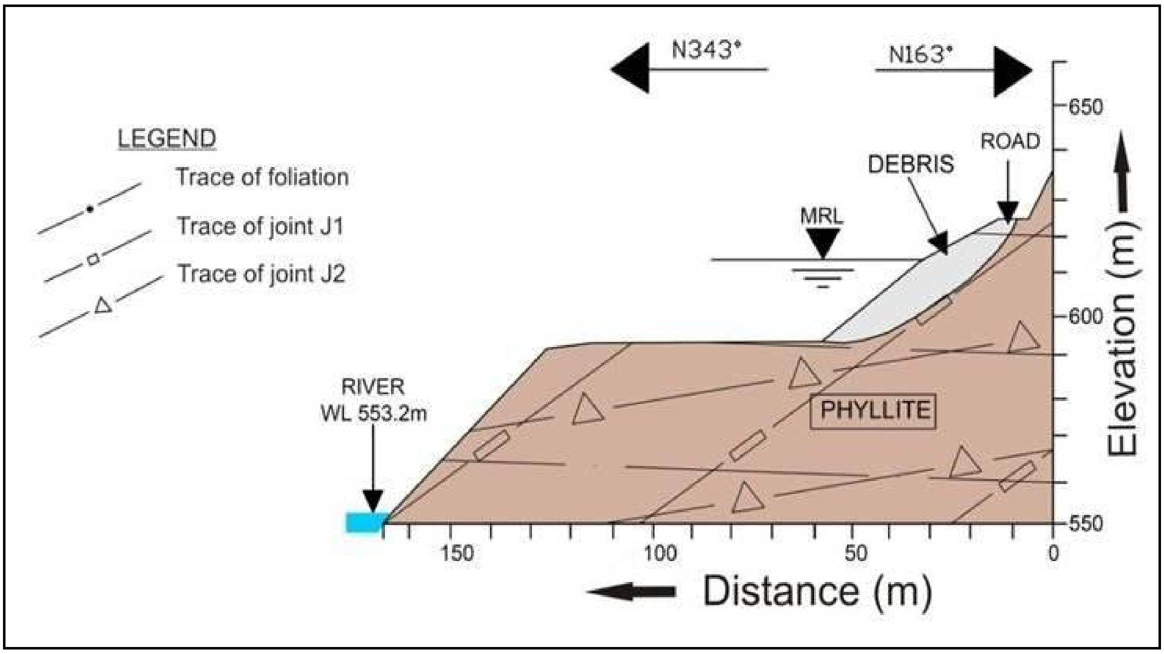


Fig. 4.17 Geological Section of Slope RBS16 Located at 15.5 km d/s of Zero Bridge (u/s of Dam Axis)

Plate 4.16 View of Slope RBS16 Located 15.5 km d/s of Zero Bridge (u/s of Dam Axis)

El ± 595 m and extend further down up to river bed level (El ± 553 m). The road has been excavated within the debris. Under full reservoir conditions (El 613 m), the MRL may rise by about 60 m above the river bed. The reservoir may submerge a part of the debris material at the toe at the maximum reservoir level. The Plate 4.16 shows the nature of slope conditions and extension of the debris.

Slope Section: RBS17

The slope section RBS17 is located on the right bank at 18 km d/s of Zero Bridge (near Payalgaon) (Fig. 4.18). The main road is located just below the Shiva temple and the slope below the road has a long slope up to the river bed. This slope shows varying slope angles – initially about 28˚ up to El.595 m and gets flattened to about 10˚ towards N73˚ direction further below. The foliations are the predominant geological discontinuity in the rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 30^0 towards $N80^0$. In addition, there are two sets of joints J1 and J2, which are dipping 47^0 towards $N30^0$ and 65^0 towards $N260^0$ respectively. However, since the MRL is located at El.613 m, it will be touching the toe of the top slope of 31˚ and hence it is more important for analysis. On an average, the slope has a fairly thick overburden cover of about 12 m below the road. Rocks are not exposed on the entire slope and the debris extends continuously down up to river bed level (El ± 554 m). The road has been excavated within the debris. Under full reservoir conditions (El 613 m), the MRL may rise about 60 m above the river bed. The reservoir may submerge a part of the debris material at the toe at the maximum reservoir level. Under submergence conditions, the slope materials may be subjected to saturation. A view of the slope as whole along with debris materials on the slope is indicated in the Plate 4.17.

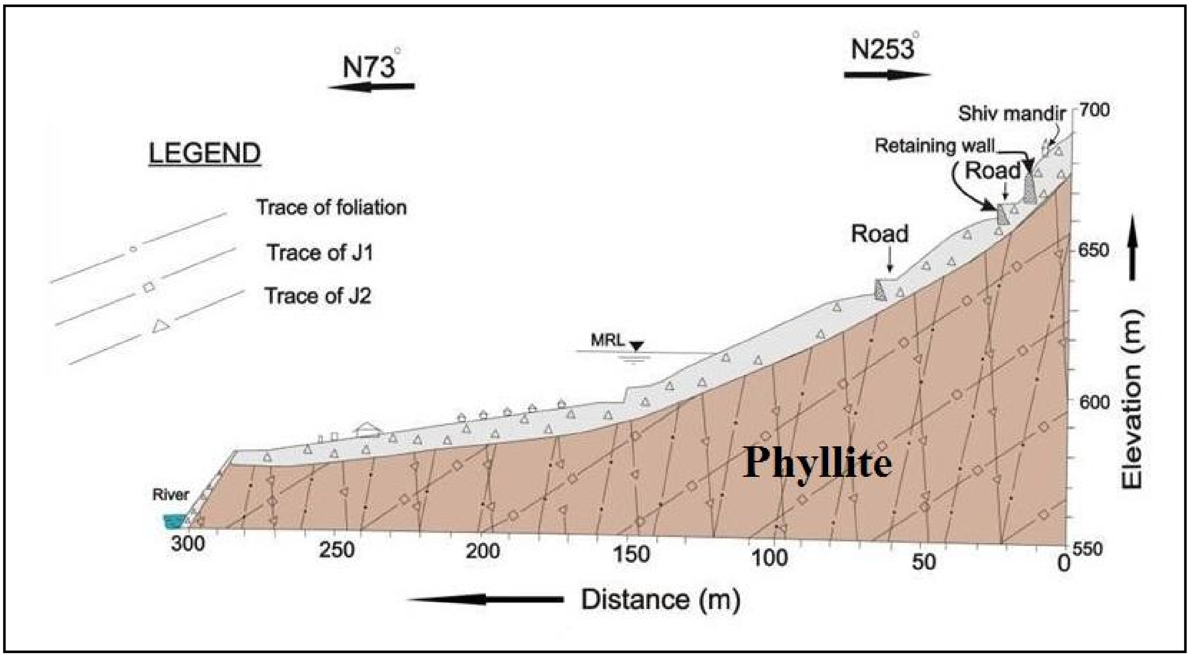


Fig. 4.18 Geological Section of Slope RBS17 Located 18 km d/s of Zero Bridge (below Shiva Temple, Payalgaon)

Plate 4.17 A view of Slope RBS17 Located 18 km d/s of Zero Bridge (below Shiva Temple, Payalgaon)

4.1.2 Left Bank Slope Sections

Slope Section: LBS1

This slope section LBS1 is located on the left bank of the river over the existing dump materials at a distance of 250 m d/s of Zero Bridge (Fig. 4.19). It is presently one of the sites, where the excavated muck is being dumped. The thickness of the muck at the bottom is reported to have reached about 30 - 40 m. The muck extends up to road level with a slope angle of more than 46˚ towards N280˚ direction. On the road, phyllite rocks are exposed, which have been traversed by foliations and joints. Further above the road cut-slope, the rock slope is more gentle with thin debris cover. The foliation generally dips at an angle of 50^0 towards $N170^0$. In addition, there are two sets of joints J1 and J2, which are dipping 65^0 towards $N345^0$ and 73^0 towards $N72^0$ respectively.

Once the reservoir is full, the maximum reservoir level (MRL) may extend up to a height of 20 - 25 m above the river bed. Since the dumped muck is recent and is in a loose condition, the slope materials may get highly saturated under submergence condition and may cause instability. A view of muck dump under consideration is shown in Plate 4.18.

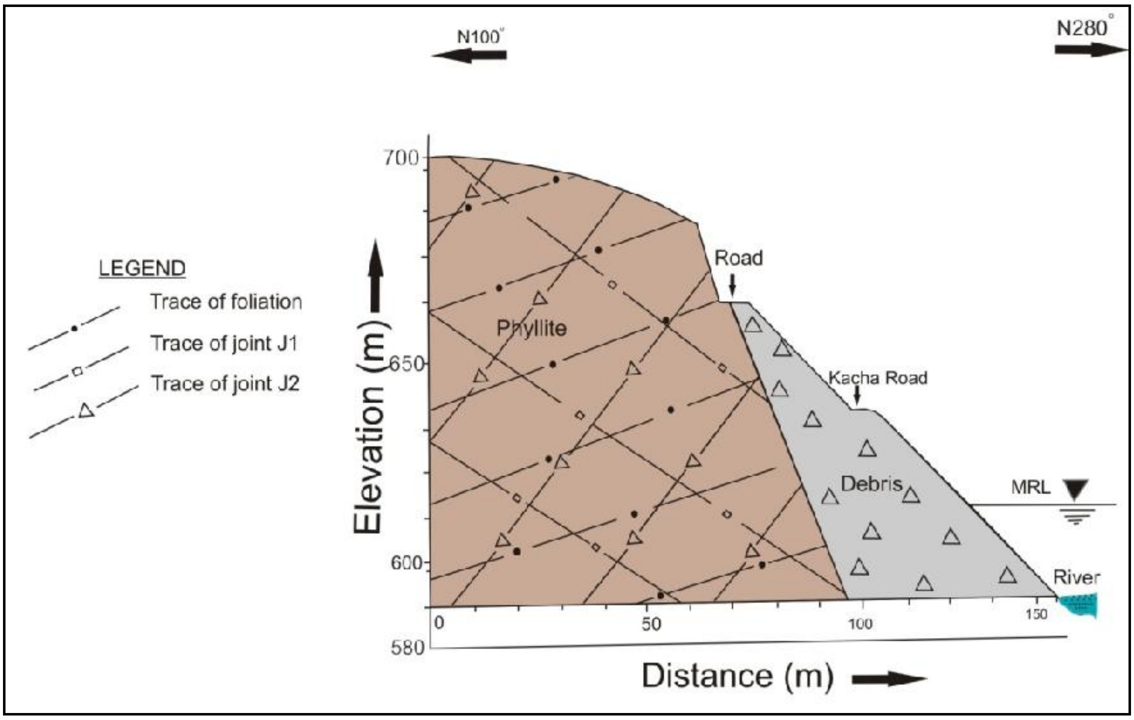


Fig. 4.19 Geological Section of Slope LBS1 Located 250 m d/s of Zero Bridge

Plate 4.18 View of Slope LBS1 Located 250 m d/s of Zero Bridge

Slope Section: LBS2

The slope section LBS2 is located 900 m d/s of Zero Bridge (opposite of Marh Stream) on the left bank of the river (Fig. 4.20). Here also, the excavated muck is being dumped down which extends up to the road level with a slope angle nearly equal to 45˚ towards N250˚ direction. The foliations are the predominant geological discontinuity in rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 50^0 towards $N100^0$. In addition, there are two sets of joints J1 and J2, which are dipping 70^0 towards $N340^0$ and 80^0 towards $N290^0$ respectively. Phyllite rocks are exposed on the road, which have been traversed by foliations and joints.

Like slope section LBS1, the slope mass may be highly saturated under submergence causing unstable conditions. A view of the slope around section LBS2 is shown in Plate 4.19.

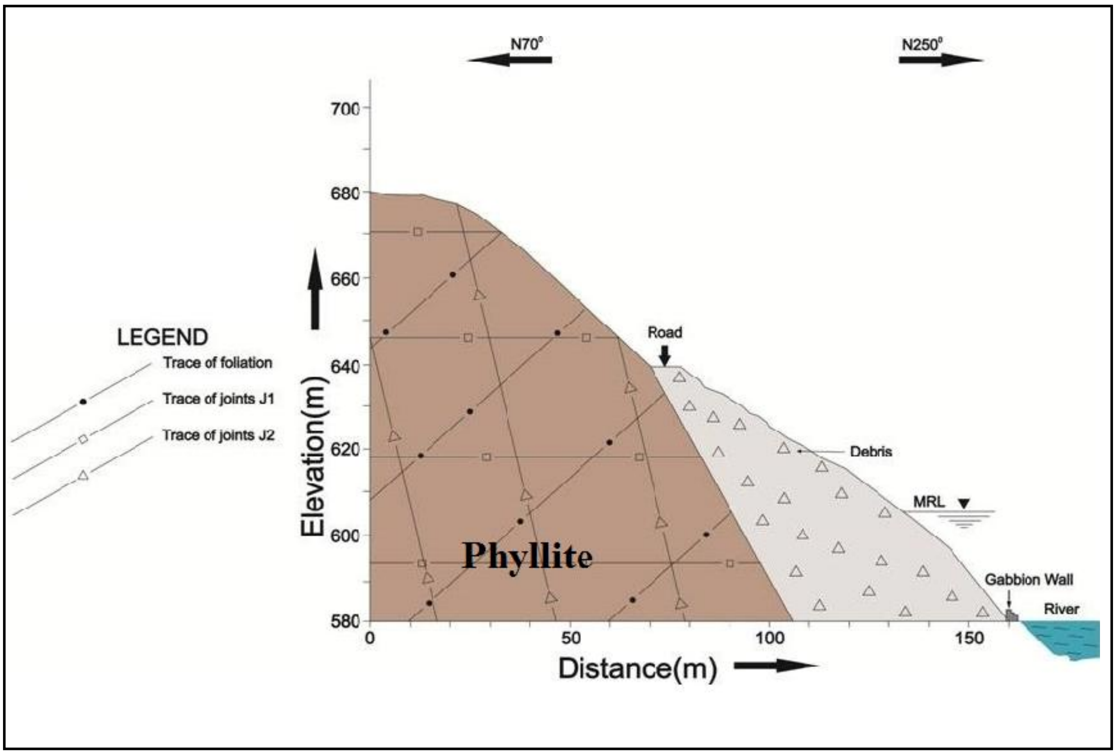


Fig. 4.20 Geological Section of Slope LBS2 Located 900 m d/s of Zero Bridge (opposite of Marh Stream)

Plate 4.19 View of Slope LBS2 Located 900 m d/s of Zero Bridge (opposite of Marh Stream)

Slope Section: LBS3

The slope section LBS3 is located 1.5 km d/s of Zero Bridge (near Chopra Village,) on the left bank of the river opposite the pumping unit which was under construction within the river bed close to right bank (Fig. 4.21). The dumped muck extends up to the road level with a fairly steep gradient of more than 40˚. Further above the road level, the old debris is present, on which agriculture is being practiced. The recent debris materials dumped below the road level are loose and are highly unconsolidated in nature. On the road, phyllite rocks are exposed, which are traversed by foliations and joints. The foliation generally dips at an angle of 25^0 towards $N115^0$. The two joint sets J1 and J2 dip at 75^0 towards $N335^0$ and 70^0 towards $N65^0$ respectively.

When the reservoir rises to maximum reservoir level (MRL), the standing water may rise to a height of 20 - 25 m above the river bed. Since the dumped muck is recent and is in a loose condition, some slope material may be washed away. A view of dumped muck is shown in Plate 4.20.

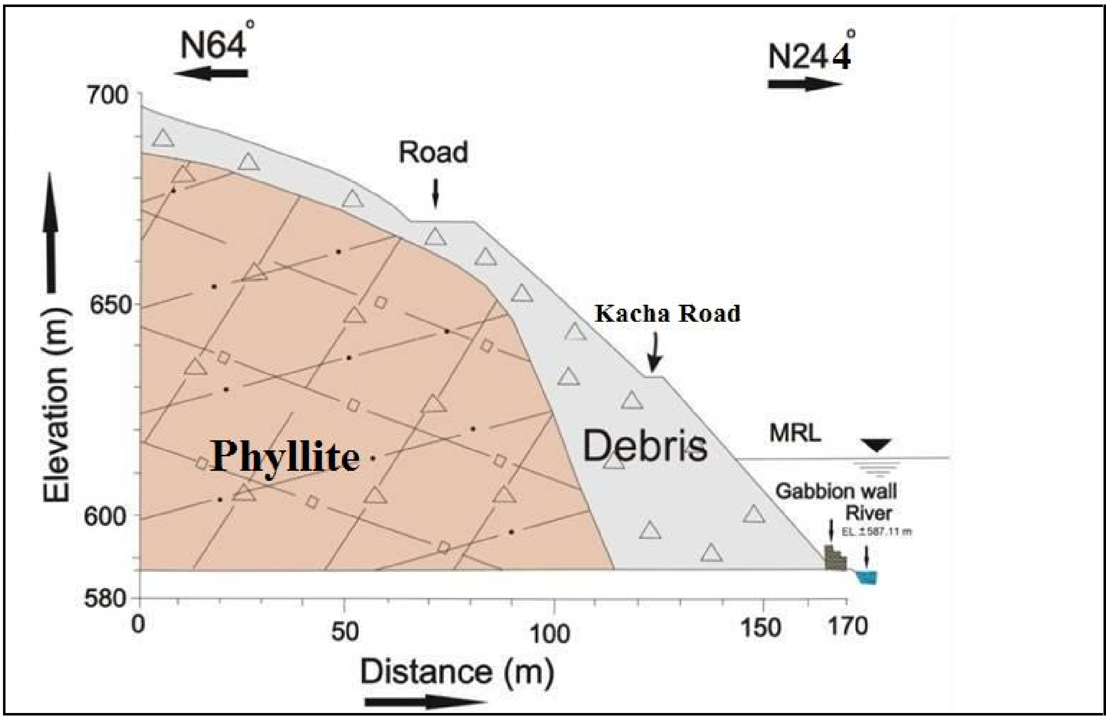


Fig. 4.21 Geological Section of Slope LBS3 1.5 km d/s of Zero Bridge (near Chopra Village, Opposite of Pumping Unit)

Plate 4.20 A View of Slope LBS3 1.5 km d/s of Zero Bridge (near Chopra Village, Opposite of Pumping Unit)

Slope Section: LBS4

The slope section LBS4 is located at 2 km d/s of Zero Bridge on the left bank to the downstream of the village Chopra (Fig. 4.22). Here the rock exposures can be seen close to the river bed for a height of about 2 m and further above, they are generally concealed by RBM and debris on a fairly steep slope (≈ 40˚). The foliations are the predominant geological discontinuity in rocks, which are strongly developed in addition to other joints. The foliation generally dips at an angle of 75^0 towards $N332^0$. In addition, there are two sets of joints J1 and J2, which are dipping 70^0 towards $N70^0$ and 30^0 towards $N145^0$ respectively. The RBM is present just above the rock exposure and extend to a height of about 10 m. Further above, there is a debris blanket on the slope over which agriculture is being practiced. The debris slope extends to a height of more than 50 m. On higher levels RBM can be seen. The MRL extends to a height which would submerge the lower RBM and also the toe of the debris. In view of presence of debris on the fairly steep slopes, the submergence may cause talus failure. The Plate 4.21 depicts the area of section LBS4 showing the extension of debris and RBM.

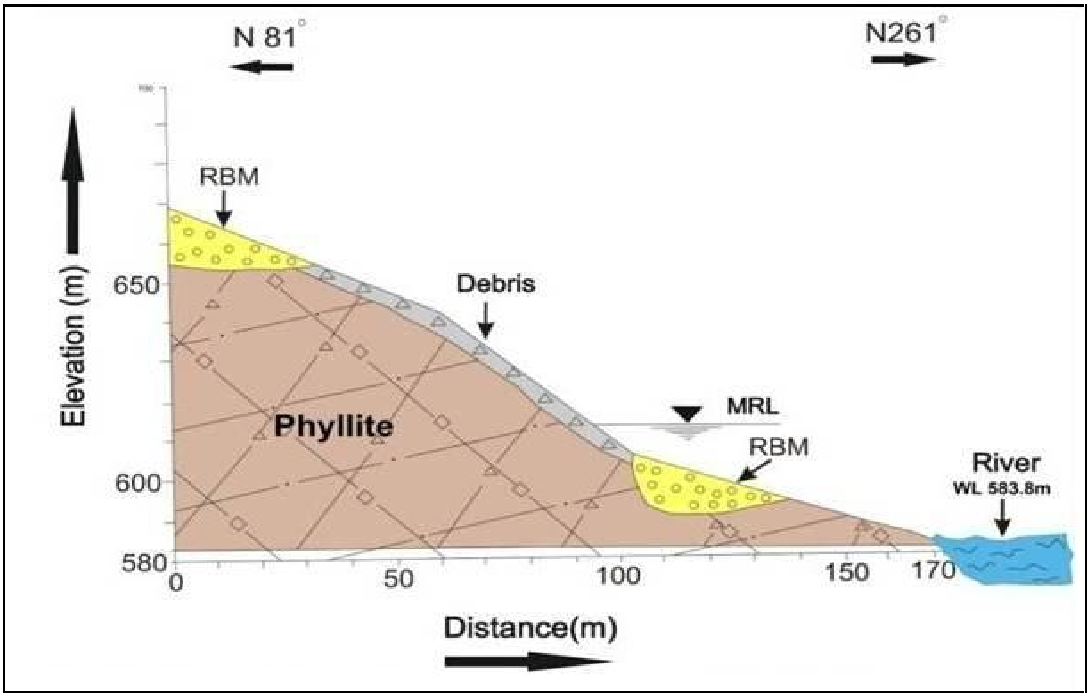


Fig. 4.22 Geological Section of Slope LBS4 at 2 km d/s of Zero Bridge (d/s of Chopra Village)

Plate 4.21 A View of Slope LBS4 2 km d/s of Zero Bridge (d/s of Chopra Village)

Slope Section: LBS5

The slope section LBS5 is located at 8.5 km d/s of Zero Bridge on the left bank along the axis of the old iron bridge on the northern side of Bhashon village (Fig. 4.23). Here, few houses are seen on the slope above the old bridge. Thin debris cover can be seen in the area of inhabitation. Phyllite rocks are exposed on the slope as a whole up to MRL, which have been traversed by foliations and joints. The foliation generally dips at an angle of 20^0 towards $N105^0$. In addition, there are two sets of joints J1 and J2, which are dipping at 30^0 towards $N180^0$ and 85^0 towards $N320^0$ respectively. Moreover, the foliations are dipping nearly in the same direction as that of the slope but at a lower angle. A study of the slope direction and the attitude of geological discontinuities indicate that the disposition of the geological discontinuities is more susceptible to planar mode of failure. The Plate 4.22 shows the nature of slope conditions on the left bank near Bhashon village.

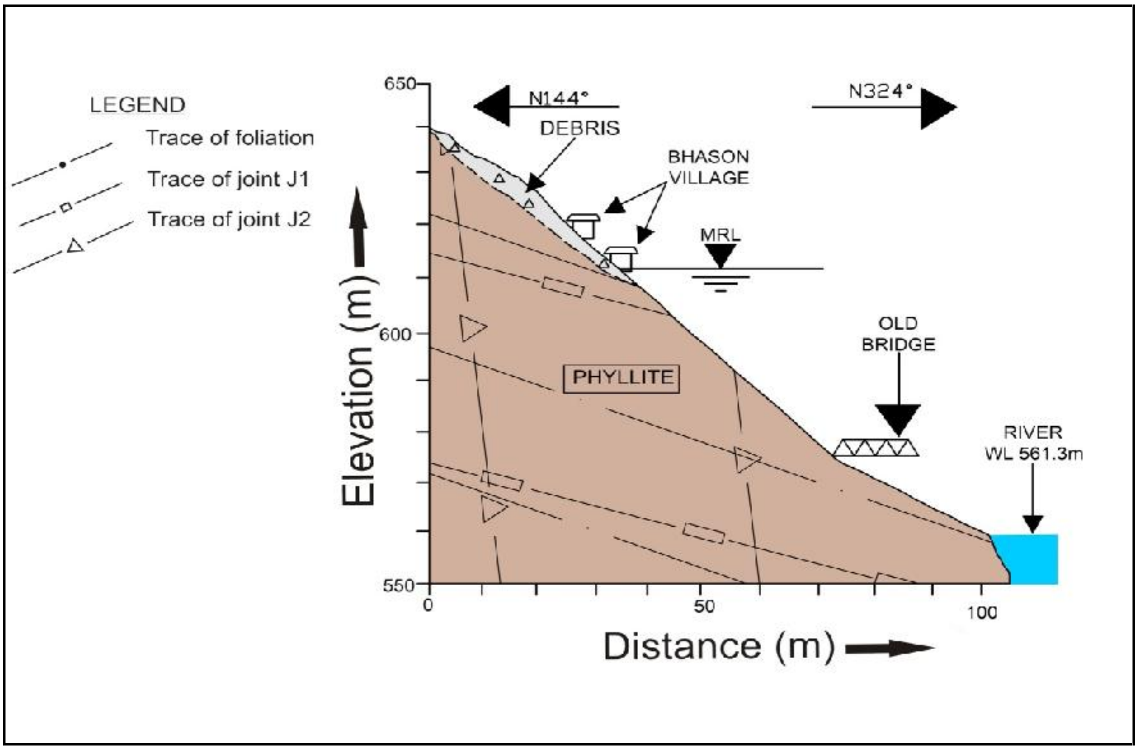


Fig. 4.23 Geological Section of Slope LBS5 8.5 km d/s of Zero Bridge (near Bhashon Village just above Old Girder Bridge)

Plate 4.22 A view of Slope LBS5 8.5 km d/s of Zero Bridge (near Bhashon Village just above Old Girder Bridge)

4.2. ROCK MASS CHARACTERIZATION

The term rock mass refers to any in-situ rock with all inherent geomechanical anisotropies (John, 1962). Rock mass is a network of rock blocks separated by discontinuities. It may be considered anisotropic and non-homogeneous material built-up of smaller and/ or larger blocks of rock. As a great variety exists both in the composition of rock and in its discontinuities, the rock mass is a material which exhibits a wider range of composition and mechanical properties. Design and construction of underground excavations in rock mass becomes extremely complex due to the uncertainties involved in the determination of its geotechnical parameters.

Description of rock mass forms an initial step for an engineering assessment, which may be done from a geological and engineering point of view. The geological classification of rocks (lithology) is based on mineralogy fabric, degree of weathering or alteration, density or porosity and texture of rock. The name of rock provides an indication of its origin, mineralogical composition and texture, and from an engineering point of view, strength, hardness, seismic velocity and modulus are the important characteristics.

A number of rock mass classification systems have been in use for the past five decades. Out of all these systems, Rock Mass Rating (RMR) system (Bieniawski, 1979) and Slope Mass Rating (SMR) system (Romana, 1985) along with modified SMR approach (Anbalagan et al., 1992) have been applied in the present study.

4.2.1 Bieniawski's Rock Mass Classification (RMR)

The Rock Mass Rating (RMR) system is a geo-mechanical classification system for rocks (Bieniawski, 1979). The following six parameters are used to classify the rock mass using the RMR system:

i. Uni- axial compressive strength (UCS) of the rock material

ii. Rock quality designation (RQD)

iii. Spacing of discontinuities

iv. Condition of discontinuities

v. Groundwater condition

vi. Orientation of discontinuities

Each of the six parameters is assigned a rating corresponding to the characteristics of rock. These values are derived from field surveys. The sum of the rating for the above six parameters gives the value of RMR, which lies between 0 and 100. Rock mass quality is assigned for each quality of rock mass based on the RMR as given in Table 4.1.

Out of a total of 22 sections, Rock Mass Rating was determined for 10 sections of rock slopes along both the banks of the Koteshwar reservoir on basis of the observations made at the site during field studies. These computations are presented for different slopes along the reservoir in Appendix-III. The summary of the RMR values for different rock slopes is presented in Table 4.2 (Appendix - III) along with the corresponding values of cohesion and friction angle of the rock mass at respective sites (Bieniawski, 1979).

Table 4.1 Classification of Rock Mass Based on RMR

RMR	Rock Quality
0-20	Very Poor
21-40	Poor
41-60	Fair
61-80	Good
81-100	Very good

Table 4.2 Summary of RMR Values for various Rock Slopes along Right Bank of the Reservoir

S. No.	Rock Slope Designation	RMR_{basic}	RMR_{adj}	Rock Mass Quality	C_{mass} (KPa)	Φ_{mass}
1	RBS1	68	43	Fair	70	20
2	RBS3	72	47	Fair	70	20
3	RBS4	68	43	Fair	70	20
4	RBS6	65	40	Poor	70	20
5	RBS8	68	63	Good	150	23
6	RBS10	68	63	Good	150	23
7	RBS12	70	45	Fair	70	20
8	RBS14	70	45	Fair	150	23
9	RBS15	59	35	Poor	70	20

Table 4.3 Summary of RMR Values for various Rock Slopes along Left Bank of the Reservoir

S.No.	Rock Slope Designation	RMR_{basic}	RMR_{adj}	Rock Mass Quality	C_{mass} (KPa)	Φ_{mass}
1	LBS5	65	40	Poor	70	20

4.2.2 Slope Mass Rating (SMR) Classification

Romana (1985) proposed a classification system called Slope Mass Rating (SMR) system for evaluating the stability of rock slopes,. Slope Mass Rating is obtained from Bieniawiski Rock Mass Rating (RMR) by subtracting adjustment factors of the joint-slope relationship and adding a factor depending on method of excavation,

$$SMR = RMR_{basic} - (F1 \cdot F2 \cdot F3) + F4 \qquad (1)$$

Where, RMR_{basic} is evaluated according to Bieniawiski (1979) classification by adding the ratings of five parameters. The F1, F2 and F3 are adjustment factors related to joint orientation with respect to slope orientation and F4 is the correction factor for method of excavation.

F1 depends upon parallelism between joints and slope face strikes. It ranges from 0.15 to 1.0. Its value is 0.15 in situations where the angle between critical joint plane and the slope face is more than 30º and the failure probability is very low, whereas its value is 1.0 when both are nearly parallel. The value of F1 can be obtained as:

$$F1 = (1 - \sin A)^2 \qquad (2)$$

where A denotes the angle between the strike of the slope face and that of joints i.e. (αs - αj) where αs is the strike of the slope face and αj is the strike of the joint.

F2 refers to joint dip angle (βj) in the planer failure mode. Its values also varies from 0.15 to 1.0. For the toppling mode of failure, F2 remains equal to 1.0.

$$F2 = \tan \beta j \qquad (3)$$

F3 refers to the relationship between the slope face and the dip of the joint. In planar failure, F3 refers to a probability of joints "day lighting" in the slope face. Conditions are called fair when the slope face and the joints are parallel. When the slope face dips 10º more than the joints, the condition is termed very unfavourable. For the toppling failure, unfavourable conditions depend upon the sum of dip of joints and the slope, (βj + βs).

Values of adjustment factors F1, F2 and F3 for different joint orientations are given in Table 4.4.

F4 pertains to the adjustment for the method of excavation. It includes the natural slope or cut slope excavated by pre-splitting, smooth blasting, mechanical excavation or normal blasting or mechanical excavation and poor blasting Values of F4 are presented in Table 4.5. The values of F4, taken for the current analysis, are +15, +10 and somewhere +8 since the slopes are natural, or excavated by pre-splitting and smooth blasting respectively.

Table 4.4 Values of Adjustment factors for Different Orientations (Romana, 1985)

Case of slope failure		**Very Favour-able**	**Favour-able**	**Fair**	**Unfavour-able**	**Very Unfavour-able**
P T W	(αj- αs) (αj- αs -180°) (αj- αs)	$>30^0$	$30\text{-}20^0$	$20\text{-}10^0$	$10\text{-}5^0$	$<5^0$
P/T/W	F1	0.15	0.40	0.70	0.85	1.0
P W	(βj) (βi)	$<20^0$	$20\text{-}30^0$	$30\text{-}35^0$	$35\text{-}45^0$	$>45^0$
P/W	F2	0.15	0.40	0.70	0.85	1.0
T	F2	1.0	1.0	1.0	1.0	1.0
P W	(βj - βs) (βj - βs)	$>10^0$	$10\text{-}0^0$	0^0	$0\text{-}(-10^0)$	$<-10^0$
T	(βj +βs)	$<110^0$	$110\text{-}120^0$	$>120^0$	--	--
P/T/W	F3	0	-6	-25	-50	-60

P- Planar failure ; T- Toppling failure ; W- Wedge failure ; βi- Plunge of line of intersection

Table 4.5 Value of Adjustment Factor, F4 for Method of Excavation (Romana, 1985)

Method of Excavation	F_4
Natural slope	+15
Pre-splitting	+10
Smooth Blasting	+8
Normal Blasting or Mechanical Excavation	0
Poor Blasting	-8

According to the SMR values, Romana (1985) defined five stability classes. These are described in Table 4.6

Table 4.6 Various Stability Classes as per SMR Values (Romana, 1985)

Class	V	IV	III	II	I
SMR value	0-20	21-40	41-60	61-80	81-100
Description	Very poor	Poor	Fair	Good	Very good
Stability	Very unstable	Unstable	Partially stable	Stable	Fully stable
Failures	Large planar or soil like	Planar or large wedge	Some joints or many wedge	Some blocks	None
Support	Re-excavation	Extensive corrective	Systematic	Occasional	None

Many remedial measures can be taken to support a slope. Both detailed study and detailed engineering are needed to stabilize a slope. Classification systems can only try to point the normal techniques for each different class of support as presented in Table 4.7.

Table 4.7: Suggested Supports for Various SMR Classes (Singh and Goel, 1999)

SMR Classes	SMR Values	Suggested Supports
I a	91-100	None
I b	81-90	None, scaling is required
II a	71-80	(None, toe ditch or fence) spot bolting
II b	61-70	(Toe ditch or fence nets), spot or systematic bolting.
III a	51-60	(Toe ditch and/or nets), spot or systematic bolting, spot shotcrete.
III b	41-50	(Toe ditch or nets), systematic bolting/ anchors, systematic shotcrete, toe wall and/or dental concrete.
IV a	31-40	Anchors, systematic shotcrete, toe wall and/or concrete (re-excavation), drainage
IV b	21-30	Systematic reinforced shotcrete, toe wall and/or concrete re-excavation, deep drainage.
V a	11-20	Gravity or anchored wall, re-excavation.

The values of SMR for all the rock slopes along both the banks of the reservoir site were determined by considering the planar, toppling and wedge failure modes separately and are presented in Appendix IV and V. The summary of these analyses is presented in Table 4.8 for right bank rock slopes and in Table 4.9 for left bank rock slopes

Table 4.8 Identification of Stability Classes using SMR Values for Right Bank

S No.	Slope	RMR_{basic}	SMR	Stability Classes	Rock Mass Description	Stability	Failures	Probability of failure
1	RBS1	68	76	II	Good	Stable	Some block failure	0.2
2	RBS3	72	77	II	Good	Stable	Some block failure	0.2
3	RBS4	68	70	II	Good	Stable	Some block failure	0.2
4	RBS6	65	66	II	Good	Stable	Some block failure	0.2
5	RBS8	68	83	I	Very good	Completely stable	No Failure	0
6	RBS10	68	83	I	Very good	Completely stable	No Failure	0
7	RBS12	70	63	II	Good	Stable	Some block failure	0.2
8	RBS14	70	55	III	Normal	Partially Stable	Planar along some joints and many wedges	0.4
9	RBS15	59	43.35	III	Normal	Partially Stable	Planar along some joints and many wedges	0.4

Table 4.9 Identification of Stability Classes using SMR Values for Left Bank

S No.	Slope	RMR_{basic}	SMR	Stability Classes	Rock Mass Description	Stability	Failures	Probability of failure
1	LBS5	65	68.7	II	Good	Stable	Some block failure	0.2

4.2.3 Modified Slope Mass Rating (SMR) Classification

Anbalagan et al. (1992) proposed a classification system called as modified SMR approach for evaluating the stability of rock slopes based on the plane and wedge modes of failure. In the modified SMR approach, the same method is applicable for planar and the strike and the dip of the plane are used for the analysis. But in the case of wedge failure, the plunge and the direction of line of intersection of the unstable wedge are used. Thin wedges with low angle dip are likely to be stable and should not be considered. The details of computation of modified values of SMR is presented in Appendix – V.

Table 4.10 Identification of Stability Classes using Modified SMR Values for Right Bank

S No.	Slope	RMR_{basic}	Modified SMR	Stability Classes	Rock Mass Description	Stability	Failures	Probability of failure
1	RBS8	68	83	I	Very good	Completely stable	No Failure	0
2	RBS10	68	83	I	Very good	Completely stable	No Failure	0
3	RBS14	70	55	III	Normal	Partially Stable	Planar along some joints and many wedges	0.4

CHAPTER – V

KINEMATIC ANALYSIS OF SLOPES

5.1 KINEMATIC ANALYSIS OF ROCK SLOPES

The stability of rock slopes is often significantly influenced by structural discontinuities such as bedding planes, rock joints, foliation and faults. Characteristics of discontinuities which affect the stability of rock slopes include orientation, spacing, persistence, surface roughness, infillings and joint water condition etc. These discontinuities are planes of weakness in the much stronger intact rock and therefore the failure tends to occur preferentially along these surfaces.

5.2 IDENTIFICATION OF MODES OF SLOPE INSTABILITY

The possible modes of failure of rock slopes include the circular failure, planar failure, wedge failure and toppling failure (Fig. 5.1). The potential mode of failure for a given geological situation can be identified by carrying out kinematic analysis through the use of stereo nets (Hoek and Bray, 1981).

The stereo plots for all the rock slopes under consideration (Chapter IV) are generated and presented in this chapter for various slope sections along both right and left banks of the Koteshwar reservoir. These have been used to carry out the kinematic analysis of these slopes. The summary of these analyses is presented in Table 5.1 which indicates potential modes of failure for various rock slopes, which are to be subsequently analysed in detail using the limit equilibrium method which is discussed in the subsequent section.

5.3 STEREO PLOTS FOR VARIOUS SECTIONS

Stereographic projections are the simple and meaningful method to identify possible modes of failure. For that purpose, the structural discontinuity planes and the great circle representing the slope face are plotted over the stereo net. The data pertaining to structural discontinuities has been collected from both right and the left bank of the reservoir site. The attitude of joints, slope and foliation have been plotted on stereo net as observed in the field along both the banks of the reservoir. Detailed description of discontinuities present in each slope section has already been given in Chapter IV.

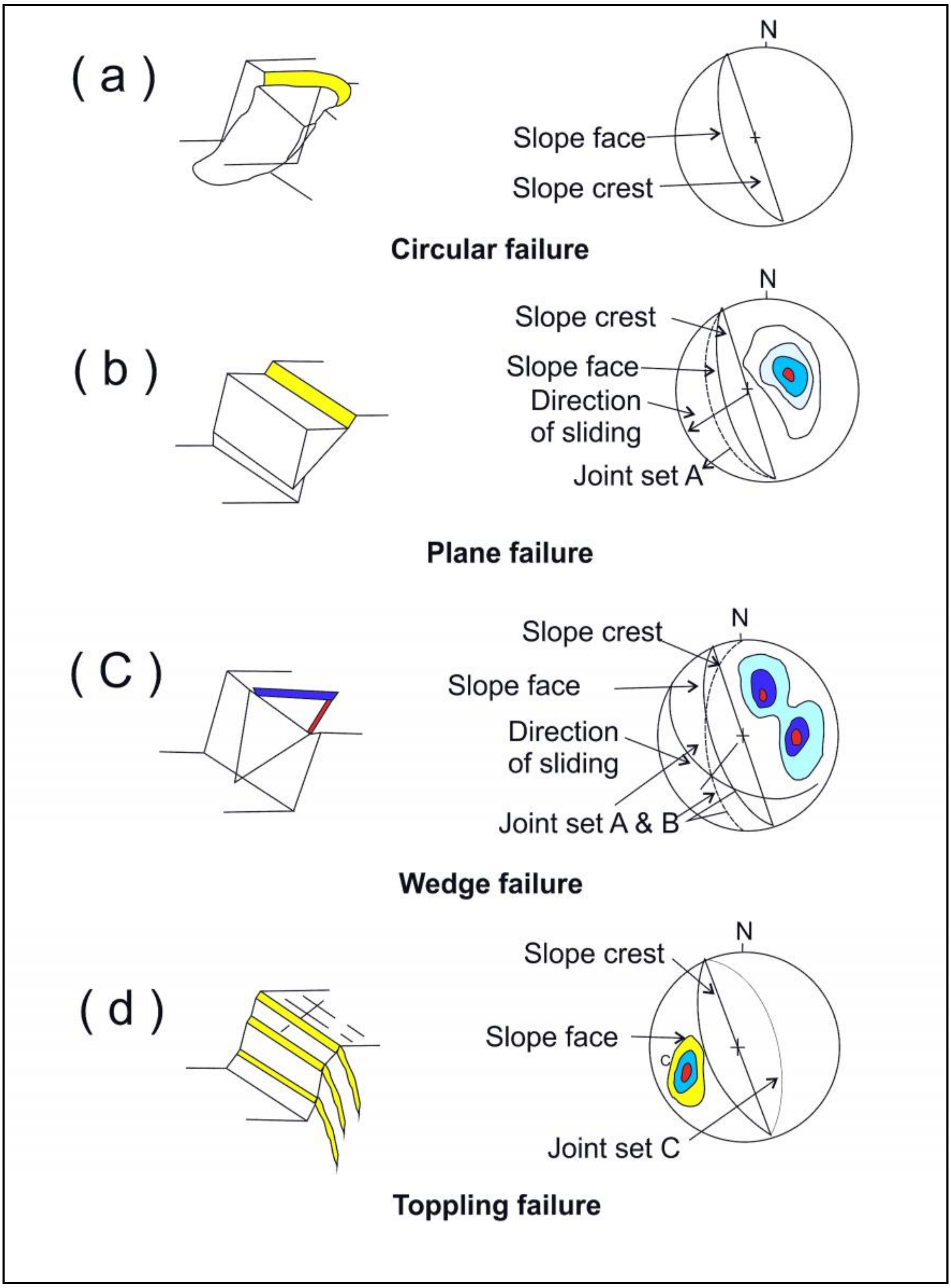


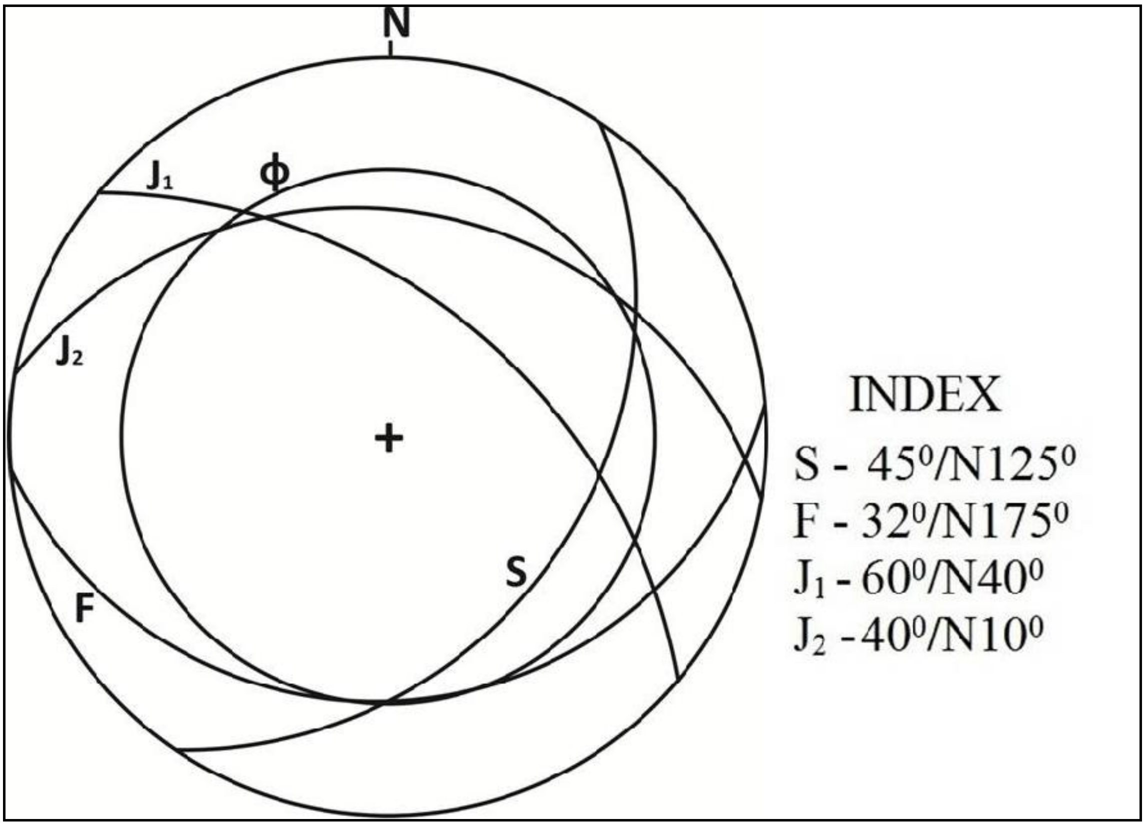
Fig. 5.1 Types of Rock Slope Failures

(a) Circular failure (b) Planar Failure (c) Wedge Failure (d) Toppling Failure

5.3.1 Right Bank Slope Sections

Slope Section: RBS1

The geological discontinuities present in slope section RBS1 have been plotted on a stereo net. The kinematic analysis of the stereo plot shows that disposition of the geological discontinuities indicates a possible planar mode of failure at the site. Depending upon the mode of failure, the stability analysis has been carried out. The stereo plot of the slope section RBS1 is shown in Fig. 5.2.



S- Slope, F- Foliation, J1- Joint Set 1 and J2- Joint Set 2

Fig. 5.2 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS1

Slope Section: RBS2

In the slope section RBS2, debris cover of about 8 m thickness is present over the rock slope. Debris material of very small thickness present on the rock slope which is the sliding material along the slope surface and so rotational failure is the most probable one at this slope section. Depending upon the mode of failure, the stability analysis has been carried out. The stereo plot of the slope section RBS2 is shown in Fig. 5.3.

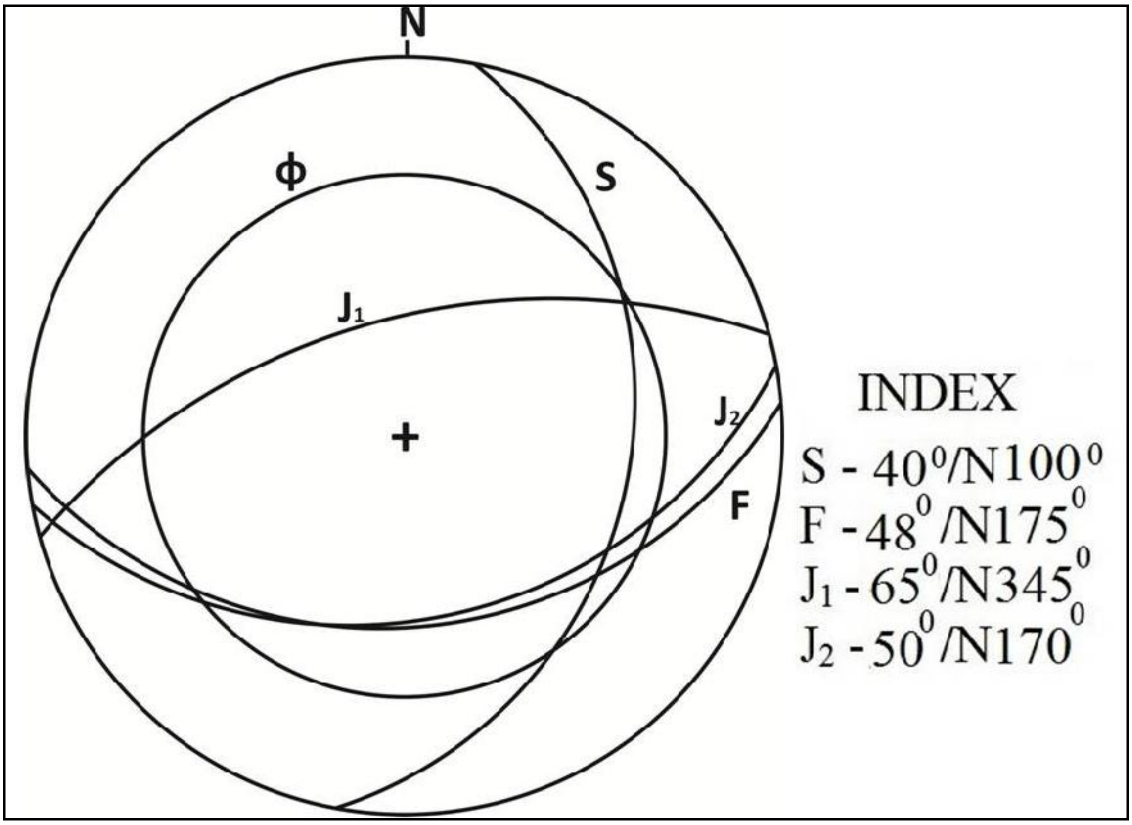


Fig. 5.3 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS2

Slope Section: RBS3

The kinematic analysis of the stereo plot shows that the disposition of the geological discontinuities indicates a possible planar mode of failure at the site. It is because of the fact that the foliations are dipping nearly in the same direction as that of the slope (easterly direction) but at a lower angle. The stereo plot of the slope section RBS3 is shown in Fig. 5.4.

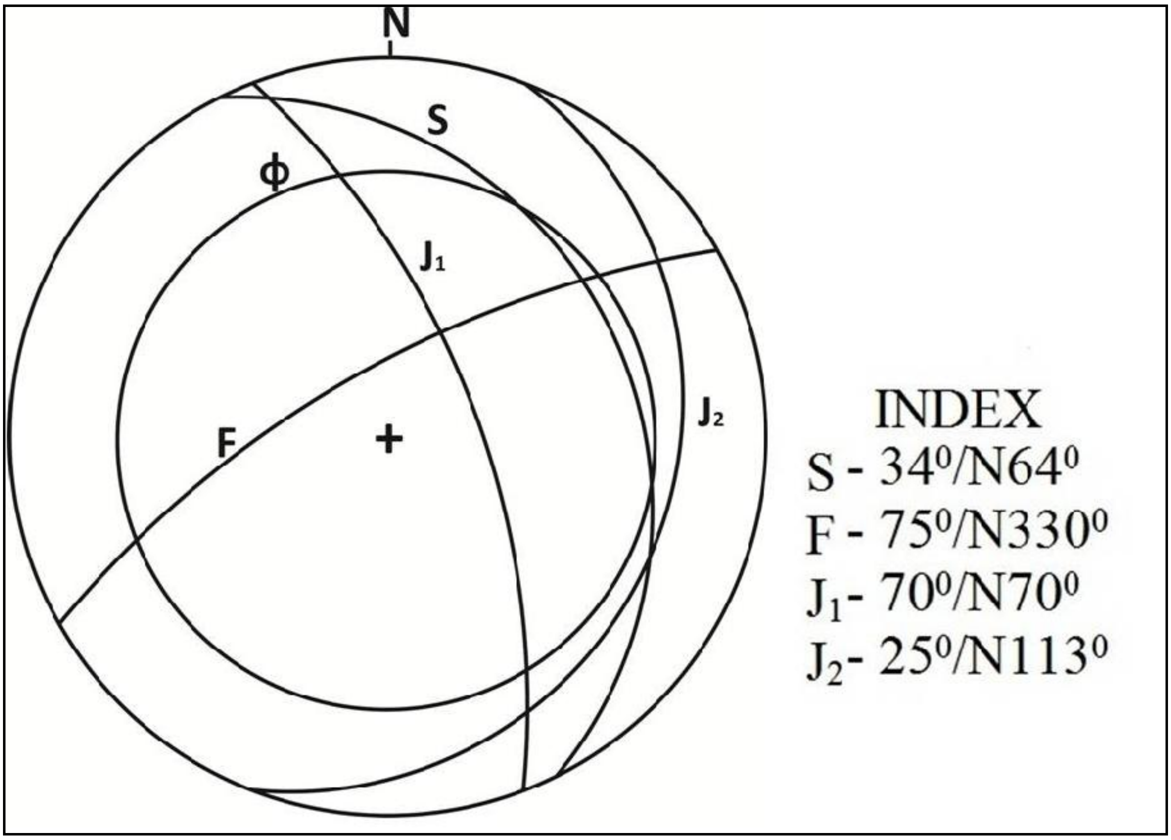


Fig. 5.4 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS3

Slope Section: RBS4

In slope section RBS4, the rocks are present at shallow depth, the structural readings collected from the exposed outcrops in the region have been plotted in a stereo net. The kinematic analysis of the stereo plot showing the disposition of the geological discontinuities indicates that planar mode of failure is more probable at the site, because the foliations are dipping nearly in the same direction as that of the slope but at a lower angle. The stereo plot of the slope section RBS4 is shown in Fig. 5.5.

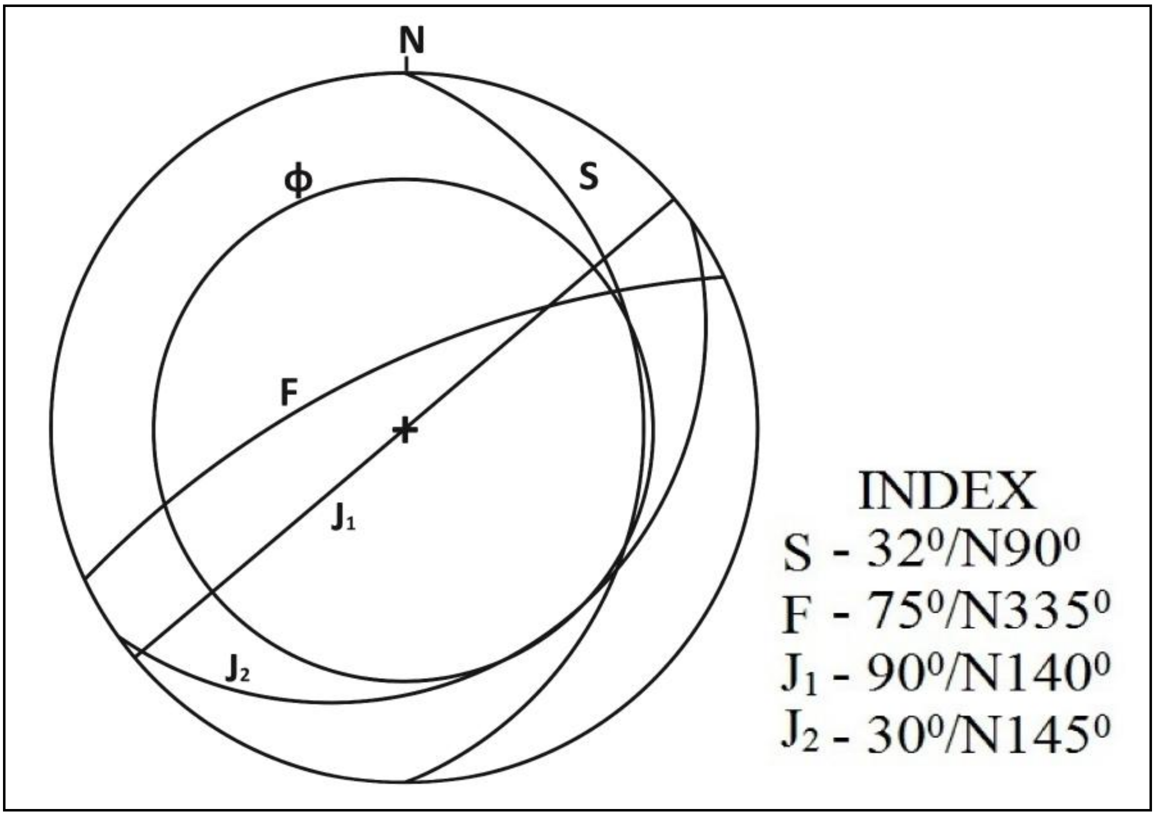


Fig. 5.5 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS4

Slope Section: RBS5

The slope section RBS5 has a moderate talus overburden cover of 6 m thickness and hard rocks are exposed at lower levels. Talus of very small thickness is the sliding material along the slope surface. Accordingly the stability analysis has been carried out depending upon the mode of failure. The stereo plot of slope section RBS5 is shown in Fig. 5.6.

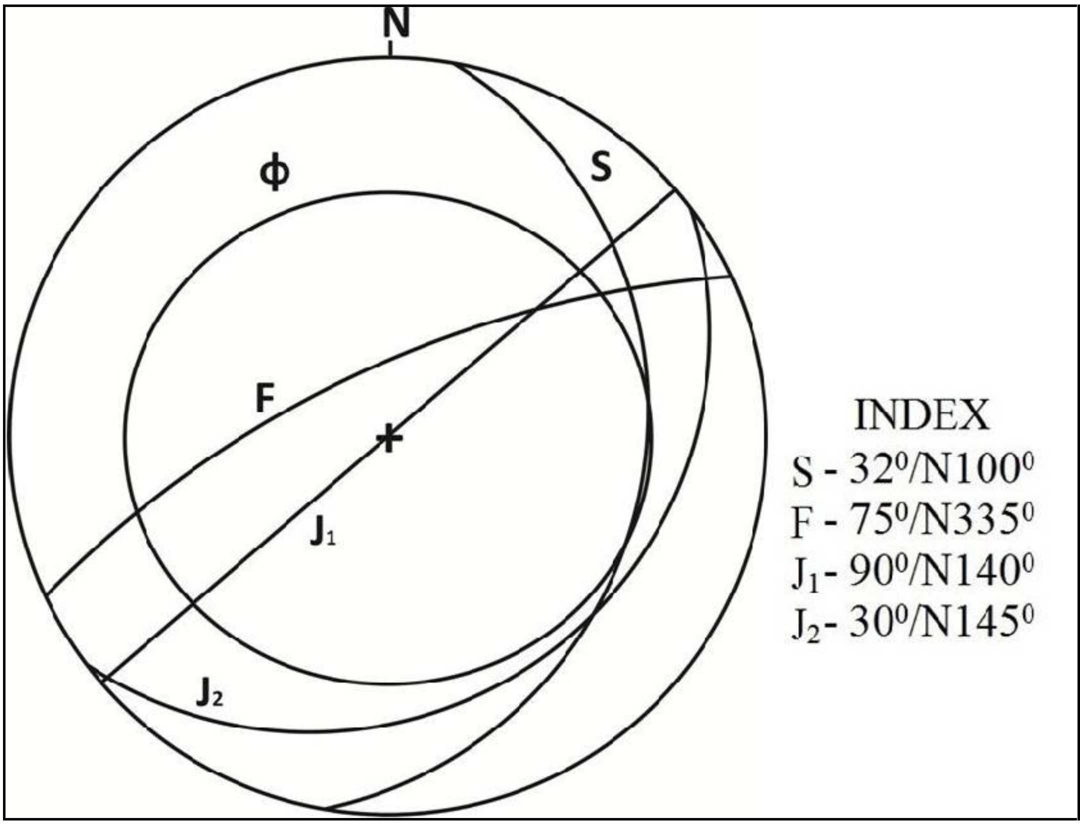


Fig. 5.6 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS5

Slope Section: RBS6

The kinematic analysis of the stereo plot showing the disposition of the geological discontinuities indicates that planar mode of failure is more probable at the site, because the foliations are dipping nearly in the same direction as that of the slope but at a lower angle. The stereo plot of the slope section RBS6 is shown in Fig. 5.7.

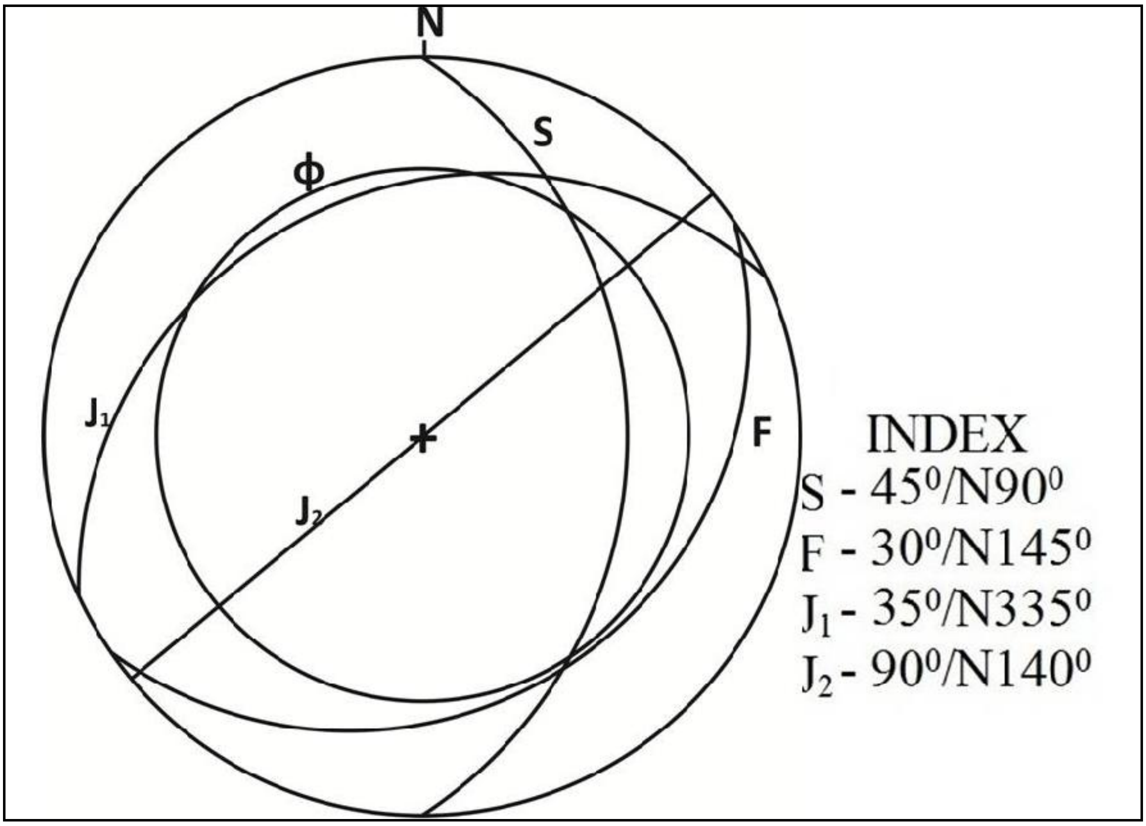


Fig. 5.7 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS6

Slope Section: RBS7

The slope section RBS7 has moderate overburden cover of about 6 m thickness which is the sliding material along the slope surface. Depending upon the mode of failure i.e. talus failure, the stability analysis has been carried out. The stereo plot of the slope section RBS7 is shown in Fig. 5.8.

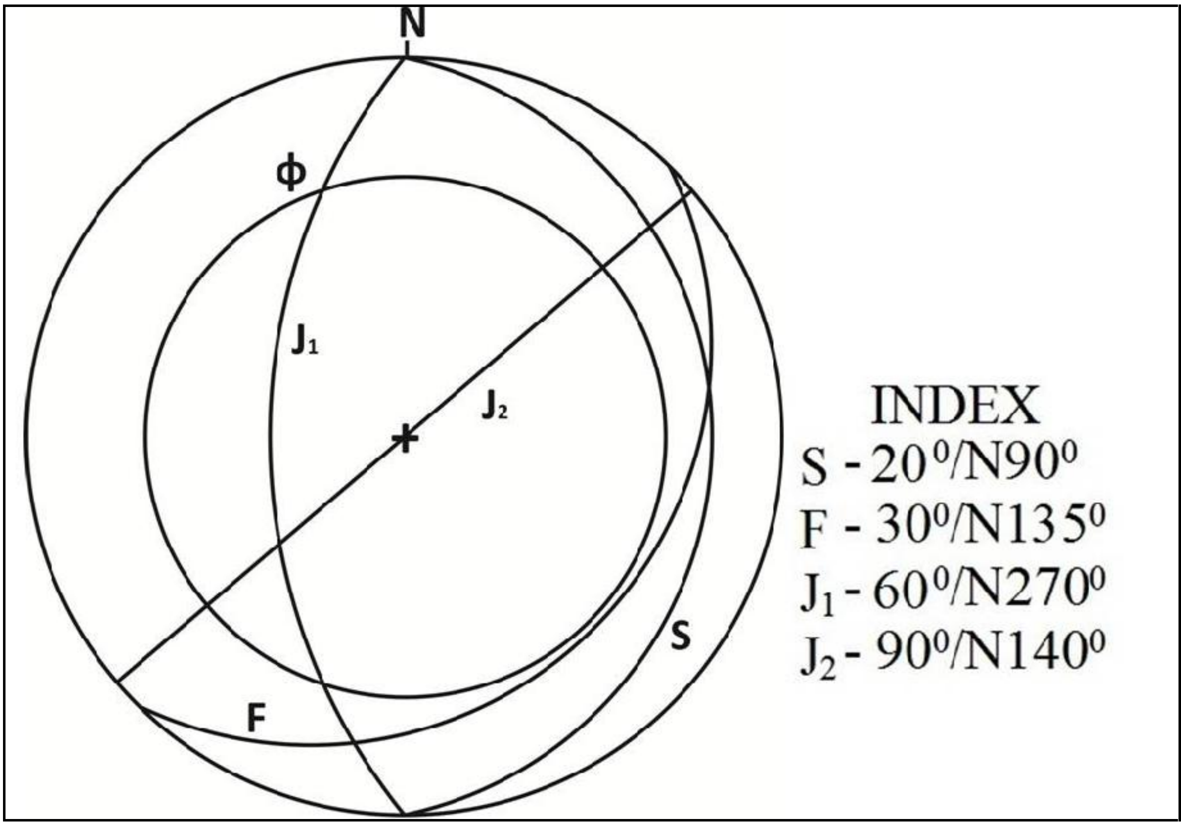


Fig. 5.8 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS7

Slope Section: RBS8

The structural readings collected from the exposed outcrops in the region have been plotted in a stereo net. The kinematic analysis of the stereo plot showing the disposition of the geological discontinuities indicates that 3-D wedge failure is more probable at the site. Fig. 5.9 shows the stereo plot of the slope section RBS8.

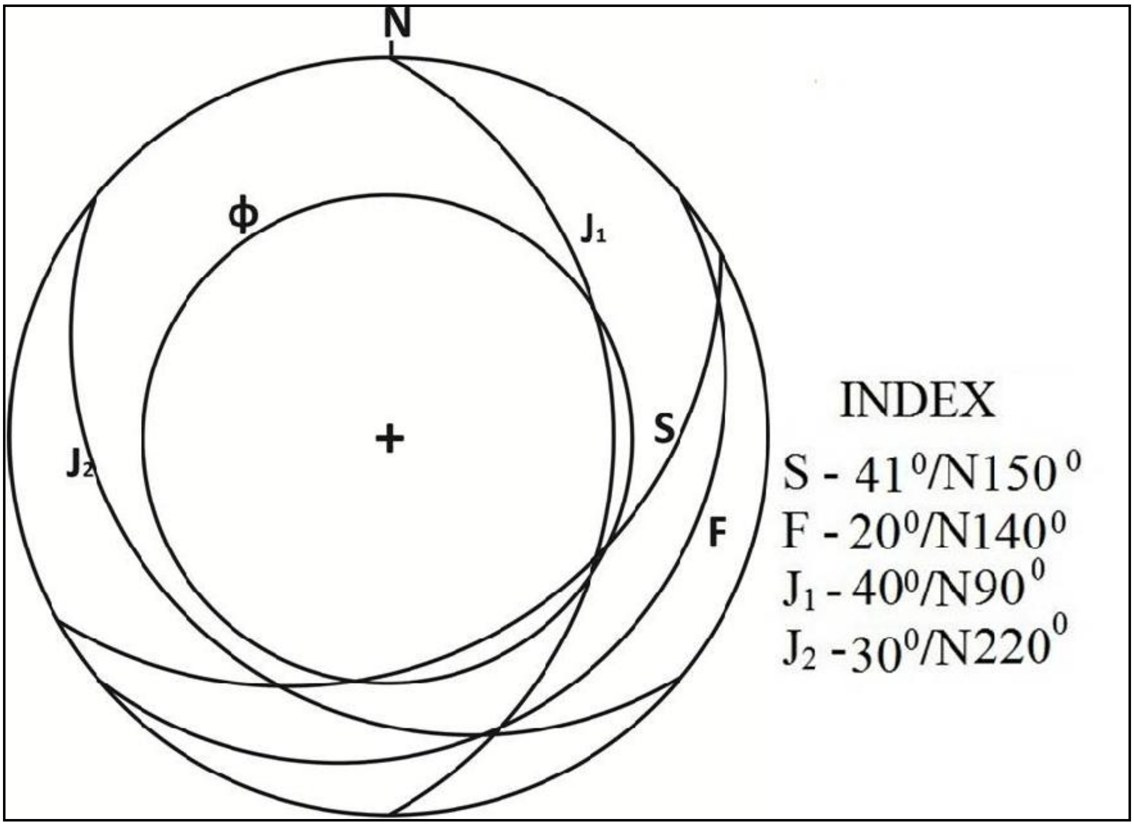


Fig. 5.9 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS8

Slope Section: RBS9

In slope section RBS9, river borne materials (RBM) with a thickness of about 35 m are present. Rocks are exposed below the RBM up to the river bed level. Since the thickness of RBM is more, rotational failure of RBM is the probable mode of failure. The Fig. 5.10 shows the stereo plot of the slope section RBS9.

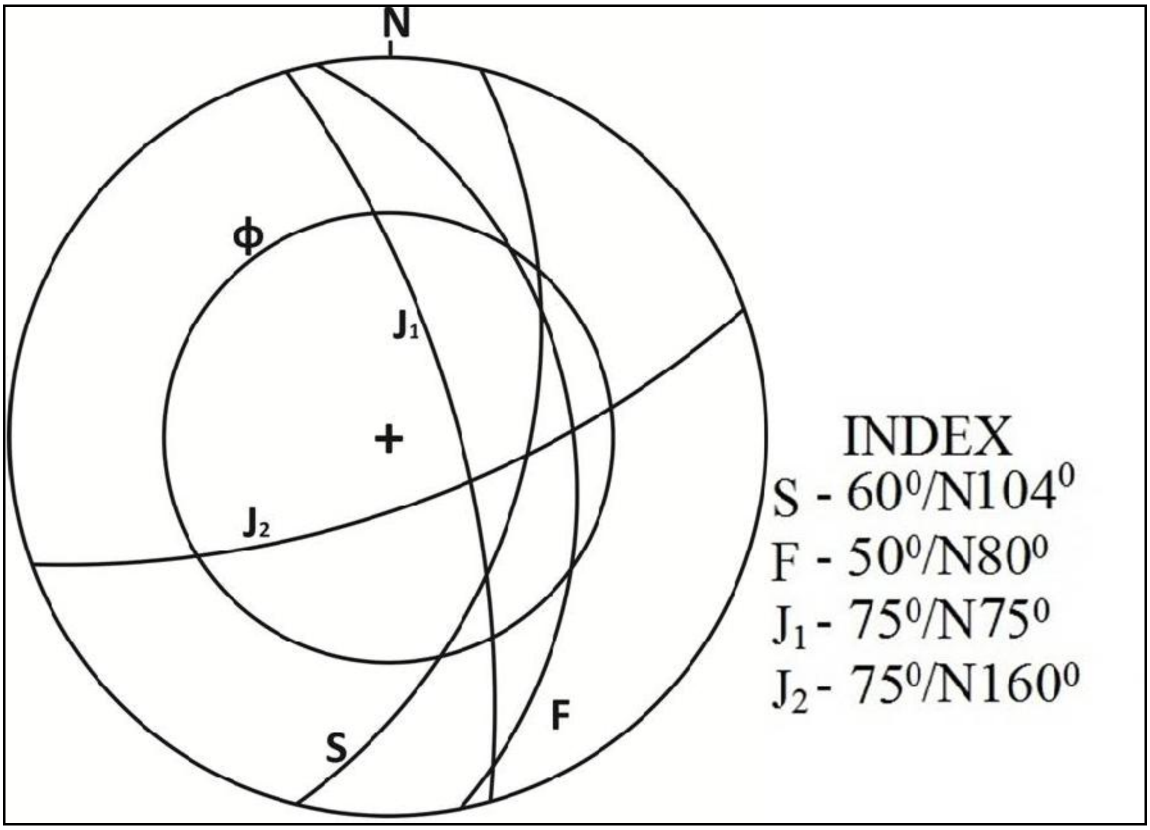


Fig. 5.10 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS9

Slope Section: RBS10

The kinematic analysis of the stereo plot showing the disposition of the geological discontinuities indicates that 3-D wedge failure is more probable at the site. The Fig. 5.11 shows the stereo plot of the slope section RBS10.

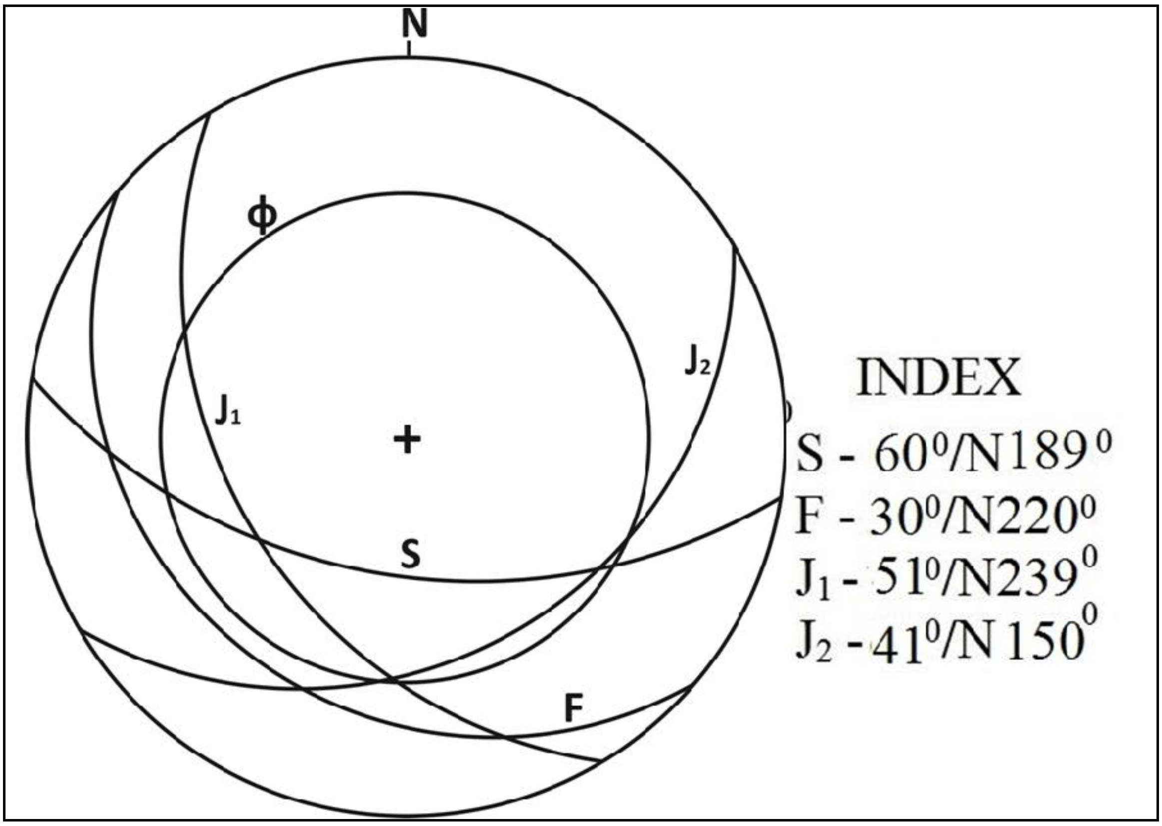


Fig. 5.11 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS10

Slope Section: RBS11

The slope section RBS11 has overburden cover of about 10 m and rocks are exposed in the lower level. Since the thickness of the debris is about 10 m, the material may follow talus failure. Accordingly talus failure analysis has been done. The Fig. 5.12 shows the stereo plot of the slope section RBS10.

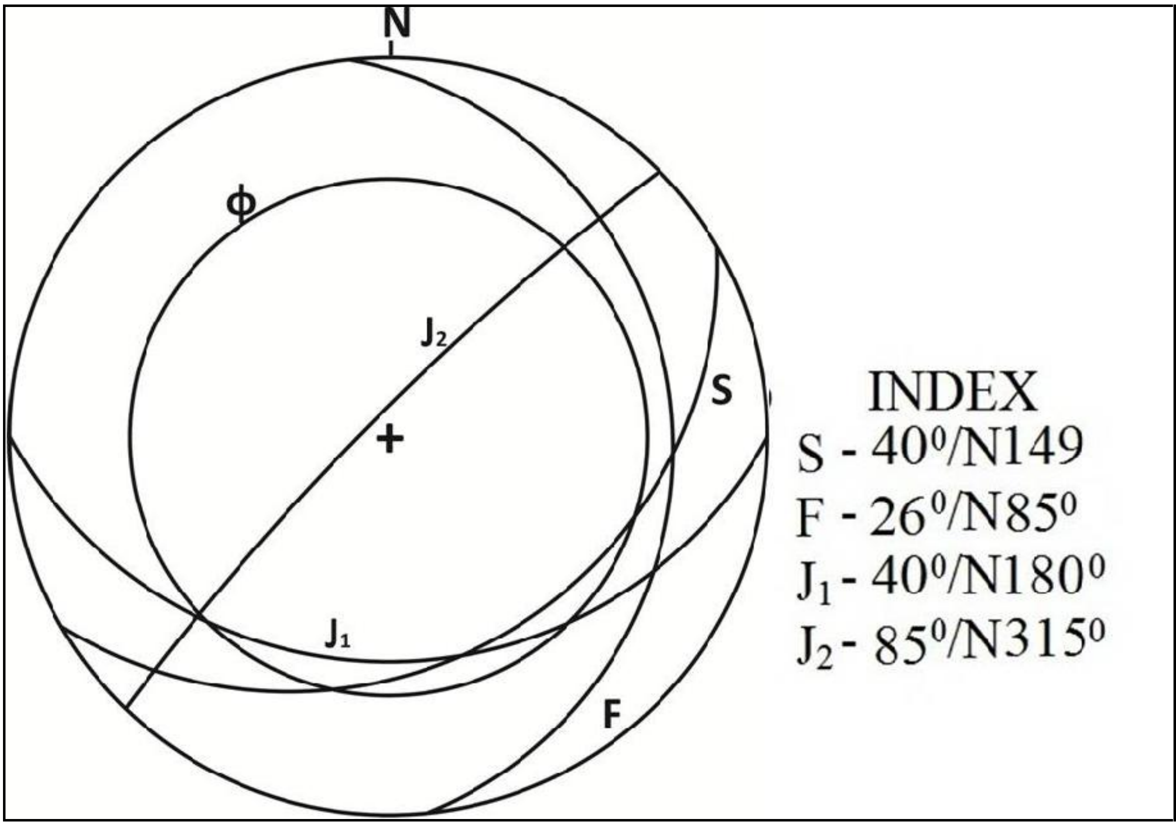


Fig. 5.12 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS11

Slope Section: RBS12

The observed readings of geological discontinuities have been plotted on a stereo net. Kinematic analysis taking into consideration the slope direction and the attitude of the geological discontinuities indicate that the disposition of the geological discontinuities is more favorable to planar mode of failure. Moreover, the foliations are dipping nearly in the same direction as that of the slope but at a lower angle. The Fig. 5.13 shows the stereo plot of the slope section RBS12.

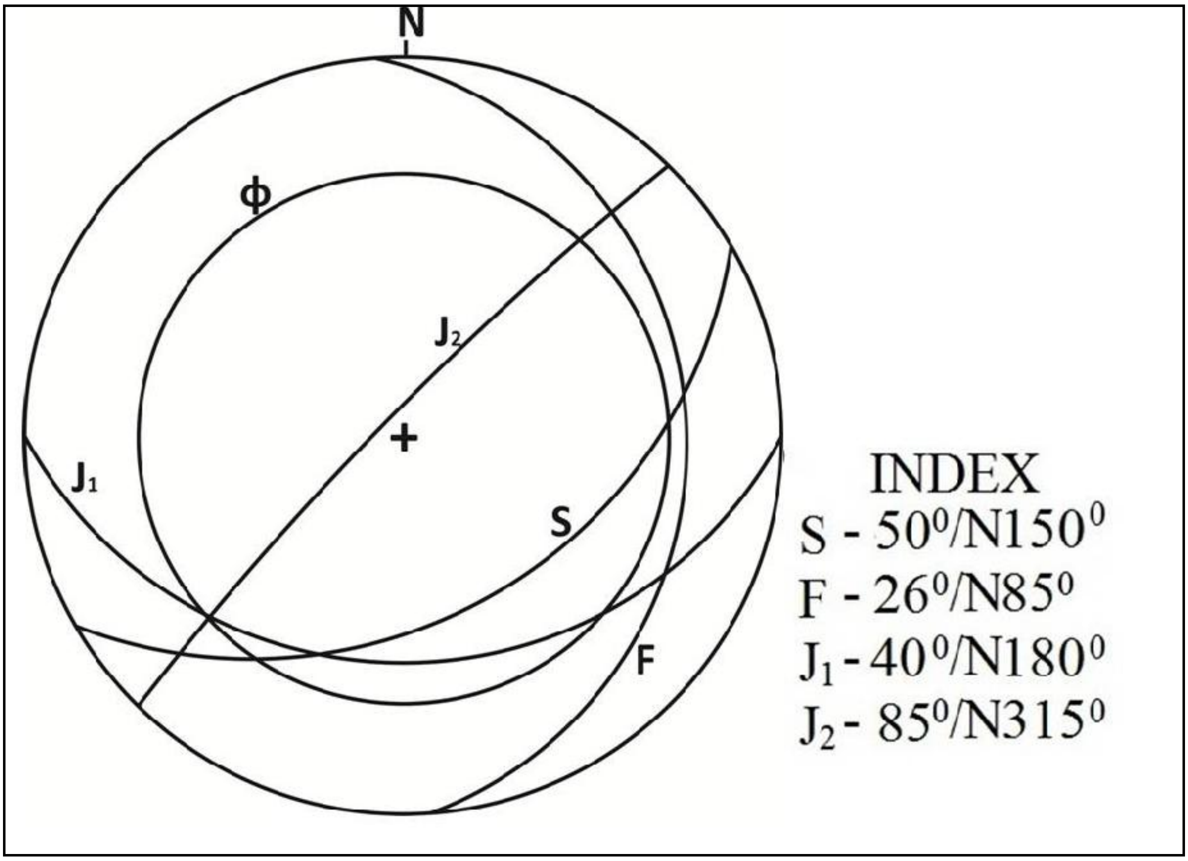


Fig. 5.13 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS12

Slope Section: RBS13

The river borne materials of thickness more than 40 m is present at the slope section RBS13. So it is anticipated that rotational mode of failure may be the probable mode in case of instability. The Fig. 5.14 shows the stereo plot of the slope section RBS13.

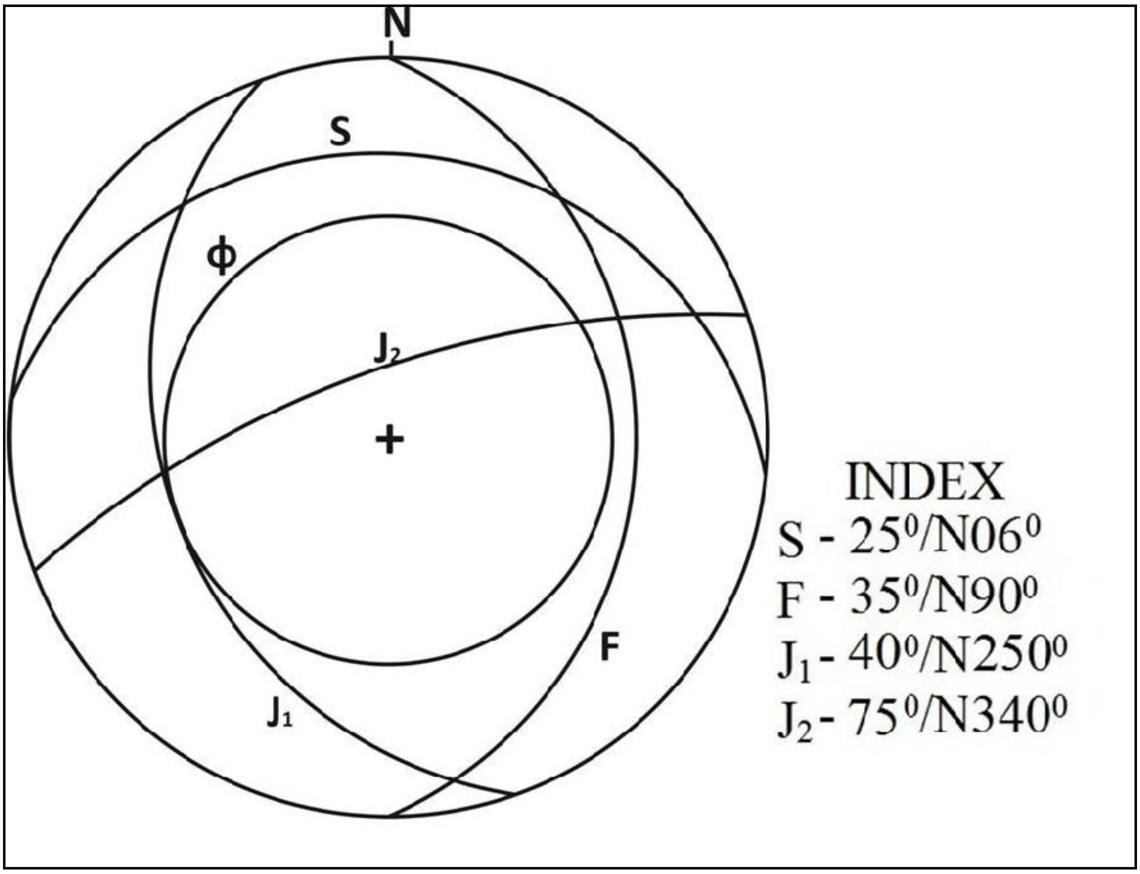


Fig. 5.14 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS13

Slope Section: RBS14

The kinematic analysis of the geological discontinuities indicates that 3-D wedge failure is more probable at the site. Accordingly wedge failure analysis has been done for the slope section RBS14. The Fig. 5.15 shows the stereo plot of the slope section RBS14.

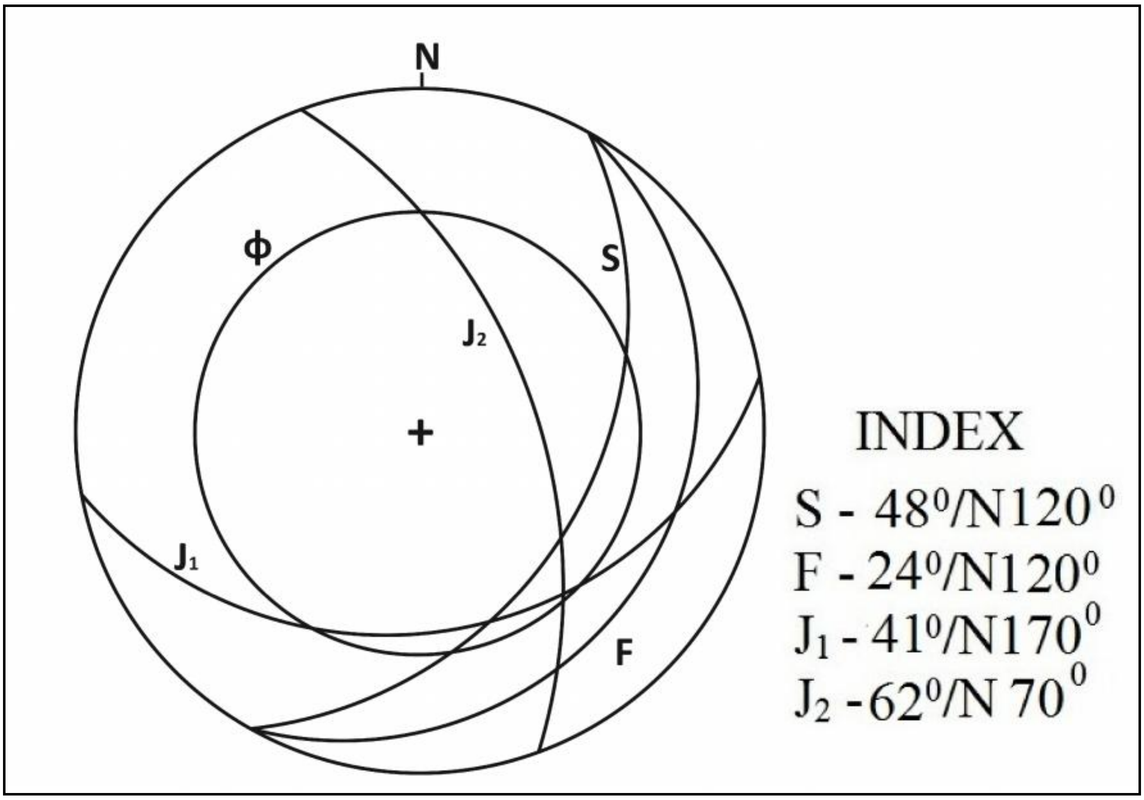


Fig. 5.15 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS14

Slope Section: RBS15

The observed readings of the geological discontinuities have been plotted on a stereo net. Kinematic analysis taking into consideration the slope direction and the attitude of the geological discontinuities suggests that the disposition is more favorable to planar mode of failure. The foliations are dipping nearly in the same direction as that of the slope but at a lower angle. Accordingly, plane failure analysis was carried out. The Fig. 5.16 shows the stereo plot of the slope section RBS15.

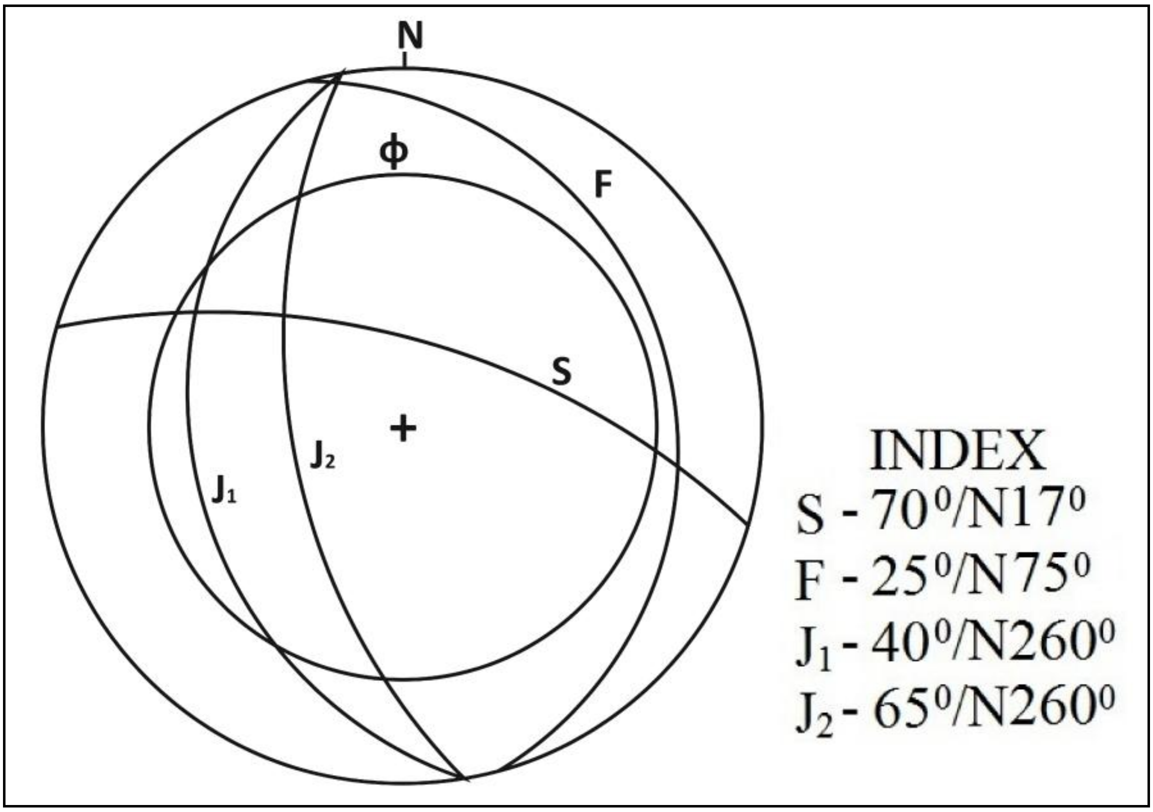


Fig. 5.16 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS15

Slope Section: RBS16

In the slope section RBS16, debris of about 8 m thickness was present, which on saturation may follow talus failure. Accordingly talus failure analysis has been done. The Fig. 5.17 shows the stereo plot of the slope section RBS16.

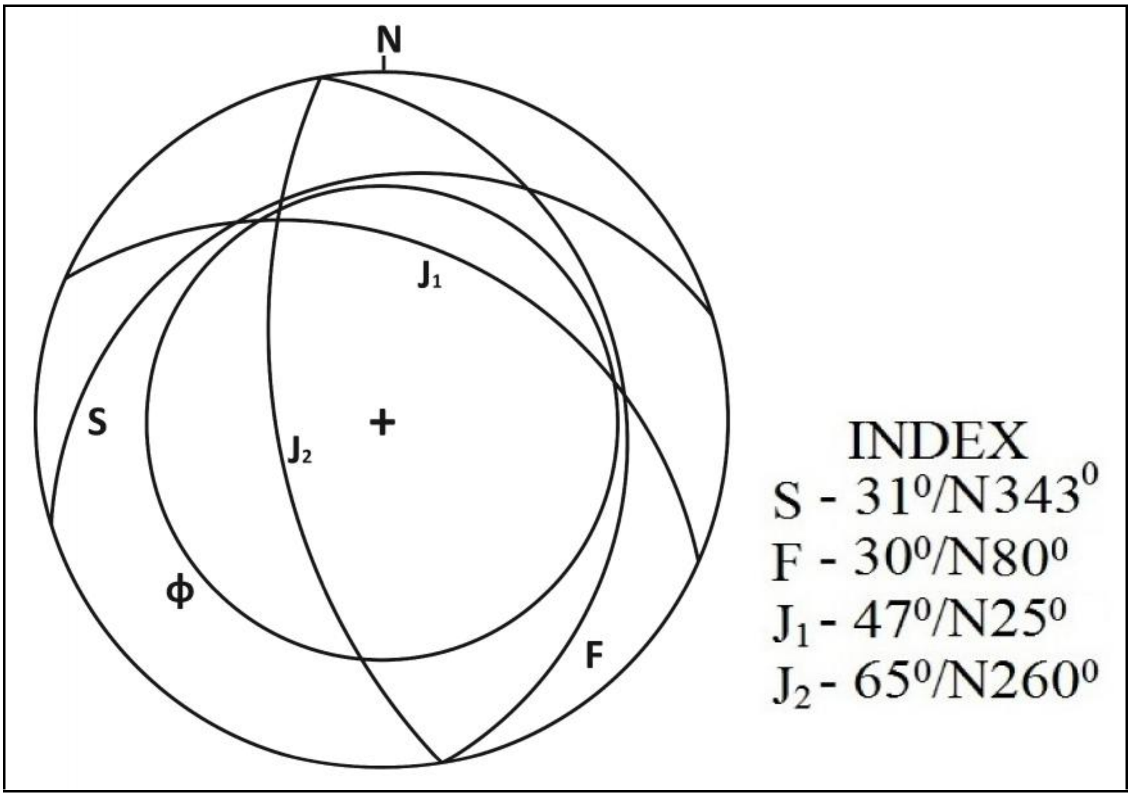


Fig. 5.17 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS16

Slope Section: RBS17

In case of slope section RBS17, 8 m thick debris cover was present, which is the sliding material along the slope surface. Accordingly, talus failure analysis has been done. The Fig. 5.18 shows the stereo plot of the slope section RBS17.

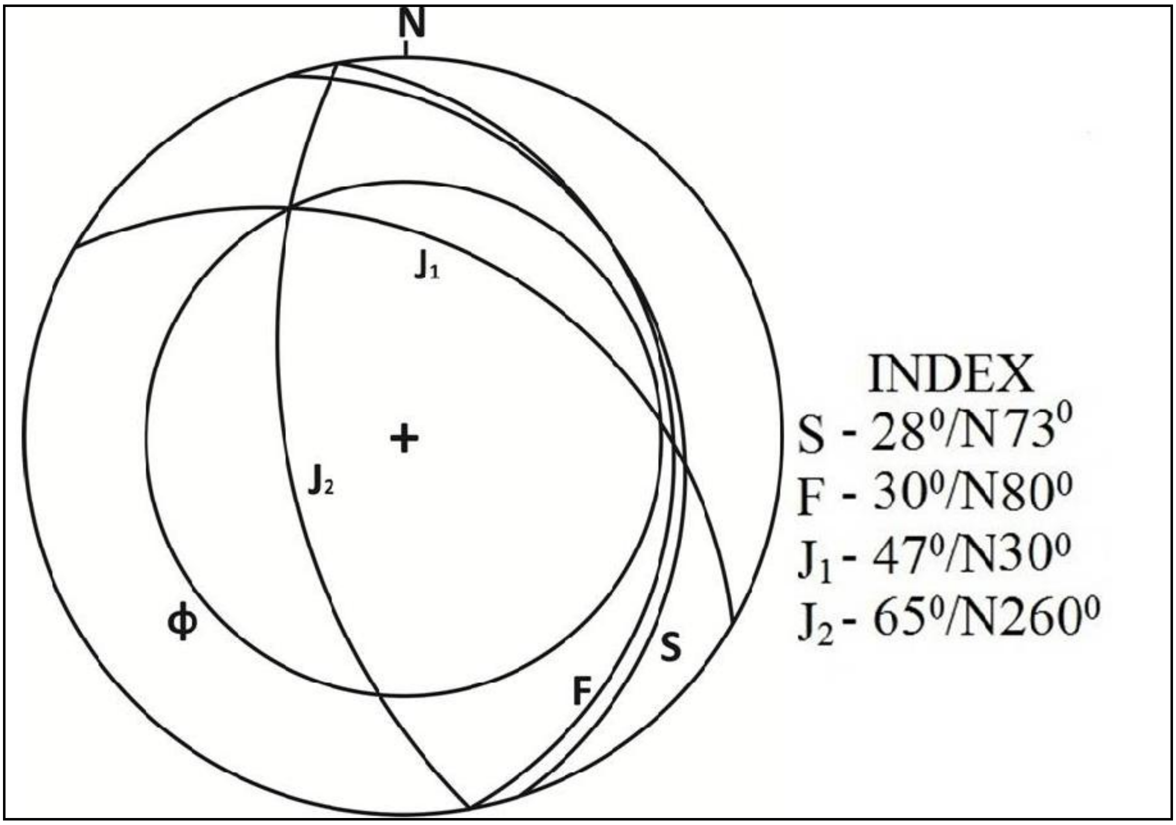


Fig. 5.18 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: RBS17

5.3.2 Left Bank Slope Sections

Slope Section: LBS1

In case of slope section LBS1, muck of thickness 30 to 40 m was dumped at the bottom level of the slope. Since the dumped muck was in loose condition this may lead to rotational failure of slope material. The Fig. 5.19 shows the stereo plot of the slope section LBS1.

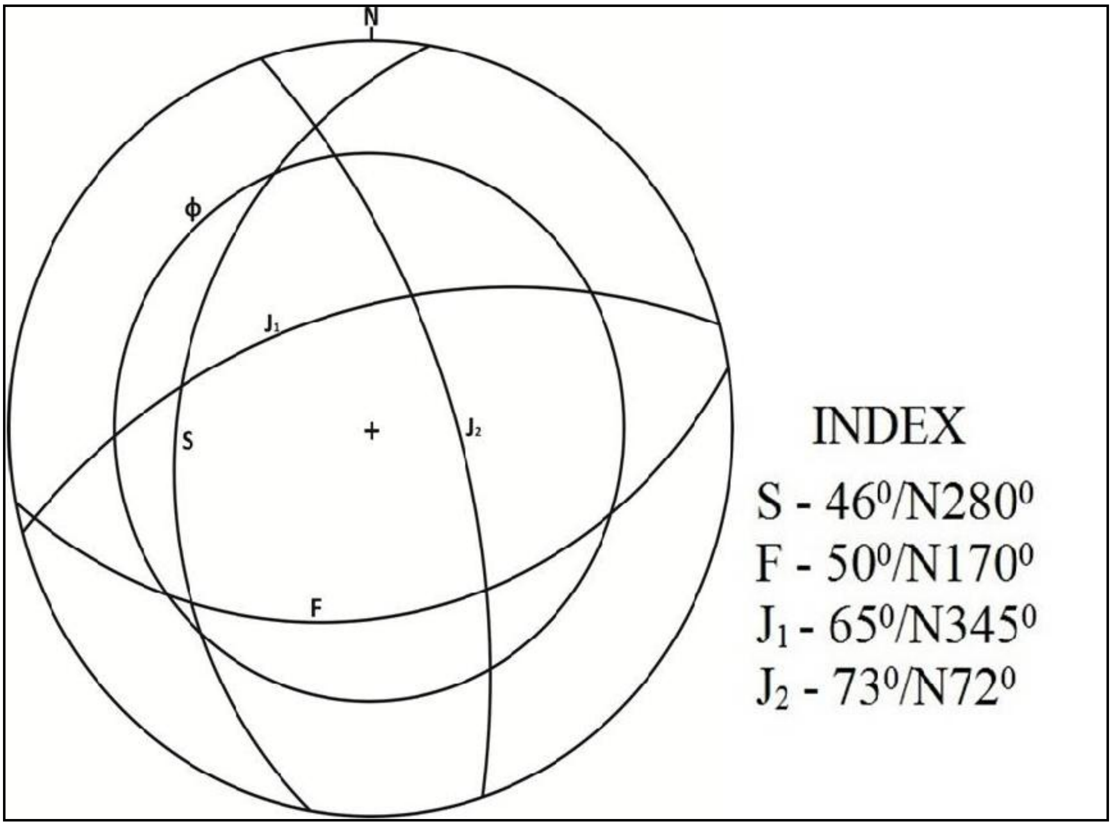


Fig. 5.19 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: LBS1

Slope Section: LBS2

Analogous to slope section LBS1, in this case muck of thickness more than 35 m was dumped at the bottom level of the slope section LBS2. Since the dumped muck was in loose condition, this may lead to rotational failure of slope material. The Fig. 5.20 shows the stereo plot of the slope section LBS2.

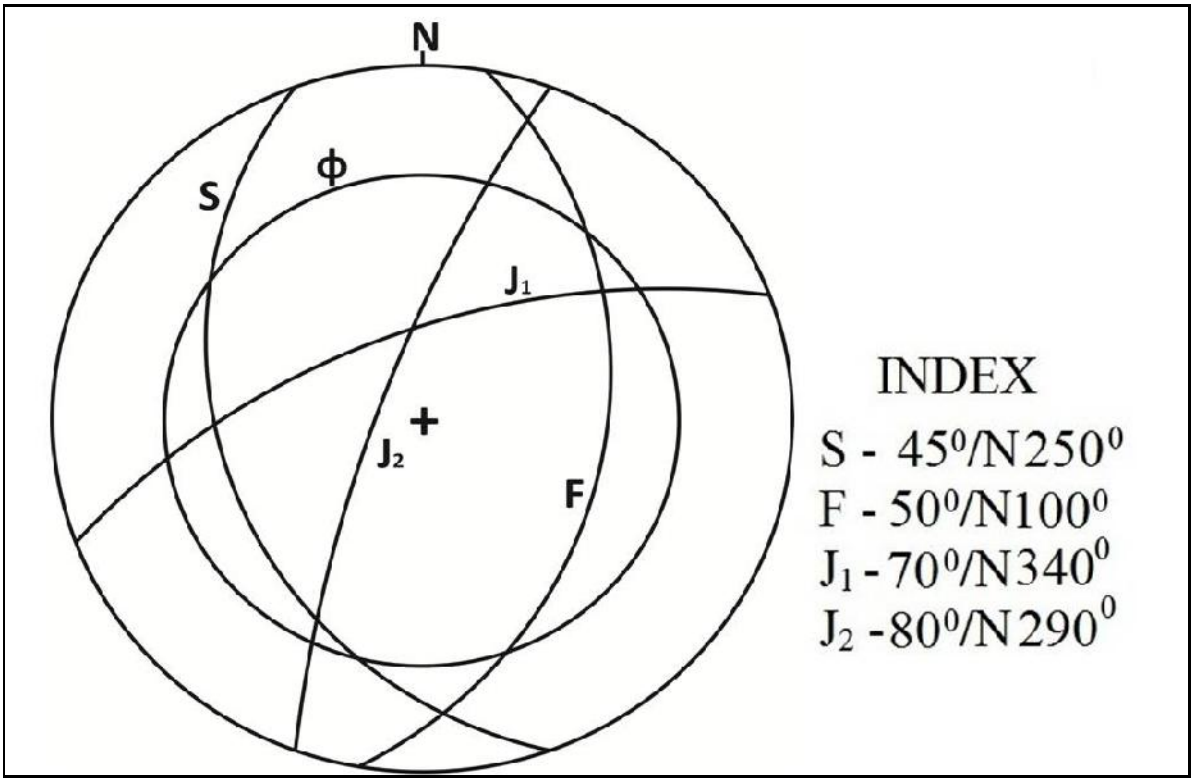


Fig. 5.20 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: LBS2

Slope Section: LBS3

In the slope section LBS3, recent debris material was dumped below the road level which is loose and highly unconsolidated in nature. Accordingly, stability analysis of the dumped material has been carried out for rotational mode of failure. The Fig. 5.21 shows the stereo plot of the slope section LBS3.

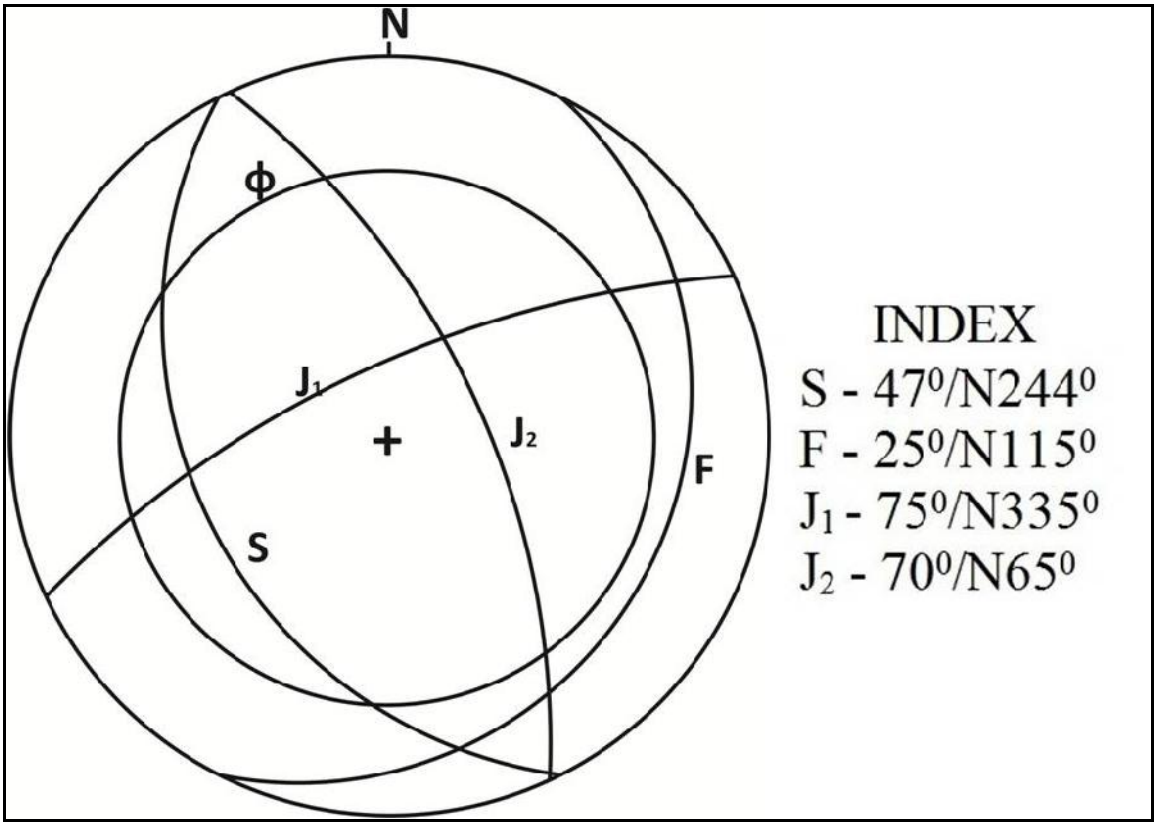


Fig. 5.21 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: LBS3

Slope Section: LBS4

In the slope section LBS4, river borne material (RBM) is present above the rock exposure of about 2 m height. The RBM extends to a height of about 10 m. Further above, debris material of thickness more than 15 m was present which may cause talus failure. Accordingly, stability analysis has been carried out. Fig. 5.22 shows the stereo plot of the slope section LBS4.

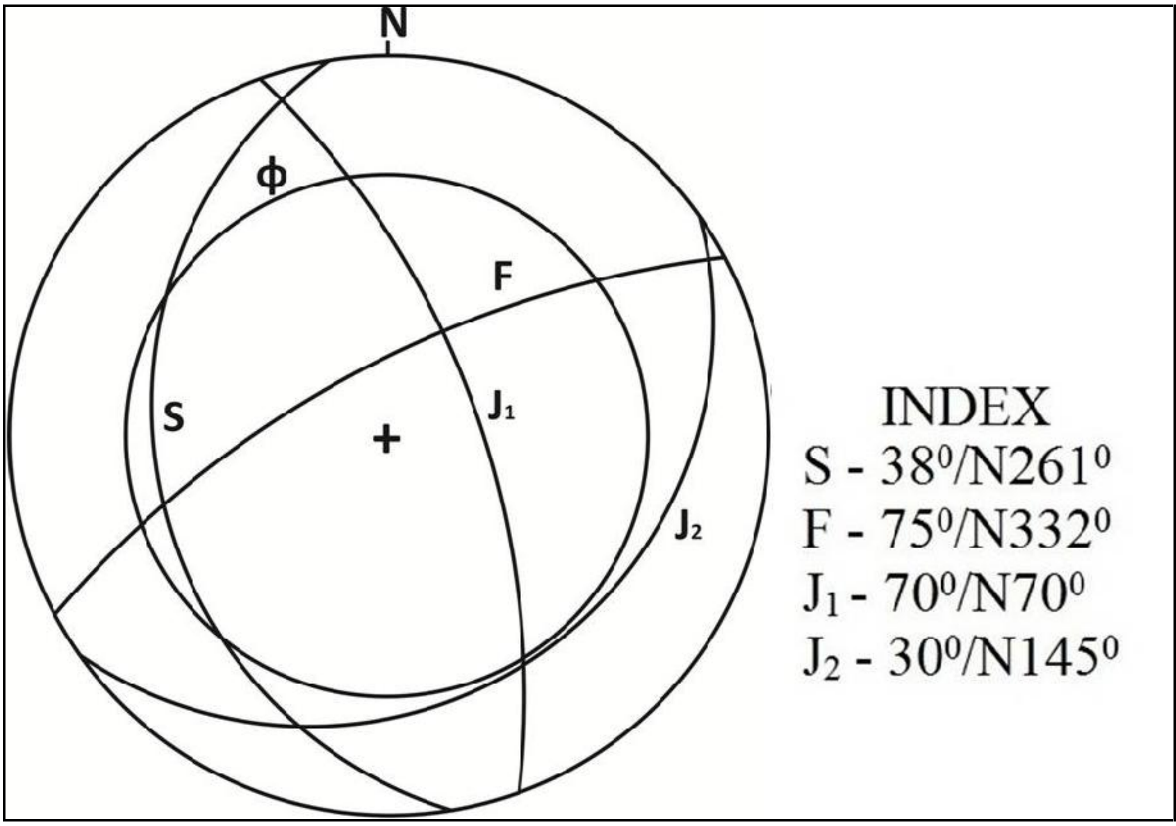


Fig. 5.22 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: LBS4

Slope Section: LBS5

The observed readings of the geological discontinuities in slope section : LBS5 have been plotted on a stereo net. A study of the slope direction and the attitude of the geological discontinuities indicates that the disposition of the geological discontinuities is more favorable to planar mode of failure and accordingly plane failure analysis was carried out. The Fig. 5.23 shows the stereo plot of the slope section LBS5.

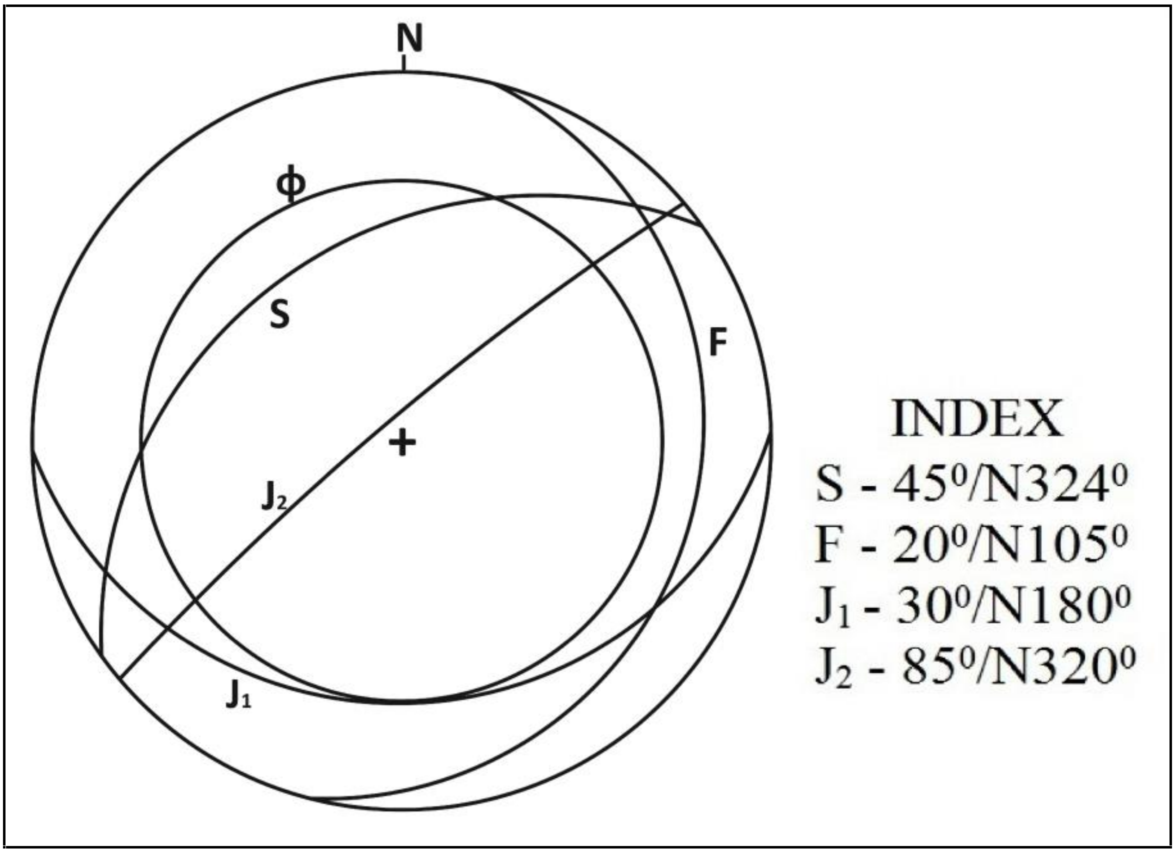


Fig. 5.23 Stereo Plot showing Attitude of Structural Discontinuities of Slope Section: LBS5

5.4 POSSIBLE MODE OF FAILURE

The modes of failure at various slope sections as predicted on basis of stereo plots are summarized in Table 5.2 below:

Table 5.1 Potential Modes of failure of Rock Slopes from Kinematic Analysis using Stereo Nets

S. No.	Slope	Potential Failure Mode
1	RBS1	Planar
3	RBS3	Planar
4	RBS4	Planar
6	RBS6	Planar
8	RBS8	3-D Wedge formed by J1,J2 and S
9	RBS9	Circular
10	RBS10	3-D Wedge formed by J1,J2 and S
12	RBS12	Planar
13	RBS13	Circular
14	RBS14	3-D Wedge formed by J1,J2 and S
15	RBS15	Planar
18	LBS1	Circular
19	LBS2	Circular
20	LBS3	Circular
22	LBS5	Planar

CHAPTER – VI

MATERIAL STRENGTH CHARACTERIZATION

6.1 SHEAR STRENGTH PARAMETERS FOR DEBRIS/TALUS SLOPES

6.1.1 Slope Sections Identified for Analysis

Plate 6.1 shows typical view of the debris slopes along the bank of the reservoir. The slope sections are identified (Chapter IV) for the stability analysis, especially from the locations where debris/talus slides were expected to occur.

6.1.2 Collection of Data

The large size direct shear tests were performed by the project authorities in their laboratory on samples of debris material (1m x 1m x 0.4m) in dry condition only at different normal stresses ($1t/m^2$, $2t/m^2$, $3t/m^2$). The shear strength parameters like cohesion, c (t/m^2) and friction angle, Φ^0 values of debris/talus material along both the banks of the reservoir are taken from (Anbalagan et al., 2010). By using these values of c and Φ, analysis for obtaining the factor of safety of debris slopes have been carried out. No data was available for shear strength parameters in partially/fully saturated conditions. Therefore in the absence of such data, the only choice left out was to assume the values of cohesion (c) and angle of friction (Φ) with some rational basis. The c and Φ values of the debris material for each slope section which are used for the analysis are presented in Table 6.1. The rational used is as follows:

On the basis of classification tests, it was found that there was presence of plastic silt fraction in the debris material. Upon saturation, it was expected that the silt material may get partly washed out affecting the cohesion (c) significantly. The cohesion component in debris material therefore was reduced to 50% while carrying out stability analysis of saturated debris slopes. Similarly, the friction angle (Φ) was reduced by 2/3.

Plate 6.1 View of Debris Slope along the Reservoir

6.2 UCS OF ROCK MASS

Uni-axial Compression Strength Tests

The Uni-axial compressive strength (UCS) tests were performed by the project authorities as per IS: 9143 (1979) on the un-weathered samples obtained from the dam site. The UCS of the fresh un-weathered phyllite rock has been obtained to be 21.0 MPa (Anbalagan et al., 2010).

6.3 SHEAR STRENGTH PARAMETERS FOR ROCK SLOPES

Along the entire periphery of the reservoir of Koteshwar Dam, wherever the rock mass slopes were encountered, the basic rock type found was phyllite with uniformity in strength. Moreover, the jointing pattern and the overall conditions of the joints was also found to be same. Therefore the values of the shear strength parameters were maintained constant for similar rock slopes.

Typical view of the Rock slopes along the bank of the reservoir are shown in Plate 6.2. The shear strength parameters like cohesion, c (t/m^2) and angle of friction, Φ (^{0}) for various rock slope sections are taken off from the RMR values of Bieniawski (1974, 1979).

Computations for obtaining factor of safety for rock slopes are carried out by using these shear strength parameters. The values of c and Φ have been summarized in Table 6.2 below.

The in-situ direct shear tests were performed by the project authorities on dry samples of rock joints. No data was available for shear strength parameters in partially/fully saturated conditions. Therefore in the absence of such data, the only choice left out was to assume the values of cohesion (c) and angle of friction (Φ) with some rational basis. The rational used is as follows:

The rock joints in-situ were found to be tight or fairly tight joints indicating that the bond between joint wall surfaces was quite strong and therefore it was expected that cohesion (c) would reduced by about 50% upon saturation as compared to cohesion in dry condition. In the same manner angle of friction (Φ) would reduced to about 2/3 of the original value.

Table 6.1 Shear Strength Parameters of Debris / Talus Material along Right and Left banks of the Reservoir

S. No.	Slope Identification	Slope Location	Cohesion, c (t/m^2)	Friction Angle Φ (^{0})
1	RBS2	Right bank	1.870	32
2	RBS4	Right bank	1.870	32
3	RBS5	Right bank	1.870	32
4	RBS6	Right bank	1.870	32
5	RBS7	Right bank	1.870	32
6	RBS9	Right bank	0	40
7	RBS11	Right bank	1.870	32
8	RBS13	Right bank	0	40
9	RBS15	Right bank	1.870	32
10	RBS16	Right bank	1.870	32
11	RBS17	Right bank	1.870	32
12	LBS1	Left bank	10	30
13	LBS2	Left bank	10	30
14	LBS3	Left bank	10	30
15	LBS4	Left bank	1.870	32

Table 6.2 Shear strength Parameters of Rock Joints for Various Slopes along Right and Left banks of the Reservoir

S. No.	Slope	C (t/m^2)	Φ (^{0})
1	RBS1	15	30
2	RBS3	15	30
3	RBS4	15	30
4	RBS6	15	30
5	RBS8	30	35
6	RBS10	30	35
7	RBS12	15	30
8	RBS14	30	35
9	RBS15	15	30
10	LBS5	15	30

Plate 6.2 View of Rock Slope along the Reservoir

CHAPTER – VII

STABILITY ANALYSIS OF DEBRIS AND TALUS SLOPES

7.1 APPLICATION OF HOEK AND BRAY (1981) CHARTS

The debris material acts like a homogenous, isotropic mass and the potential failure surface in such cases can be assumed to be circular. Charts have been presented by Hoek and Bray (1981) for the stability analysis of slopes with circular failure surface and for different drainage conditions. These charts are available for five different drainage conditions ranging from fully drained condition to the condition of saturated slope due to heavy surface recharge. These charts have been reproduced in Fig. 7.1, 7.2, 7.3 and have been used here to carry out the preliminary stability analysis of the debris slopes.

All the debris slopes along both the banks of the reservoir have been analysed using Hoek and Bray (1981) charts. The shear strength parameters used in this study were obtained from Anbalagan et al. (2010). For determining the factor of safety by using the Hoek and Bray (1981) charts, the expression which is presented in eqn. 7.1 should be used. The results of such stability analysis are presented in Tables 7.1for the right bank slope sections and in Table 7.2 for the left bank sections.

$$F = C / \gamma H \,.\, \tan\Phi \qquad (7.1)$$

where, C defines the cohesion of debris material; γ, the unit weight of debris; H, the height of the slice, and Φ is the angle of shearing resistance of debris material. Values of shear strength parameters in the stability analysis of debris slopes are taken from Anbalagan et al. (2010).

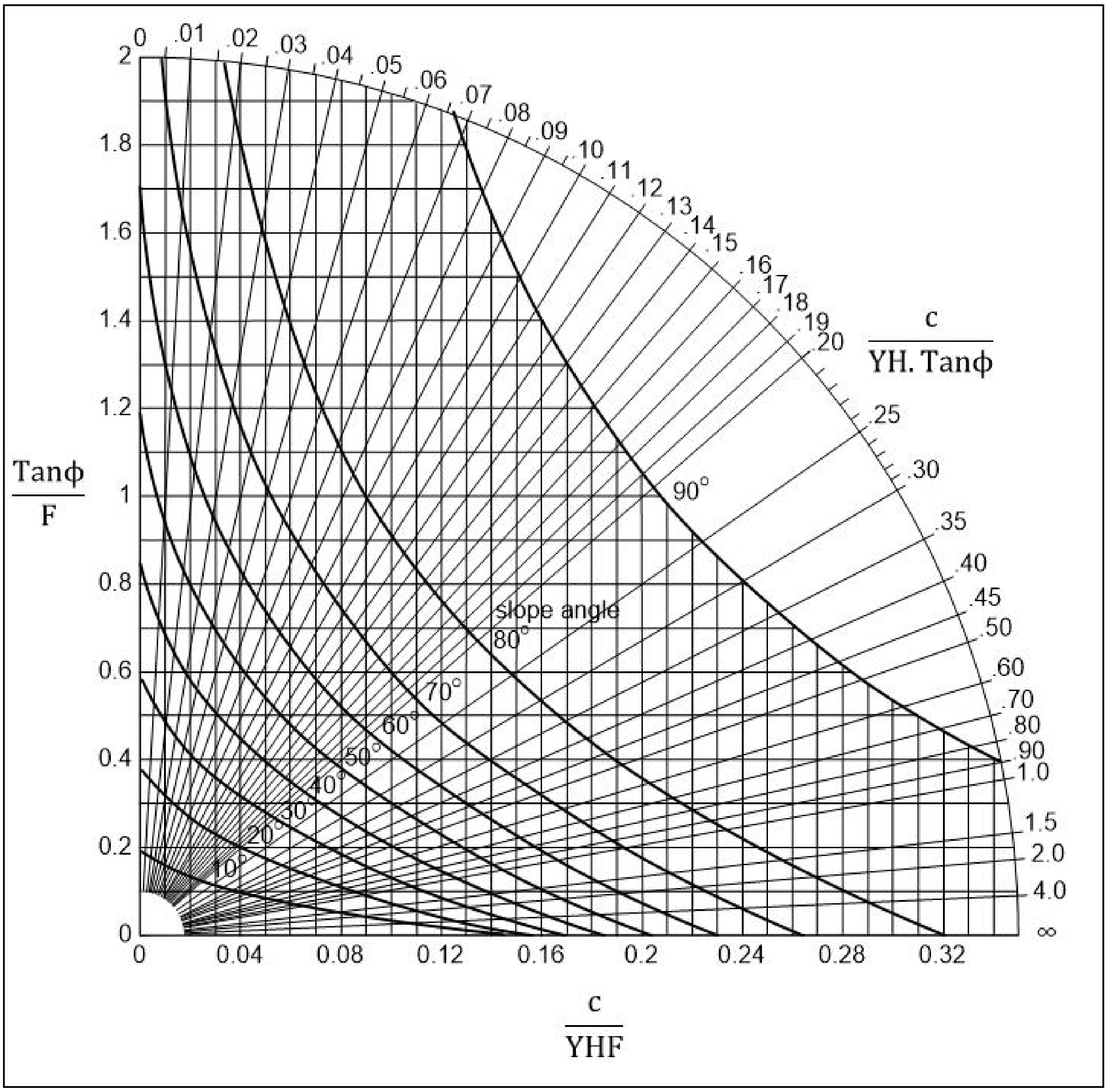


Fig. 7.1 Circular Failure Chart Number 1 (Hoek and Bray, 1981)

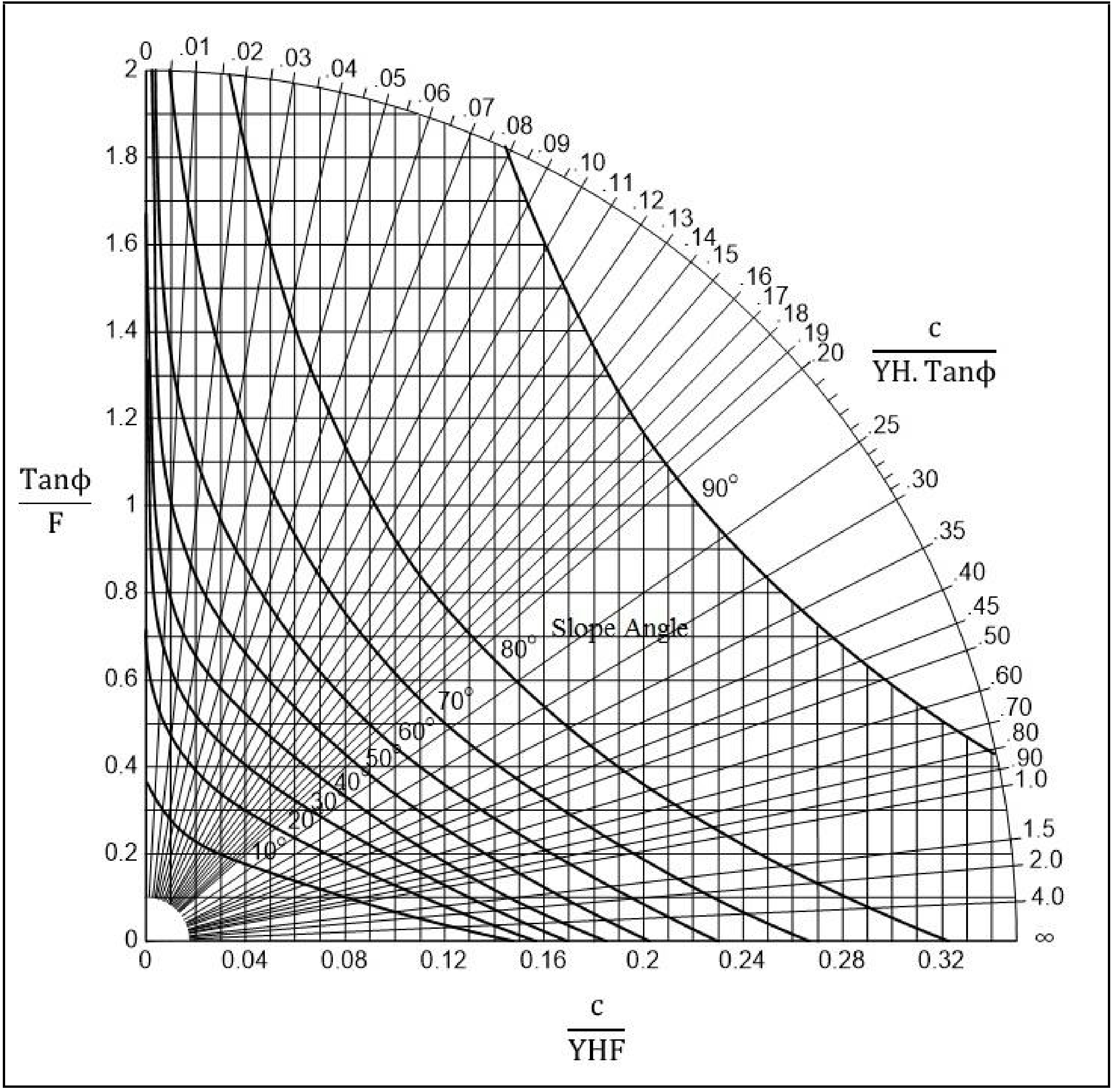


Fig. 7.2 Circular Failure Chart Number 2 (Hoek and Bray, 1981)

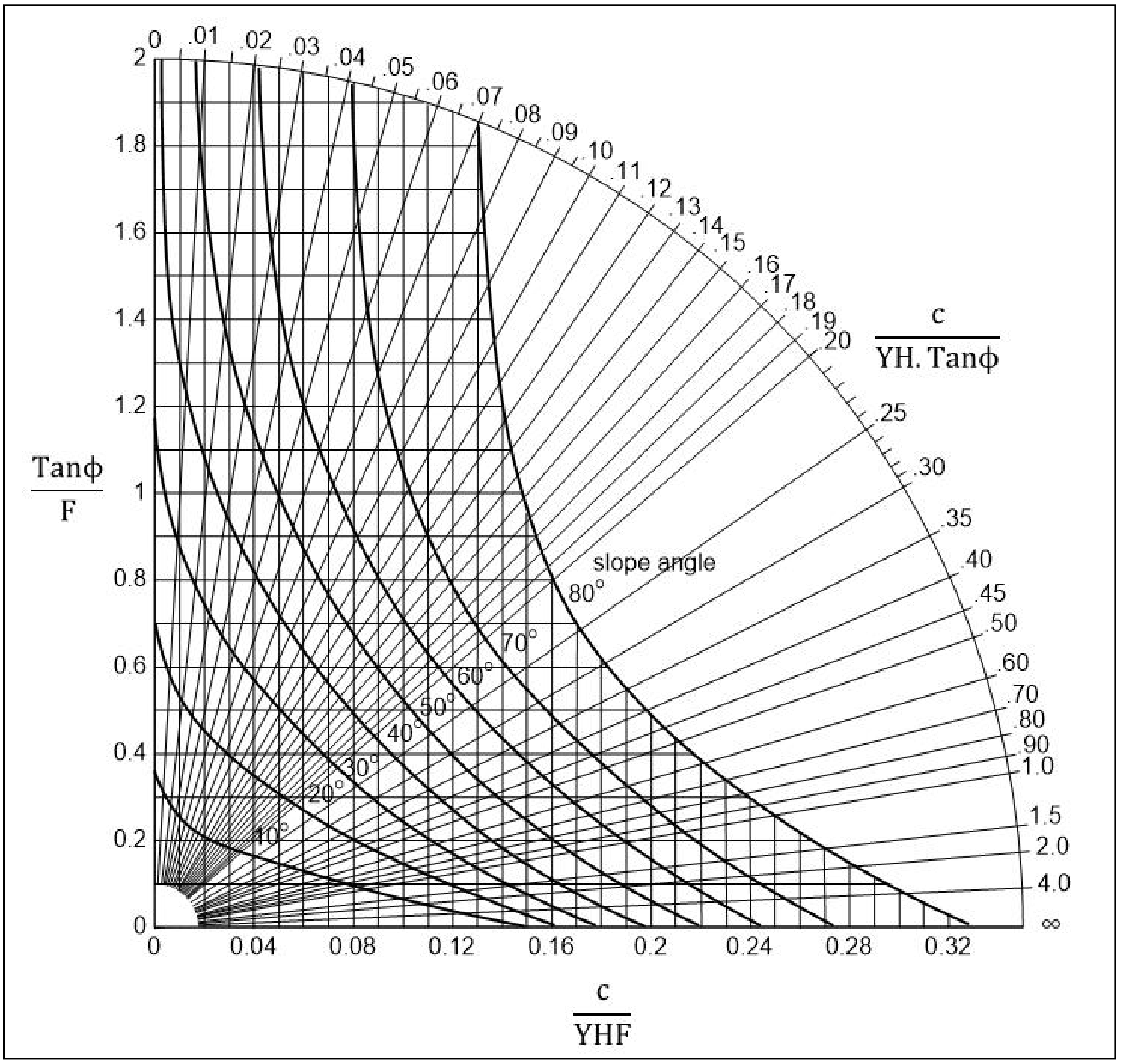


Fig. 7.3 Failure Chart Number 5 (Hoek and Bray, 1981)

7.2 STABILITY ANALYSIS USING HOEK AND BRAY (1981) CHARTS

7.2.1 Debris Slopes along Right Bank

Debris slopes identified along the right bank of the reservoir are RBS9 and RBS13. For stability analysis, three drainage conditions, namely, dry, partially saturated and fully saturated conditions have been considered. Further, both global and local slope stability of slope have been studied. The value of cohesion has been taken as 0.0 kPa as there is no presence of plastic fines in the debris material at this slope section.

A close look at Table 7.1 suggests that on right bank, slope section RBS9 has been found to be unstable in dry condition both globally and locally. The stability deteriorates further both in partially saturated and fully saturated condition. Since the maximum reservoir water level is supposed to reach El. 615 m, the chances of the entire slope mass getting fully saturated are remote. The slope mass can be expected to be fully saturated only during an extreme rainfall event and that too for a shorter duration.

The above observation is also true of the slope at section RBS13.

Table 7.1 Stability Analysis of Debris Slopes for Right Bank Slope Sections using Hoek and Bray (1981) Charts

Slope Designation	Slope Condition	RL of Toe, m	RL of Top, m	Drainage Condition	Slope angle , degree	Height, m	C, kPa	Phi, degrees	Gamma , kN/cu.m.	C/(gamma*H*tan(phi)	Chart No.	tan (phi)/F	F from phi	C/(F.gamma.H)	F from C
RBS9	Global	570	672	Dry	60	102	0.0	30	17	0.0	1	1.70	0.339	0.0	0.0
RBS9	Global	570	672	Partially saturated	60	102	0.0	20	19	0.0	2	2.0	0.182	0.0	0.0
RBS9	Global	570	672	Fully saturated	60	102	0.0	15	19	0.0	5	2.0	0.134	0.0	0.0
RBS9	Local	665	672	Dry	50	7	0.0	30	17	0.0	1	1.20	0.48	0.0	0.0
RBS9	Local	665	672	Partially saturated	50	7	0.0	20	19	0.0	2	2.0	0.182	0.0	0.0
RBS9	Local	665	672	Fully saturated	50	7	0.0	15	19	0.0	5	2.0	0.134	0.0	0.0

F = Factor of Safety

………. Contd.

Slope Designation	Slope Condition	RL of Toe, m	RL of Top, m	Drainage Condition	Slope angle , degree	Height, m	C, kPa	Phi, degrees	Gamma , kN/cu.m.	C/(gamma*H*tan)phi)	Chart No.	tan (phi)/F	F from phi	C/(F.gamma.H)	F from c
RBS13	Global	550	695	Dry	40	145	0.0	30	17	0.0	1	0.93	0.620	0.0	0.0
RBS13	Global	550	695	Partially saturated	40	145	0.0	20	19	0.0	2	1.7	0.214	0.0	0.0
RBS13	Global	550	695	Fully saturated	40	145	0.0	15	19	0.0	5	2.0	0.134	0.0	0.0
RBS13	Local	670	695	Dry	30	25	0.0	30	17	0.0	1	0.58	0.995	0.0	0.0
RBS13	Local	670	695	Partially saturated	30	25	0.0	20	19	0.0	2	1.65	0.220	0.0	0.0
RBS13	Local	670	695	Fully saturated	30	25	0.0	15	19	0.0	5	1.18	0.227	0.0	0.0

F = Factor of Safety

7.2.2 Debris Slopes along Left Bank

Similarly on the left bank, slopes at the sections LBS1, LBS2 and LBS3 have been identified and studied for both global and local slope stability.

Table 7.2 suggests that 70.0 m high left bank slope LBS1 is unstable in all the three states, i.e. dry, saturated and fully saturated. Locally, the slope (height = 20.0 m) is stable when it is in dry state. However, it becomes unstable in partial or fully saturation condition. The same is true for slopes LBS2 and LBS3. Since the maximum reservoir water level is supposed to reach El. 615 m, the chances of the entire slope mass getting fully saturated are rare. The slope mass can be expected to be fully saturated only during an extreme rainfall event and that too for a shorter duration.

Table 7.2 Stability Analysis of Debris Slopes for Left Bank Slope Sections using Hoek and Bray (1981) Charts

Slope Designation	Slope Condition	RL of Toe, m	RL of Top, m	Drainage Condition	Slope angle , degree	Height, m	C, kPa	Phi, degrees	Gamma , kN/cu.m.	C/(gamma*H*tan)phi)	Chart No.	tan (phi)/F	F from phi	C/(F.gamma.H)	F from C
LBS1	Global	590	660	Dry	46	70	50	20	17	0.115	1	0.45	0.809	0.07	0.600
LBS1	Global	590	660	Partially saturated	46	70	25	13	19	0.081	2	0.55	0.420	0.044	0.427
LBS1	Global	590	660	Fully saturated	46	70	25	10	19	0.107	5	0.68	0.260	0.072	0.261
LBS1	Local	640	660	Dry	55	20	50	20	17	0.404	1	0.30	1.213	0.115	0.132
LBS1	Local	640	660	Partially saturated	55	20	25	13	19	0.285	2	0.38	0.607	0.105	0.626
LBS1	Local	640	660	Fully saturated	55	20	25	10	19	0.373	5	0.37	0.476	0.140	0.470

…………… contd.

Slope Designation	Slope Condition	RL of Toe, m	RL of Top, m	Drainage Condition	Slope angle , degree	Height, m	C, kPa	Phi, degrees	Gamma , kN/cu.m.	C/(gamma*H*tan)phi)	Chart No.	tan (phi)/F	F from phi	C/(F.gamma.H)	F from C
LBS2	Global	580	640	Dry	45	60	50	20	17	0.135	1	0.435	0.837	0.052	0.942
LBS2	Global	580	640	Partially saturated	45	60	25	13	19	0.095	2	0.53	0.435	0.048	0.457
LBS2	Global	580	640	Fully saturated	45	60	25	10	19	0.124	5	0.65	0.271	0.072	0.304
LBS2	Local	618	640	Dry	45	22	50	20	17	0.367	1	0.25	1.455	0.095	1.407
LBS2	Local	618	640	Partially saturated	45	22	25	13	19	0.260	2	0.35	0.660	0.090	0.665
LBS2	Local	618	640	Fully saturated	45	22	25	10	19	0.340	5	0.35	0.503	0.115	0.520

…………… contd.

Slope Designation	Slope Condition	RL of Toe, m	RL of Top, m	Drainage Condition	Slope angle , degree	Height, m	C, kPa	Phi, degrees	Gamma , kN/cu.m.	C/(gamma*H*tan)phi)	Chart No.	tan (phi)/F	F from phi	C/(F.gamma.H)	F from C
LBS3	Global	588	690	Dry	55	102	50	20	17	0.079	1	0.64	0.568	0.050	0.577
LBS3	Global	588	690	Partially saturated	55	102	25	13	19	0.056	2	0.75	0.308	0.038	0.340
LBS3	Global	588	690	Fully saturated	55	102	25	10	19	0.073	5	0.95	0.176	0.062	0.208
LBS3	Local	670	690	Dry	47	20	50	20	17	0.404	1	0.26	1.34	0.10	1.470
LBS3	Local	670	690	Partially saturated	47	20	25	13	19	0.285	2	0.35	0.660	0.090	0.731
LBS3	Local	670	690	Fully saturated	47	20	25	10	19	0.373	5	0.34	0.519	0.122	0.540

7.3 LIMITATIONS OF ANALYSIS BY HOEK AND BRAY (1981) CHARTS

Major limitation of the analysis presened in section 7.2 using Hoek and Bray (1981) charts is that these charts can be used to carry out the analysis only for the static condition. Also, it does not take in to consideration the variation in the thickness of debris. However, the Koteshwar Hydro Electric Project area lies in seismic Zone IV and therefore these charts give only a preliminary idea regarding the stability of debris slopes. For a realistic understanding of the behaviour of the slope in seismic condition, it is essential to carry out seismic analysis which has been carried out using softwere packages: SARC/SAST, developed at IIT Roorkee and these analyses are presented in art. 7.4.

7.4 STABILITY ANALYSIS USING SOFTWARE : SARC

The SARC computer program is a simple and versatile program, which is used for the stability analysis of slopes with circular failure and with the provision of surface water at the toe of the slope. Bishop's (1955) method of slices has been used in this program and the expression for the factor of safety has been modified taking into account earthquake forces as pseudo-static forces and considering rotational mode of failure. The input parameters are the geometry of the slope and the shear strength parameters. The SARC program automatically considers innumerable number of possible slip circles and indicates the one with the minimum factor of safety. SARC is being used in more than 20 countries. Singh and Goel (2002) provide a detailed method of analysis for this type of failure.

Rotational or circular modes of failure are usually found in soils, highly weathered or crushed rocks. In such slope materials, failure occurs along a surface which attains a circular shape. Circular failures is common in rock masses, where the material is so intensely fractured that it may be considered as randomly jointed and isotropic(Viladkar et al. 2011).

7.4.1 Overview of "SARC"

In the entire reservoir rim area, the conditions discussed above have been observed to prevail only at five slope sections. These are RBS9, RBS13, LBS1, LBS2, and LBS3. The rocks exposed at these slope sections are phyllites. The stability analysis has been carried out by using computer program 'SARC' for rotational mode of failure. A brief description of program SARC is given below.

The computer program – SARC is for the stability analysis of submerged reservoir slopes with circular mode of failure (Singh and Goel, 2002) and facilitates to compute the factor of safety with circular failure surface emerging at the toe. The program uses following input parameters:

Cohesion = c

Angle of shearing resistance = Φ

Ratio of pore water pressure parameter to the unit weight times the average height of the slice = $\bar{B}$ / γH

Corresponding magnitude of earthquake on Richter's scale for the seismic zone = M

It analyses any general profile of the slope surface and for various forces i. e. pore water pressure, depth of tension crack at the top of the slope, depth of water in tension crack and earthquake force. In the first step, it draws various slip surfaces along which failure can take place. Then it calculates the radius and centre of each slip surface.

In the next step, the factor of safety is computed using Bishop's equation for various slip surfaces until a minimum factor of safety is obtained (Fig. 7.4) for a particular slip cirle. The factor of safety for such a case is given by eqn 7.2

$$F = \frac{C + \sigma \cdot \tan\Phi}{\tau_{mb}} \qquad (7.2)$$

where, τ_{mb} is the shear stress mobilized along the failure surface acted upon by the normal stress, σ.

For obtaining the factor of safety in saturated condition, αh and α_v should be used as 0 and the value of Φ in saturated condition should be 2/3 of the value of Φ in dry condition. Similarly, the value of C in saturated condition should be used ½ of C value of dry, the pore water pressure , $\bar{B}$ remains 0 in dry condition and for saturated the value of $\bar{B}$ should be used as 0.1 to estimate the factor of safety.

In seismic condition, the values of seismic coefficients αh and α_v and the corresponding earthquake magnitude M should be used and other parameters like C and Φ should remain as those in case of static dry and static saturated conditions.

The analysis evaluates the critical acceleration for slopes with factor of safety less than unity and computes the dynamic displacement employing the correlation developed by Lavania et al. (1987). The output of the program includes the factor of safety –

i) both in static and seismic conditions and

ii) dynamic displacement of the slope due to seismicity

Debris slopes, in general, have been analyzed for the following conditions:

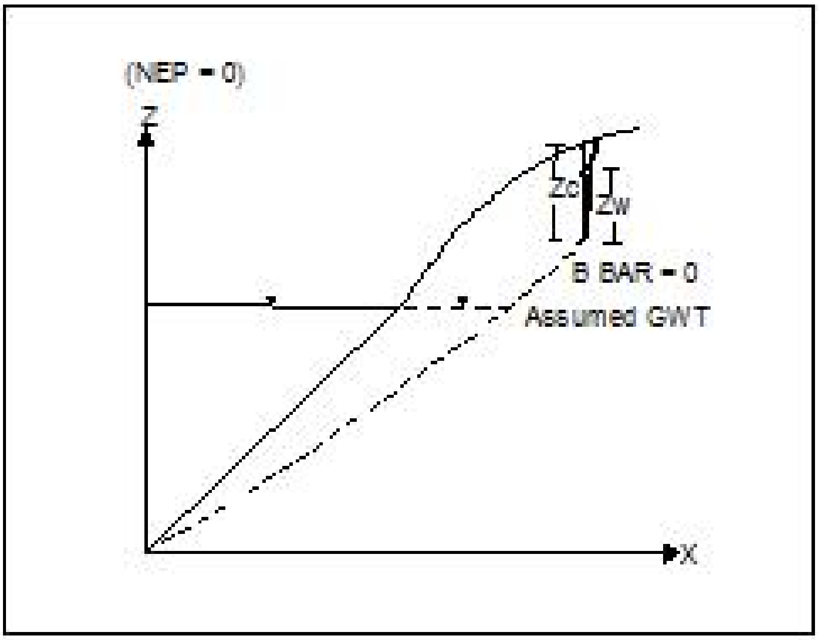
i) Static with dry slope,

ii) Static with fully saturated slope,

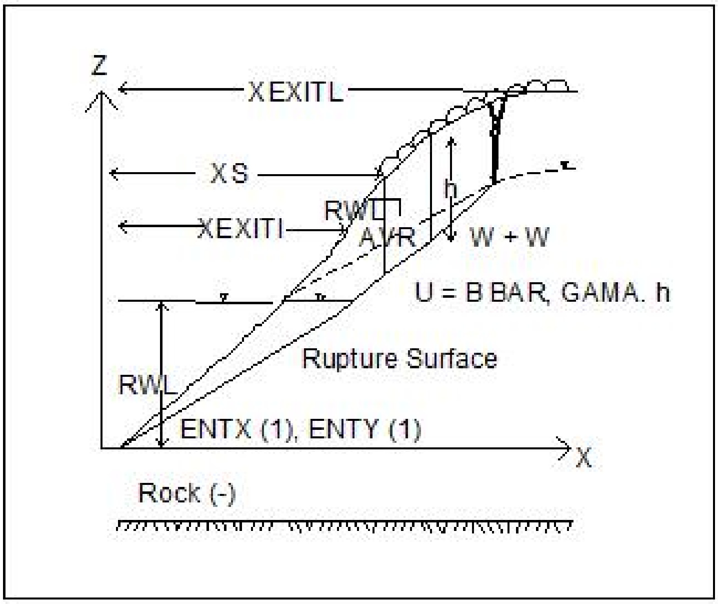
iii) Seismic with dry slope, and

iv) Seismic with partly saturated slope but with reservoir full condition.

A typical input file of the programs SARC is presented in Appendix - VI .



(a)



(b)

Fig. 7.4 (a, b) Input variables for Stability Analysis of Debris Slopes with Circular Failure (SARC)

7.4.2 Stability analysis of debris slopes using "SARC"

The output files, which include the results of stability analysis of various debris slopes, have been presented in Appendix - VII . Various debris slopes around the periphery of the reservoir which have been analyzed using the program SARC are listed below in Table 7.3. A summary of these analyses in terms of least factors of safety obtained for various slope conditions has been presented in Tables 7.4 and 7.5 respectively for slopes on right bank and in left bank of the reservoir area.

Table 7.3 Debris Slopes analyzed by using "SARC"

S. No.	Bank	Rock Slopes at Sections
1	Right	RBS9
2	Right	RBS13
3	Left	LBS1
4	Left	LBS2
5	Left	LBS3

In the reservoir area, slopes at sections RBS9 (near village Palam, 5.7 km d/s of zero bridge), RBS13 (near village Bandria 8.5 km d/s of zero bridge) along the right bank and slopes at sections LBS1 (250 m d/s of Zero Brodge), LBS2 (opposite to Marh Stream, 900 m d/s of Zero Bridge) and LBS3 (near Chopra village, 1.5 km d/s of Zero Bridge) along the left bank, are the debris slopes. Tables 7.4 and 7.5 give the values of least factors of safety obtained.

Table 7.4 suggests that the slope sections RBS9 and RBS13 are stable only in static-dry condition whereas these sections become unstable even in static condition when the slopes become fully saturated.

The slopes at sections LBS1, LBS2 and LBS3 on the left bank are stable in dry condition both in static and seismic .situations (Table 7.5). However, these slopes are unstable in saturated condition for both in static and seismic situations. This warrants the provision of cable anchors for their stabilization.

Table 7.4 Stability Analysis of Debris Slopes along Right Bank using "SARC"

S. No.	Slope Section	Program File Name	Slope Angle (°)	Slope Height (m)	Slope Condition	C (t/m2)	Φ (°)	Unit Weight of Debris Mass (γ)	$\bar{B}$	F.O.S.		Dynamic Displacement (m)
										Static (α_h = 0.0)	Seismic (α_h = 0.1)	
1	RBS9	ORBS9	60^0/N104^0	45	DRY	0.0	40	1.7	0.0	1.047	0.681	0.310
					SAT	0.0	30	1.9	0.1	0.715	0.493	10.572
2	RBS13	ORBS13	25^0/N06^0	40	DRY	0.0	40	1.7	0.0	1.246	0.807	0.083
					SAT	0.0	30	1.9	0.1	0.857	0.583	10.572

Table 7.5 Stability Analysis of Debris Slopes along Left Bank using "SARC"

S. No.	Slope Section	Program File Name	Slope Angle (°)	Slope Height (m)	Slope Condition	C (t/m^2)	Φ (°)	Unit Weight of Rock Mass (γ)	$\bar{B}$	Factor of Safety		Dynamic Displacement (m)
										Static (α_h = 0.0)	Seismic (α_h = 0.1)	
1	LBS1	OLBS1	46^0/N280^0	58	DRY	10	30	1.7	0.0	1.688	1.381	0.0
					SAT	5	20	1.9	0.1	0.850	0.699	10.572
2	LBS2	OLBS2	45^0/N250^0	21	DRY	10	30	1.7	0.0	1.511	1.236	0.0
					SAT	5	20	1.9	0.1	0.770	0.631	10.572
3	LBS3	OLBS3	47^0/N244^0	70	DRY	10	30	1.7	0.0	1.549	1.266	0.0
					SAT	5	20	1.9	0.1	0.788	0.645	10.572

7.4.3 Remedial Measures

7.4.3.1 Right Bank

Slope Section: RBS9

The slope at section RBS9 is located near village Palam, 5.7 km d/s of zero bridge along the right bank of the reservoir. The slope below the road shows steep angles of slope of 60^0/N104^0 direction. For a height of about 45 m down, the road has been excavated within the debris. Further down, river borne materials (RBM) are present, where a private quarry is in operation at present. The excavated benches are encroaching fast towards the hill slope towards west. The thickness of the RBM is more than 35 m. The slope extends to a height beyond an elevation 672 m. The stability analyses have been carried out considering both the local slope above the road surface (El. 570.0 m) and the global or the overall slope up to its full height.

Table 7.4 shows that the overall slope is just stable under static dry condition with factor of safety 1.047 and unstable in static saturated condition with factor of safety 0.715. Under seismic conditions, the factor of safety works out to be 0.681 when the slope is dry. So the slope is unstable under seismic condition. The corresponding dynamic displacement has been found to be 0.310 m which is less than 1% of the height of the slope. However, when the seismic stability of the slope under saturated condition was checked, the factor of safety has been found to be 0.493 and the corresponding dynamic displacement was 10.572 m which is greater than 1% of the height of the slope. So the slope was found to be unsafe.

The analysis indicates that the slope is just stable under the existing conditions with reservoir water at the toe. However since the RBM is prone to internal erosion, the finer materials within RBM may get washed out under saturated condition. This actually causes local instability of the slope particularly at different cut slopes. Since the road is located more than 45m above MRL, the local failures sate not likely affect the road.

Slope Section: RBS13

The slope at section RBS13 is located near village Bandria 8.5 km d/s of zero bridge along the right bank of the reservoir. The slope below the road has debris cover for more than 40 m. Further down, river borne materials are present. Table 7.4 shows that the slope is safe under static dry condition with a factor of safety of 1.246 whereas in saturated condition, the factor of safety is 0.857. Under seismic conditions, the factor of safety has been found to be 0.807 when the slope is dry and 0.583 when the slope is saturated. The corresponding dynamic displacement values have been found to be 0.083 m (less than 1% of slope height) and 10.572 m for dry and saturated states of the slope respectively. The slope may therefore be treated as safe in seismic dry condition but unsafe in seismic saturated condition.

Since the RBM is prone to internal erosion, the finer materials within RBM may get washed out under saturation condition. This may lead to local instability of the slopes particularly at different cut slopes. Since the road is located more than 55m above MRL, the local failures are not likely affect the road.

7.4.3.2 Left Bank

Slope Section: LBS1

The slope at section LBS1 is located 250 m d/s of Zero Bridge along the left bank of the reservoir. It is presently one of the sites, where the excavated muck is being dumped down. The thickness of the muck at the bottom is reported to have reached about 30 - 40 m. The muck extends up to road level with a slope angle of more than 46˚ towards N280˚ direction. Once the reservoir is full, the maximum reservoir level (MRL) may extend up to a height of 20 - 25 m above the river bed level. Since the dumped muck is recent and is in a loose condition, the slope materials may become saturated due to rise of reservoir water level and create instability. This may lead to rotational failure of slope materials. Accordingly stability analysis of the dumped muck has been carried out using the computer program SARC with reservoir water at the toe.

The slope has been found to be safe under dry condition with factor of safety values of 1.688 and 1.381 under static and seismic conditions respectively. The corresponding values of factor of safety in saturated condition are 0.850 and 0.699 under static and seismic conditions. The dynamic displacement has been found to be 10.572 m when the slope is seismically saturated and this is more than 1% of the height of the slope.

The results indicate that the slope is unstable with reservoir water at the toe. The dumped muck may fail in rotational pattern bringing down the muck into the reservoir. This section is far away from the dam axis and hence any failure at this location should not b ea matter of serious concern.

Slope Section: LBS2

The slope at section LBS2 is located opposite to Marh Stream, 900 m d/s of Zero Bridge. Here also, the excavated muck is being dumped down which extends up to the road level with a slope angle nearly equal to 45˚ towards N250˚ direction. The slope materials may be highly saturated due to filling of reservoir up to MRL causing unstable conditions. This may lead to rotational failure of slope materials. Accordingly the computer program SARC is used for the stability analysis of the dumped muck with reservoir water at the toe. The slope has been found to be safe in dry condition with factor of safety values of 1.511 and 1.236 under static and seismic conditions respectively. The corresponding values of factor of safety in saturated condition are 0.770 and 0.631 under static and seismic conditions. The dynamic displacement has been found to be 10.572 m when the slope is seismically saturated. This is more than 1% of the height of the slope. So the slope is unstable in nature and during monsoon season the slope should closely watched. As the slope section is far away from the dam site, it is not likely to cause any danger to the dam.

Slope Section: LBS3

The slope at section LBS3 is located near Chopra village, 1.5 km d/s of Zero Bridge along the left bank of the reservoir. It is located on the other dumping site of muck, being present downstream of the earlier one. The dumped muck extends up to the road level with a fairly steep gradient of more than 40˚. Further above the road level, the old debris is present, on which agriculture is being practiced. The recent debris materials dumped below the road level are loose and are highly unconsolidated in nature.

When the reservoir rises to maximum reservoir level (MRL), the standing water may rise to a height of 20 - 25 m above the river bed. Since the dumped muck is recent and is in a loose condition, the slope materials may be highly saturated under draw down conditions causing instablity conditions. Accordingly stability analysis of the dumped muck has been carried out using the computer program SARC with reservoir water at the toe. The slope has been found to be safe under dry state with values of factor of safety as 1.549 and 1.266 under static and seismic conditions respectively. The corresponding values of factor of safety in saturated state are 0.788 and 0.645 for static and seismic conditions. The dynamic displacement has been found to be 10.572 m when the slope is seismically saturated. The appears therefore to be totally unsafe in saturated condition irrespective of whether seismicity is considered or not

The results indicate that the slope is unstable with reservoir water at the toe. The dumped muck may fail with rotational pattern bringing down the muck from above the reservoir water. This may lead to loss of a part of reservoir capacity in future. Though toe walls in the form of gabions are present close to river bed for a height of 4-6 m, the standing water at MRL will rise higher than the level of gabion walls. Once the slip circles are mobilized , these circles pass above the level of the gabions and cause the failures.

7.5 STABILITY ANALYSIS USING SOFTWARE : SAST

7.5.1 Overview of "SAST"

The computer program SAST has been used for the stability analysis of slopes with talus deposit (Singh and Goel, 2002). The program uses the following input parameters.

Z = average vertical depth of talus deposit

Z_W = vertical depth of ground water during the worst rainy season below the slope surface

Q = surcharge on the slope surface

α_h and α_v = horizontal and vertical seismic coefficients

EQM = corresponding magnitude of earthquake on Richter's scale, for the seismic zone

c and Φ = shear strength parameters of soil

γ = unit weight of soil

ψ = dip of slope face

EFFCY = efficiency of drains

The program uses these input parameters to calculate the factor of safety of the slope. With respect to Fig. 7.5, the expression for factors of safety are given by eqn. 7.3

$$F = \frac{C + \sigma \cdot \text{Tan}\Phi}{\tau_{mb}} \qquad (7.3)$$

where, τ_{mb} is the shear stress mobilized along the failure surface under the influence of the normal stress, σ.

Similarly as in case of SARC, here also for obtaining the factor of safety in static condition, αh and α_v should be used as 0, the value of Φ in saturated condition should be 2/3 of the value of Φ of dry condition and the value of C in saturated condition should be used half the value of C for dry state, the pore water pressure $\bar{B}$ remains 0 in dry condition and for saturated condition, the value of $\bar{B}$ should be used as 0.1 to estimate the factor of safety.

In seismic condition, the seismic coefficients, αh and α_v and the corresponding earthquake magnitude EQM should be used and other parameters like C and Φ should remain as used in case of static dry and static saturated conditions.

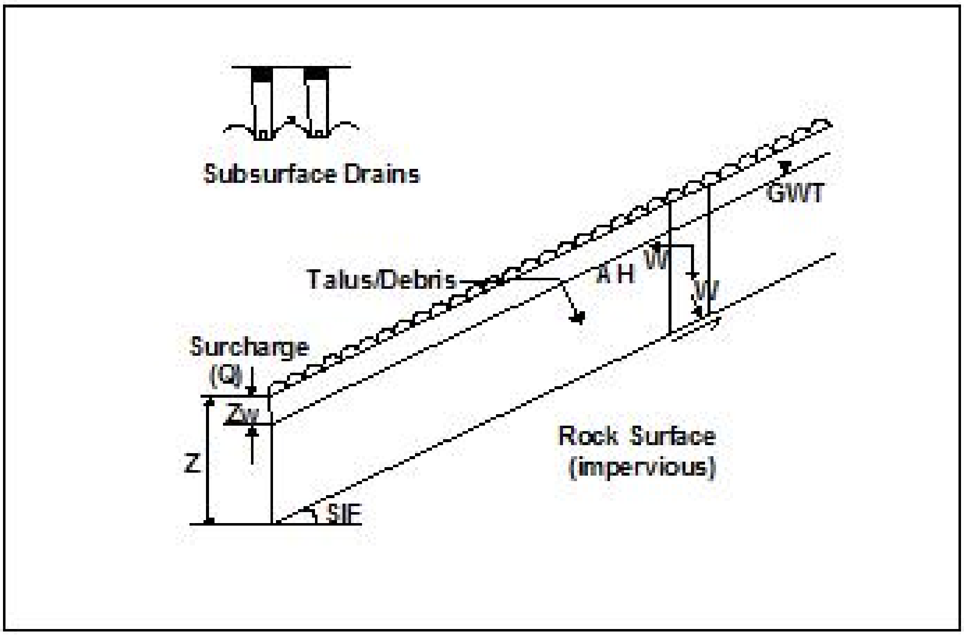


Fig. 7.5 Input variables for Stability Analysis of Talus Slopes (SAST)

7.5.2 Stability Analysis of Talus Slopes using "SAST"

The detail stability analysis of each talus slope, from the mechanics point of view, has been carried out using software SAST (Stability Analysis of Slope with Talus deposit). The talus slopes were analyzed for five different slope conditions. The output of the program includes factors of safety for the following five conditions.

i) No surcharge and earthquake, but dry, FS1

ii) With surcharge and water table, but no earthquake, FS2

iii) No surcharge and earthquake, but water table, FS3

iv) No surcharge, but with earthquake and dry, FS4

v) No surcharge, but with earthquake and water table, FS5

A typical input file of the programs SAST is presented in Appendix - VIII. Similarly, the output files, which include the results of stability analysis of various talus slopes, have been presented in Appendix - IX . Various talus slopes around the periphery of the reservoir which have been analyzed using the program SAST are listed below in Table 7.6. A summary of these analyses in terms of least factors of safety obtained for various slope conditions has been presented in Tables 7.7 and 7.8 for slopes along the two banks of the reservoir area respectively.

Table 7.6 Talus Slopes analyzed by using "SAST"

S. No.	Bank	Rock Slopes at Sections
1	Right	RBS2
2	Right	RBS4
3	Right	RBS5
4	Right	RBS6
5	Right	RBS7
6	Right	RBS11
7	Right	RBS15
8	Right	RBS16
9	Right	RBS17
10	Left	LBS4

In the reservoir area, slopes at sections RBS2 (near Marh Stream, 500 m d/s of Zero bridge), RBS4 (near Dobra village 2 km d/s of Zero bridge), RBS5 (2.3 km away from Zero bridge), RBS6 (2.7 km away from Zero bridge near Dharamghat village), RBS7 (3.2 km d/s of Zero bridge near Kyari village), RBS11 (7.2 km d/s of Zero bridge near Palam village), RBS15 (near Pendars village 14.5 d/s of Zero bridge), RBS16 (near dam axis 15.5 km d/s of Zero bridge), RBS17 (near Payalgaon 18 km d/s of Zero bridge) along the right bank and LBS4 (near Chopra village 2 km d/s of Zero Bridge) along the left bank are the talus slopes. Tables 7.7 and 7.8 give the values of least factors of safety obtained and suggest that the slope sections RBS4, RBS5, RBS6, RBS7, RBS11, RBS16, RBS17 and LBS4 are stable. The slopes at sections RBS2 and RBS15 are unstable in nature.

Table 7.7 Stability Analysis of Talus Slopes along Right Bank using "SAST"

S. No.	Slope Section	Program File Name	Slope Condition	Slope Angle (°)	Slope Height (m)	Thickness of Talus (m)	Rock Mass Condition				γ (t/m^3)		$\bar{B}$	α_h	F.O.S.	Dynamic Displacement (m)
							Dry		Sat							
							C (t/m2)	Φ (°)	C (t/m2)	Φ (°)	Dry	Sat				
1	RBS2	ORBS2	**FS1**-No surcharge & EQ but Dry (Static, Dry)	40^0/N 100^0	100	8.0	1.870	32	0.935	21	1.7	1.9	0.0 (Dry)	0.0 (Static)	1.024	0.0
			FS2-With surcharge & WT but no EQ (Static, No Q, Sat.)													
			FS3-No surcharge & EQ but WT (Static, No Q, Sat.)												0.582	0.0
			FS4-No surcharge with EQ & Dry (Seismic, Dry)										0.1(Sat)	0.10 (Seismic)	0.864	0.26
			FS5-No surcharge with EQ & WT [Worst] (Seismic, Sat)												0.487	10.57

S. No.	Slope Section	Program File Name	Slope Condition	Slope Angle (°)	Slope Height (m)	Thickness of Talus (m)	Rock Mass Condition				γ (t/m^3)		$\bar{B}$	α_h	F.O.S.	Dynamic Displacement (m)
							Dry		Sat							
							C (t/m2)	Φ (°)	C (t/m2)	Φ (°)	Dry	Sat				
2	RBS4	ORBS4	**FS1**-No surcharge & EQ but Dry (Static, Dry)	32^0/N90^0	65	5	1.87	32	0.935	21	1.7	1.9	0.0 (Dry)	0.0 (Static)	1.770	0.0
			FS2-With surcharge & WT but no EQ (Static, No Q, Sat.)													
			FS3-No surcharge & EQ but WT (Static, No Q, Sat.)												0.997	0.0
			FS4-No surcharge with EQ & Dry (Seismic, Dry)										0.1 (Sat)	0.10 (Seismic)	1.436	0.0
			FS5-No surcharge with EQ & WT [Worst] (Seismic, Sat)												0.803	10.57

S. No.	Slope Section	Program File Name	Slope Condition	Slope Angle (°)	Slope Height (m)	Thickness of Talus (m)	Rock Mass Condition				γ (t/m³)		[illegible]	α_h	F.O.S.	Dynamic Displacement (m)
							Dry		Sat							
							C (t/m2)	Φ (°)	C (t/m2)	Φ (°)	Dry	Sat				
3	RBS5	ORBS5	**FS1**-No surcharge & EQ but Dry (Static, Dry)	32^0/N100^0	45	5	1.870	32	0.935	21	1.7	1.9	0.0 (Dry)	0.0 (Static)	1.408	0.0
			FS2-With surcharge & WT but no EQ (Static, No Q, Sat.)													
			FS3-No surcharge & EQ but WT (Static, No Q, Sat.)												0.797	0.0
			FS4-No surcharge with EQ & Dry (Seismic, Dry)										0.1 (Sat)	0.10 (Seismic)	1.167	0.0
			FS5-No surcharge with EQ & WT [Worst] (Seismic, Sat)												0.656	10.57

S. No.	Slope Section	Program File Name	Slope Condition	Slope Angle (°)	Slope Height (m)	Thickness of Talus (m)	Rock Mass Condition				γ (t/m^3)		[illegible]	$α_h$	F.O.S.	Dynamic Displacement (m)
							Dry		Sat							
							C (t/m2)	Φ (°)	C (t/m2)	Φ (°)	Dry	Sat				
4	RBS6	ORBS6	**FS1**-No surcharge & EQ but Dry (Static, Dry)	45^0/N90^0	50	8	1.870	32	0.935	21	1.7	1.9	0.0 (Dry)	0.0 (Static)	1.400	0.0
			FS2-With surcharge & WT but no EQ (Static, No Q, Sat.)													
			FS3-No surcharge & EQ but WT (Static, No Q, Sat.)												0.807	0.0
			FS4-No surcharge with EQ & Dry (Seismic, Dry)										0.1 (Sat)	0.10 (Seismic)	1.142	0.0
			FS5-No surcharge with EQ & WT [Worst] (Seismic, Sat)												0.655	10.57

S. No.	Slope Section	Program File Name	Slope Condition	Slope Angle (°)	Slope Height (m)	Thickness of Talus (m)	Rock Mass Condition				γ (t/m^3)		$\bar{B}$	α_h	F.O.S.	Dynamic Displacement (m)
							Dry		Sat							
							C (t/m2)	Φ(°)	C (t/m2)	Φ(°)	Dry	Sat				
5	RBS7	ORBS7	**FS1**-No surcharge & EQ but Dry (Static, Dry)	20^0/N90^0	50	8	1.870	32	0.935	21	1.7	1.9	0.0 (Dry)	0.0 (Static)	2.287	0.0
			FS2-With surcharge & WT but no EQ (Static, No Q, Sat.)													
			FS3-No surcharge & EQ but WT (Static, No Q, Sat.)												1.310	0.0
			FS4-No surcharge with EQ & Dry (Seismic, Dry)										0.1 (Sat)	0.10 (Seismic)	1.746	0.0
			FS5-No surcharge with EQ & WT [Worst] (Seismic, Sat)												0.995	0.0

S. No.	Slope Section	Program File Name	Slope Condition	Slope Angle (°)	Slope Height (m)	Thickness of Talus (m)	Rock Mass Condition: Dry C (t/m2)	Rock Mass Condition: Dry Φ(°)	Rock Mass Condition: Sat C (t/m2)	Rock Mass Condition: Sat Φ(°)	γ (t/m³) Dry	γ (t/m³) Sat	$\bar{B}$	α_h	F.O.S.	Dynamic Displacement (m)
6	RBS11	ORBS11	**FS1**-No surcharge & EQ but Dry (Static, Dry)	40^0/N149^0	90	6	1.870	32	0.935	21	1.7	1.9	0.0 (Dry)	0.0 (Static)	1.393	0.0
			FS2-With surcharge & WT but no EQ (Static, No Q, Sat.)													
			FS3-No surcharge & EQ but WT (Static, No Q, Sat.)												0.653	0.0
			FS4-No surcharge with EQ & Dry (Seismic, Dry)										0.1 (Sat)	0.10 (Seismic)	1.177	0.0
			FS5-No surcharge with EQ & WT [Worst] (Seismic, Sat)												0.537	0.0

S. No.	Slope Section	Program File Name	Slope Condition	Slope Angle (°)	Slope Height (m)	Thickness of Talus (m)	Rock Mass Condition: Dry C (t/m2)	Dry Φ(°)	Sat C (t/m2)	Sat Φ(°)	γ (t/m³) Dry	γ (t/m³) Sat	B̄	α_h	F.O.S.	Dynamic Displacement (m)
7	RBS15	ORBS15	**FS1**-No surcharge & EQ but Dry (Static, Dry)	70^0/N17^0	100	15	1.870	32	0.935	21	1.7	1.9	0.0 (Dry)	0.0 (Static)	0.865	0.0
			FS2-With surcharge & WT but no EQ (Static, No Q, Sat.)													
			FS3-No surcharge & EQ but WT (Static, No Q, Sat.)												0.242	0.0
			FS4-No surcharge with EQ & Dry (Seismic, Dry)										0.1 (Sat)	0.10 (Seismic)	0.793	10.57
			FS5-No surcharge with EQ & WT [Worst] (Seismic, Sat)												0.199	10.57

S. No.	Slope Section	Program File Name	Slope Condition	Slope Angle (°)	Slope Height (m)	Thickness of Talus (m)	Rock Mass Condition: Dry C (t/m2)	Rock Mass Condition: Dry Φ(°)	Rock Mass Condition: Sat C (t/m2)	Rock Mass Condition: Sat Φ(°)	γ (t/m^3) Dry	γ (t/m^3) Sat	$\bar{B}$	α_h	F.O.S.	Dynamic Displacement (m)
8	RBS16	ORBS16	**FS1**-No surcharge & EQ but Dry (Static, Dry)	31^0/N343^0	35	8	1.870	32	0.935	21	1.7	1.9	0.0 (Dry)	0.0 (Static)	1.351	0.0
			FS2-With surcharge & WT but no EQ (Static, No Q, Sat.)													
			FS3-No surcharge & EQ but WT (Static, No Q, Sat.)												0.778	0.0
			FS4-No surcharge with EQ & Dry (Seismic, Dry)										0.1 (Sat)	0.10 (Seismic)	1.108	0.0
			FS5-No surcharge with EQ & WT [Worst] (Seismic, Sat)												0.634	10.57

S. No.	Slope Section	Program File Name	Slope Condition	Slope Angle (°)	Slope Height (m)	Thickness of Talus (m)	Rock Mass Condition				γ (t/m³)		B̄	α_h	F.O.S.	Dynamic Displacement (m)
							Dry		Sat							
							Φ(°)	C (t/m2)	Φ(°)	C (t/m2)	Dry	Sat				
9	RBS17	ORBS17	**FS1**-No surcharge & EQ but Dry (Static, Dry)	28^0/N73^0	130	12	1.870	32	0.935	21	1.7	1.9	0.0 (Dry)	0.0 (Static)	1.396	0.0
			FS2-With surcharge & WT but no EQ (Static, No Q, Sat.)													
			FS3-No surcharge & EQ but WT (Static, No Q, Sat.)												0.821	0.0
			FS4-No surcharge with EQ & Dry (Seismic, Dry)										0.1 (Sat)	0.10 (Seismic)	1.120	0.0
			FS5-No surcharge with EQ & WT [Worst] (Seismic, Sat)												0.656	10.57

Table 7.8 Stability Analysis of Talus Slopes along Left Bank using "SAST"

S. No.	Slope Section	Program File Name	Slope Condition	Slope Angle (°)	Slope Height (m)	Thickness of Talus (m)	Rock Mass Condition				γ (t/m^3)		$\bar{B}$	α_h	F.O.S.	Dynamic Displacement (m)
							Dry		Sat							
							C (t/m2)	Φ (°)	C (t/m2)	Φ (°)	Dry	Sat				
1	LBS4	OLBS4	**FS1**-No surcharge & EQ but Dry (Static, Dry)	38^0/N261^0	50	5	1.870	32	0.935	21	1.7	1.9	0.0 (Dry)	0.0 (Static)	1.253	0.0
			FS2-With surcharge & WT but no EQ (Static, No Q, Sat.)													
			FS3-No surcharge & EQ but WT (Static, No Q, Sat.)												0.694	0.0
			FS4-No surcharge with EQ & Dry (Seismic, Dry)										0.1 (Sat)	0.10 (Seismic)	1.068	0.0
			FS5-No surcharge with EQ & WT [Worst] (Seismic, Sat)												0.586	10.57

7.5.3 Remedial Measures

The input parameters and the results of stability analyses of all the debris/ talus slopes along with the suggested remedial measures are presented in Appendix - IX . The values of the factors of safety of these sections are summarized in Tables 7.7 and 7.8.

7.5.3.1 Right Bank

Slope Section: RBS2

The slope at section RBS2 is located near Marh Stream, 500 m d/s of Zero bridge along the right bank of the reservoir. The slope has been found to be just stable under static dry condition. In static saturated condition, the factor of safety is found to be 0.582. In seismic condition, the factors of safety have been found to be 0.864 and 0.487 in dry and saturated conditions respectively. The corresponding dynamic displacements are about 0.26 m and 10.57 m. The dynamic displacement in case of seismic dry as well as saturated condition is less than 1% of the slope height which is 100 m. Therefore the slope is treated as just stable seismically.

The analysis indicates that the slope is just stable under static dry condition (FoS > 1). The values of Factor of safety becomes less than unity when the slope is saturated with water. Since the elevation difference between MRL and the road is less than 15 m, the chances of sinking of the road exists under saturated condition with reservoir water close to MRL.

Slope Section: RBS4

Slope section RBS4 is located near Dobra village 2 km d/s of Zero bridge along the right bank of the reservoir. The analysis indicates that the slope is stable under dry conditions (FoS > 1) as the factors of safety have been found 1.770 and 1.436 statically and seismically. The values of factor of safety become less than unity when the slope is saturated with water in both static and seismic condition. The dynamic displacement obtained in seismic saturated condition is 10.57 m, i.e. 0.01 mm which is far less than 1% of the slope height which is 65 m. Since the elevation difference between MRL and the road is about 30m, the local instability close to MRL may not extend up to affect the stability of the road under draw down conditions. However probability of slope instability reaching up to the road cannot be ruled out. It is worth providing a 5.0 m high

Gabion wall in the form of a toe wall at the toe of the talus slope for giving protection to the toe and arrest the sliding of the slope mass.

Slope Section: RBS5

The slope at section RBS5 is located at 2.3 km away from Zero bridge along the right bank of the reservoir. The factor of safety in dry condition has been found to be 1.408 under static condition and 1.167 in seismic condition. The values of factor of safety become less than unity when the slope is saturated in both static and seismic conditions. The corresponding values of factor of safety are 0.797 and 0.656 respectively. The dynamic displacement obtained in seismic saturated condition is 10.57 m, which is more than 1% of the slope height (which is 45 m) and hence unstable.

The analysis indicates that the slope is just stable under dry conditions (FoS > 1). The values of factor of safety become less than unity when the slope is highly saturated with reservoir levels rising up to MRL. However, the failure may be local in nature. Since the elevation difference between MRL and the road is about 25 m, the local instability close to MRL may not extend up to the road level. Here also, it would be useful to provide toe protection in the form of a 5.0 m high gabion wall to arrest the sliding of the slope mass.

Slope Section: RBS6

The slope at section RBS6 is located 2.7 km away from Zero bridge near Dharamghat village along the right bank of the reservoir. The factors of safety in dry condition have been found to be 1.400 and 1.142 in static and seismic conditions. The values of factor of safety in both static and seismic conditions become less than unity when the slope is saturated. Respective values of factors of safety are 0.807 and 0.655. The dynamic displacement obtained in seismic saturated condition is 10.57 m, i.e. 0.01 mm which is far more than 1% of the slope height which is 50 m. The slope is therefore unsafe in seismic condition.

Since the slope mass is not going to be affected by rise of water level up to MRL, the slope may not attain completely saturated conditions. Hence the slope may be treated as stable.

Slope Section: RBS7

Slope section RBS7 is located 3.2 km d/s of Zero bridge near Kyari village along the right bank of the reservoir having a height of 50 m. The factors of safety, when the slope mass is dry, are 2.287 and 1.746 in static and seismic conditions respectively. These become less than unity when the slope is saturated-seismic condition. The values of factor of safety in saturation state are 1.310 and 0.995 in static and seismic conditions respectively.

The analysis indicates that the slope is stable under dry conditions (FoS > 2). The slope may remain stable under static saturated condition. However since the toe of the talus would be just submerged due to rise of water up to MRL, the erosion may cause local failures, which may not affect the road in any way as is located about 25 m above MRL . It is therefore suggested that toe protection in the form of a 5.0 m high gabion toe wall must be provided.

Slope Section: RBS11

Slope section RBS11 is located 7.2 km d/s of Zero bridge near Palam village along the right bank of the reservoir. The height of the slope is 90 m. The factor of safety in static dry state has been found to be 1.393 and 1.177 in seismic state. These become less than unity both in static and seismic conditions when the slope becomes saturated up to its mid-height due to reservoir filling up to MRL. These factors of safety are 0.653 and 0.537 respectively.

The analysis suggests that the slope is just stable under dry conditions (FoS > 1). The slope remain unstable under saturated conditions. However due to reservoir filling up to MRL, the talus material lying below reservoir water may undergo erosion, causing local failures. Since the road is located more than 53 m above MRL, the drawdown conditions may not affect the road. However, since the slope angle is fairly high and the thickness of the materials is almost 10 m – 15 m, continuous toe failure in lower levels may get propagated and this may result in minor sinking of the road. This situation can be overcome by constructing a series of gabion walls, each 5 m high, between El. 580 m and El. 600 m.

Slope Section: RBS15

The slope at section RBS15 is located near Pendars village 14.5 d/s of Zero bridge along the right bank of the reservoir. The height of the slope is 100 m. The factors of safety have been found to be 0.865 and 0.793 in static-dry and seismic-dry conditions. These values become 0.242 and 0.199 in static and seismic conditions respectively when the slope mass attains saturation. The dynamic displacement obtained in dry and saturated conditions has been found to be 10.57 m, which is little over 1% of the slope height which is 100 m.

Though the slope has very less factor of safety (FoS < 0.9) indicating the slope is already a failed slope. However, the slope is stable at site due to extremely high cementation present in the slope amss. However, once the reservoir is filled up to MRL, it will touch just the toe of the steep slope. Then the seepage water may lubricate the materials, erode the delicate bonding of the cement between the particles and cause the failure of the slope. Under such a condition, the stability of road will be seriously affected. The Administrative building also may also be affected.

Slope Section: RBS16

Slope section RBS16 is 85 m high and is located near the dam axis and is 15.5 km d/s of Zero bridge along the right bank of the reservoir. The static and seismic factors of safety in dry condition have been found to be 1.351 and 1.108 respectively. When the slope mass becomes saturated due to rise of reservoir level up to MRL, the corresponding factors of safety reduce to 0.778 and 0.634 respectively. This gives rise to dynamic displacement seismic-saturated condition of 10.57 m, which is much more than 1% of the slope height which is 35 m. Hence the slope is unstable in seismic case.

The slope remains unstable under saturated conditions. the talus material lying below reservoir water may undergo erosion, causing local failures. Since the road is located just 10-12m above MRL, the drawdown conditions may affect the stability of the road as it is located on the talus itself.

Slope Section: RBS17

The slope at section RBS17 is also located near the dam axis and near Payalgaon, 18 km d/s of Zero bridge along the right bank of the reservoir. The factors of safety in dry condition have been found to be 1.396 and 1.120 respectively in static and seismic conditions. The corresponding values in static and seismic conditions are 0.821 and 0.656 respectively. The dynamic displacement obtained in seismic saturated condition is 10.57 m, which is far more than 1% of the slope height (130 m). Hence, the slope is totally unstable.

The analysis indicates that the slope is just stable under dry conditions and totally unstable upon saturation. The talus material lying below the reservoir water may undergo erosion, almost half the slope mass would be submerged under water, causing major failure. Since a local road is located about 25m above MRL, the submergence may cause sinking of the road as it is located within the talus. However, the main road is located another about 25 m above the lower road and this too may suffer damage due to the reservoir functioning. A series of gabions, each 5.0 m high, can be constructed along the slope between El. 580.0 m and 615 m which alone can provide enough toe protection and the protection to the two roads.

7.5.3.2 Left Bank

Slope Section: LBS4

The slope at section LBS4 is located near Chopra village 2 km d/s of Zero Bridge along the left bank of the reservoir. The height of the slope having talus material is about 50 m and the thickness of talus on it is about 5.0 m.. There is thick vegetation on this slope. Its stability analysis indicates that the slope becomes unstable when it gets either partly or fully saturated; the corresponding values of factor of safety being 0.694. In seismic condition when partly saturated, the factor of safety works out to be 0.586. The corresponding dynamic displacement has been found to be 10.57 m which is much more than 1% of the height of the slope. Therefore the slope is unstable in nature.

7.5.4 Critical Remarks

The analysis of various slopes along the right and the left banks of the reservoir suggest in general that even though the slopes at various sections appear to be stable in static-dry condition, they become unstable due to submergence. The stability is further adversely affected in seismic situation. For all those slope sections which are close to the dam body, stabilization / protection measures are suggested. These measures may not be undertaken in case of sections which are far away from the dam axis. In case of such sections, even if a major landslide occurs, the waves generated may generate waves, which will die down before these reach the dam body.

CHAPTER – VIII

STABILITY ANALYSIS OF ROCK SLOPES USING LIMIT EQUILIBRIUM METHOD

8.1 STABILITY ANALYSIS OF ROCK SLOPES USING LIMIT EQUILIBRIUM APPROACH

The limit equilibrium method (LEM) is a widely used approach by engineers and researchers for two dimensional slope stability analyses which is a traditional and well established method. It is well-known to be a statically indeterminate problem and assumptions on the internal force distribution are required to evaluate the factor of safety (Bishop, 1955).

In case of fully joint-controlled mechanisms, slope failure is due to block movements fully limited by geological discontinuities, whereas geometry and joint shear strength are the key parameters in the analysis. Provided the assumptions are true, the limit equilibrium method is enough to obtain reliable results (Viladkar et al., 2010).

8.2 STABILITY ANALYSIS OF ROCK SLOPES USING FRICTION ONLY

In the present study, the LEM approach is considered using friction only. A rapid check can be made for the stability of a wedge if the slope is drained and there is zero cohesion on both the slide planes A (flatter) and B (steeper). The factor of safety for such a case is given by (Hoek and Bray, 1981) as -

$$FOS = (A \tan \Phi_A + B \tan \Phi_B) \tag{8.1}$$

where A and B are the dimensionless factors which depend upon the dip and dip direction of the two planes (Fig. 8.1). Values of these two factors have been computed for different slopes with different dips and dip directions, and the factors of safety have been computed. The summary of these results is presented in Table 8.1. It may be noted that these values of factors of safety are only suggestive of the vulnerability of rock slopes and these are not the final values of the factors of safety.

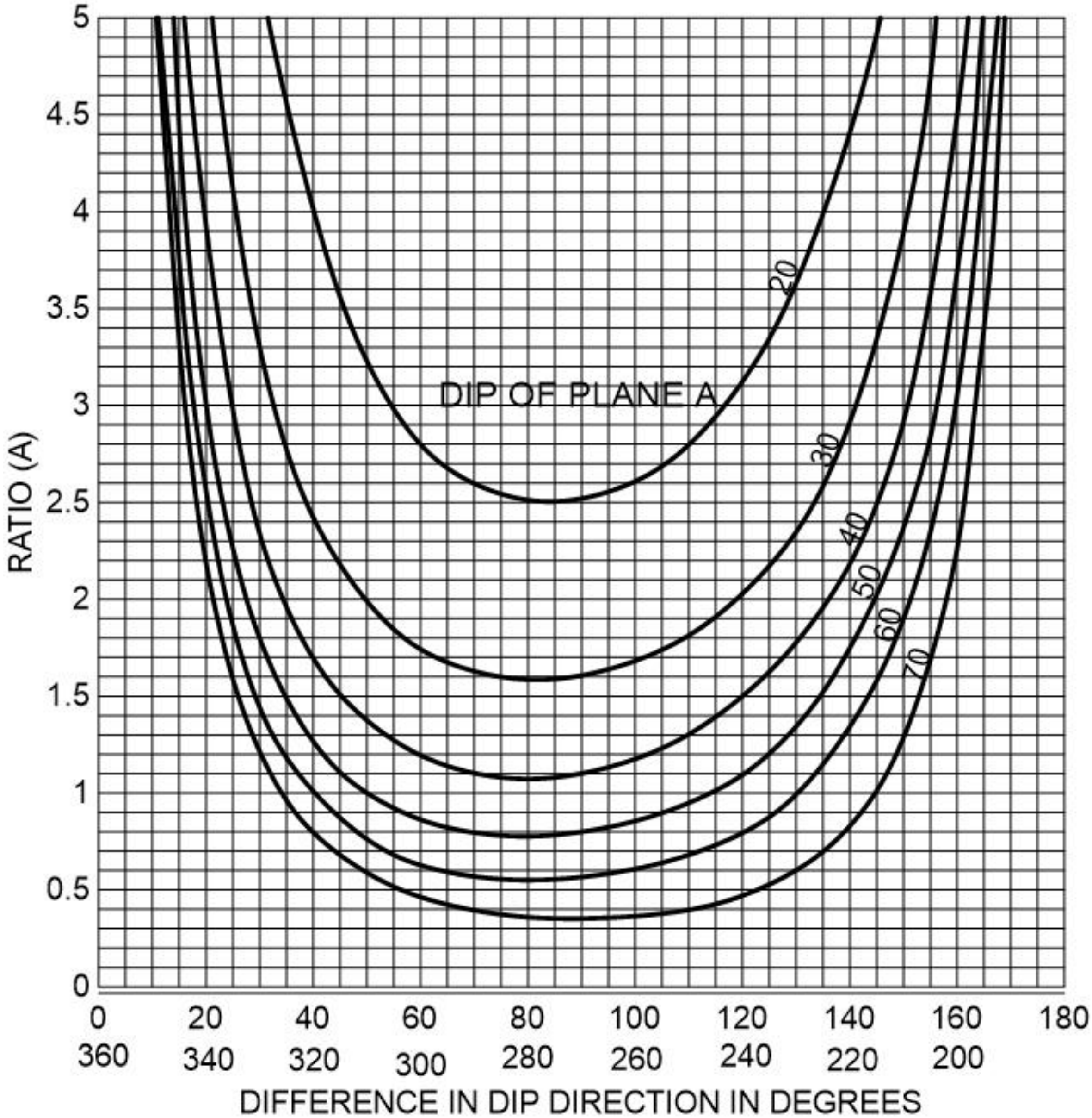


Fig. 8.1 A- Chart- Dip Differences 10 degrees (after Hoek and Bray, 1981)

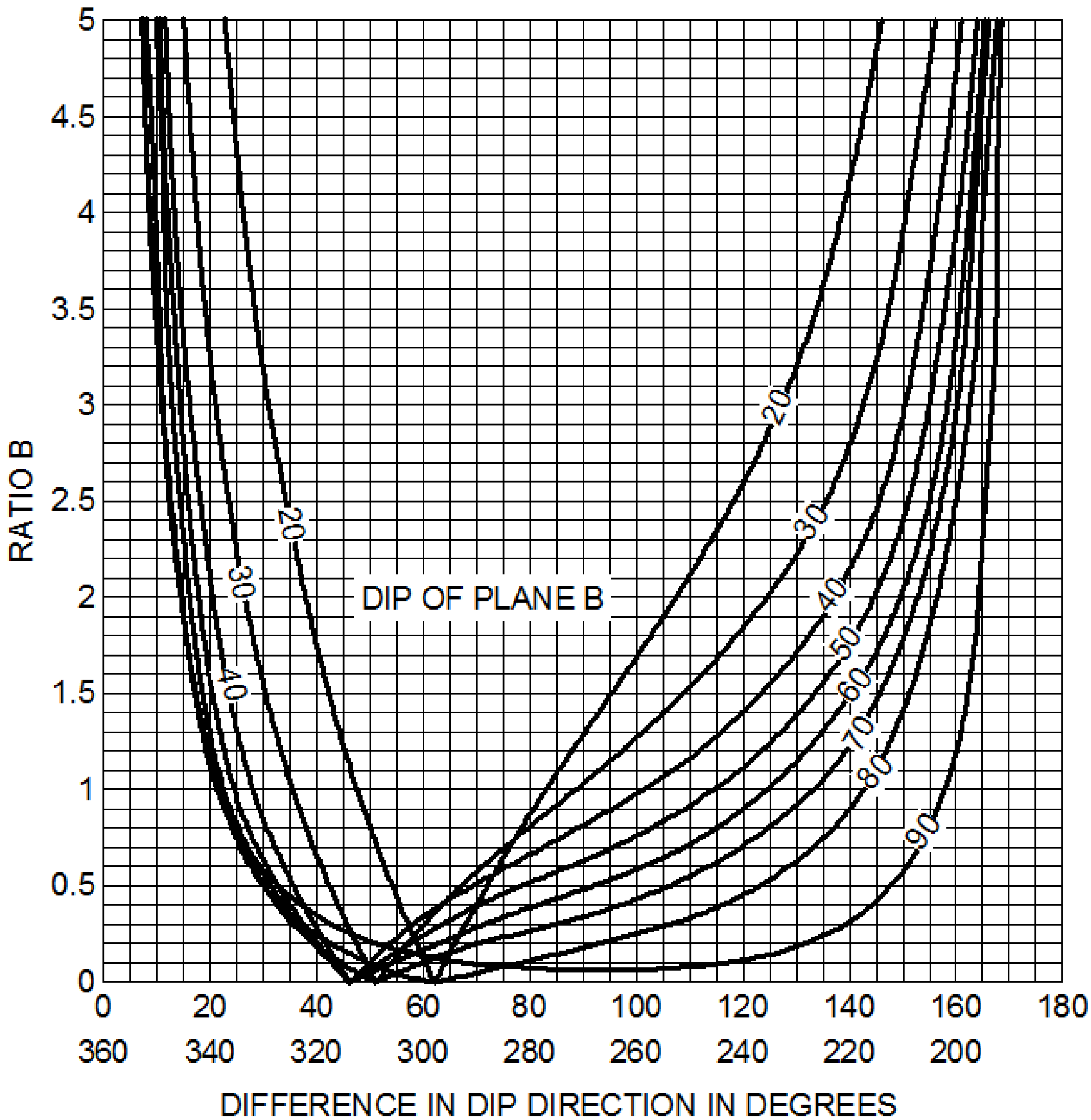


Fig. 8.2 B- Chart- Dip Differences 10 degrees (after Hoek and Bray, 1981)

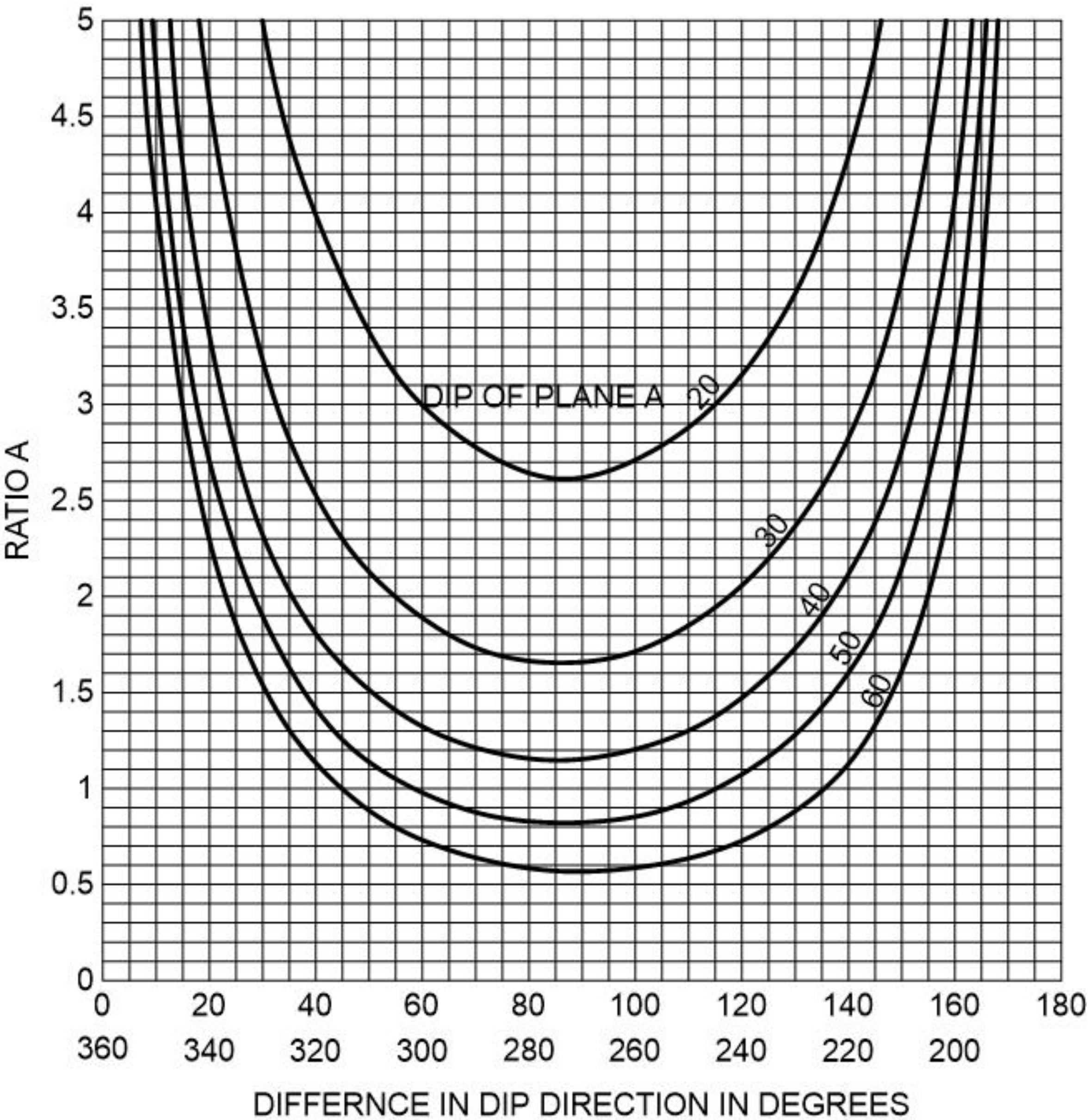


Fig. 8.3 A- Chart- Dip Differences 30 degrees (after Hoek and Bray, 1981)

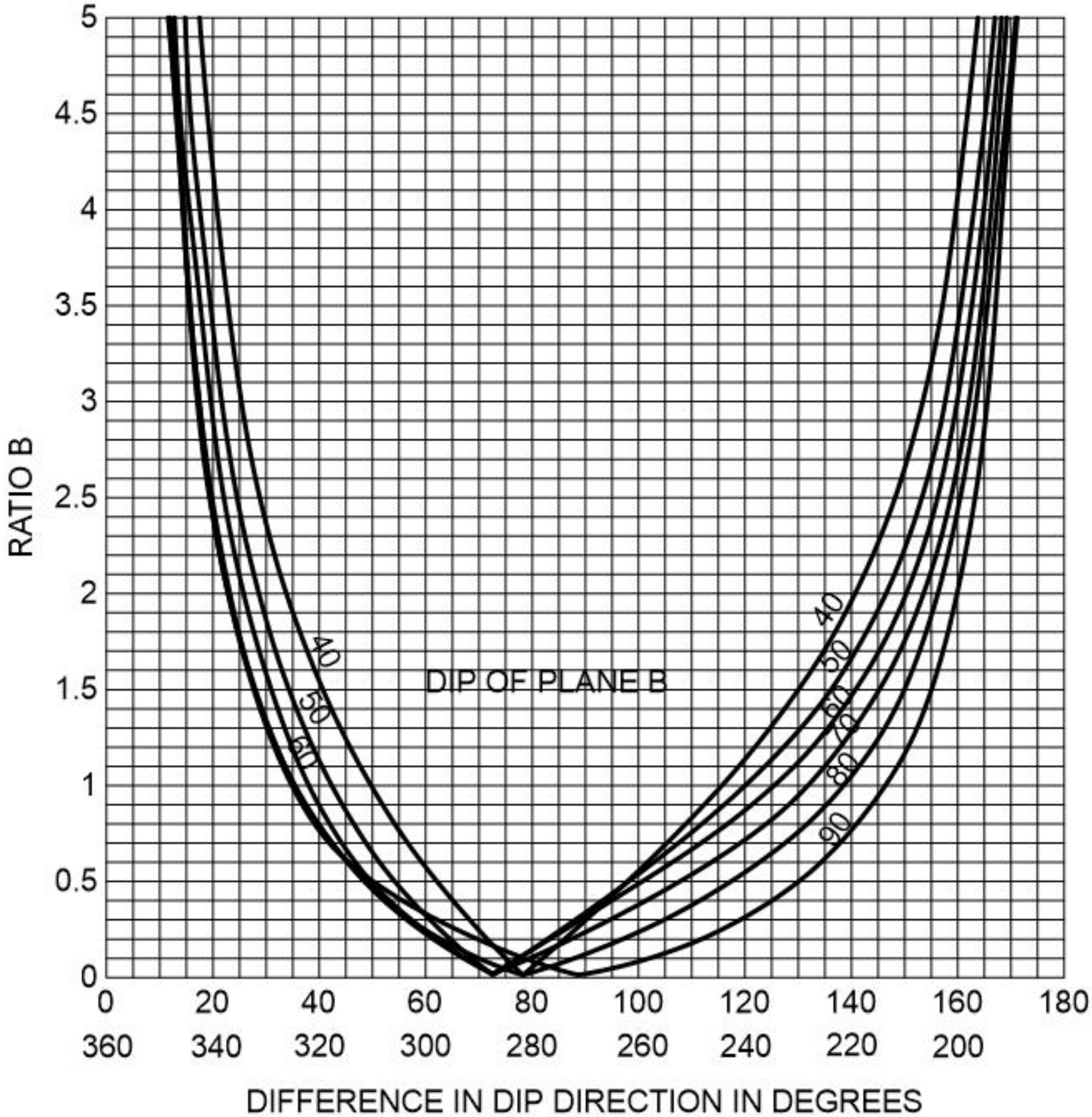


Fig. 8.4 B- Chart- Dip Differences 30 degrees (after Hoek and Bray, 1981)

Table 8.1 Summary of Analysis using Friction only Stability Charts

S. No.	Slope Section	Joints Forming Wedge	A	B	Factor of Safety
1	RBS8	J1, J2	1.7	2.2	4.460
2	RBS10	J1, J2	0.8	0.8	0.738
3	RBS14	J1, J2	1.2	0.4	0.923

It can be seen from this Table 8.1 that slope RBS8 is quite stable whereas both the slopes RBS10 and RBS14 are unstable as the factor of safety is less than one in both the cases.

8.3 STABILITY ANALYSIS OF ROCK SLOPES USING SOFTWARE "SASP"

The software "SASP" (Singh and Goel, 2002) is meant for the stability analysis of reservoir slopes with planar failure and toe cutting and is based on the Barton and Bandis (1990) theory of shear strength of joints. The computer program also designs the rock anchor system.

8.3.1 Overview of "SASP"

A theory of design of rock anchor system was suggested by Hoek and Bray (1981). Based on this theory, the software SASP (Stability analysis of rock slope with planar slide) was developed. Hence, it is recommended that all the anchor bars are of the same length to avoid the problem of supervision during construction. The input variables for the program SASP are given below (Fig. 8.2) and also described in Appendix - X.

ZW = Depth of Water In Tension Crack

Z_C = Depth of Tension Crack (If 0 , Program Will Calculate It)

FAL= Fixed Anchor Length

P = Safe Anchor Capacity

THETA= Angle of Anchor with respect to Normal of Joint Plane

T = Normal Force

H = Height of Slope

SIF = Slope Angle

SIP = Dip of Joint Plane

GAMA = Unit Weight of Rock Mass

GAMAW = Unit Weight of Water

C = Cohesion

Φ = Residual Sliding Angle of Friction

$\bar{B}$ = Bishop's pore pressure parameter

α_h = Horizontal seismic coefficient

α_v = Vertical seismic coefficient

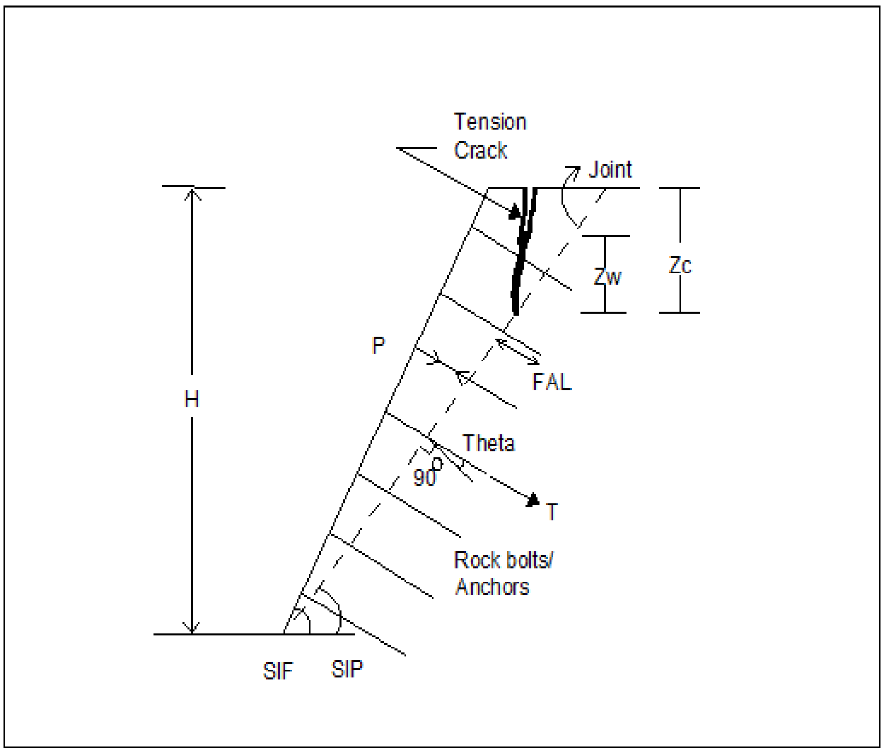


Fig. 8.5 Input variables for Stability Analysis of Rock Slopes with Planar Wedge Failure (SASP)

The software SASP is based on the theory of the shear strength of joints (Barton and Bandis, 1990). However it is assumed that $\Phi j \leq 45^0$ in joints which are weathered in nature. The drawback of Hoek and Bray (1981) theory is that the depth of tension crack (Zc) is predicted to be equal to the height of slope (H) where the slope angle is vertical". In nature, Zc < 2H/3. The above mentioned checks are included in SASP.

The detail stability analysis of each rock slope has been carried out, from the mechanics point of view, using software SASP (Stability Analysis of Planar Slides). The rock slopes were analyzed for four different slope conditions:

i) Dry slope, static analysis
ii) Saturated slope, static analysis
iii) Dry slope, seismic analysis, and
iv) Saturated slope, seismic analysis.

The rock joints in-situ were found to be tight or fairly tight joints indicating that the bond between joint wall surfaces was quite strong and therefore it was expected that cohesion (c) would reduce by about 50% upon saturation as compared to cohesion in dry condition. In the same manner angle of friction (Φ) would reduce to about 2/3 of the original value.

With respect to Fig. 8.2 and on basis of limit equilibrium approach, the expressions for the factors of safety are given by Eq. 8.2, 8.3, 8.4 and 8.5 for static analysis with dry slope, static analysis with saturated slope, seismic analysis with dry slope, and seismic analysis with saturated slope respectively.

$$FOS = (C.A + W \cos \psi_P \, . \tan \Phi) / W \sin \psi_P \tag{8.2}$$

$$FOS = (C.A + W \cos \psi_P - U_1 \sin \psi_P - U_2 + T \sin \Theta) / (W \sin \psi_P + U_1 \cos \psi_P - T \cos \Theta) \tag{8.3}$$

where, $A = H - Z_c \operatorname{Cosec} \psi_P$,

$U_1 = 1/2 \; (\gamma_w Z_W^2)$

$U_2 = 1/2 \; (\gamma_w Z_W)(H - Z_c) \operatorname{Cosec} \psi_P$

$$FOS = \frac{W \cos(\psi_P + \Theta) \tan \Phi - \{U_1 (\sin \psi_P + U_2) \tan \Phi - C\} / k}{W \sin(\psi_P + \Theta) + (U_1 \cos \psi_P) / k} \tag{8.4}$$

where, $k = \sqrt{\{A_H^{\,2} + (1 + Av)^2\}}$

$$FOS = \frac{C.A + \{W(\cos \psi_P - A_H \sin \psi_P) - U_1 \sin \psi_P - U_2 + T \cos \Theta + qB \cos \psi_P\} \tan \Phi}{W(\sin \psi_P + A_H \cos \psi_P) + U_1 \cos \psi_P - \sin \Theta + qB \sin \psi_P} \tag{8.5}$$

where, qB = surcharge placed at the top of the slope B subjected to horizontal seismic force

8.3.2 Stability Analysis of Rock Slopes using "SASP"

The output files, which include the results of stability analysis, have been presented in Appendix - XI. Various rock slopes around the periphery of the reservoir which have been analyzed using the program SASP are listed below in Table 8.2. In the reservoir area, slope at section LBS5 (near Bhashon village just above the old girder bridge) along the left bank and slopes at sections RBS1 (near zero bridge), RBS3 (d/s of newly constructed pumping unit), RBS4 (u/s of graveyard), RBS6 (near Kyari village), RBS12 (d/s of new iron bridge), and RBS15 (near THDCIL admin. building) along the right bank, are the rock slopes analysed.

Table 8.2 Rock Slopes Analyzed by using "SASP"

S. No.	Reservoir Bank	Rock Slopes
1	Right	RBS1
2	Right	RBS3
3	Right	RBS4
4	Right	RBS6
5	Right	RBS12
6	Right	RBS15
7	Left	LBS5

A summary of these analyses in terms of least factors of safety obtained for various slope conditions has been presented in Tables 8.3 and 8.4 respectively for slopes in right bank and in left bank of the reservoir area. Discussion regarding the stability aspects of various slopes has been included as part of the remedial measures in art. 8.3.3.

Table 8.3 Stability Analysis of Rock Slopes along Right Bank using SASP (Planar Mode of Failure)

S. No.	Slope Section	Program File Name	Slope Angle (°)	Slope Height (m)	RMR_{Basic}	RMR_{Adj}	SMR	Rock Mass Class	Slope Condition	C (t/m2)	Φ (°)	Unit Weight of Rock Mass (γ)	$\bar{B}$	α_h	F.O.S.		Dynamic Displacement (m)
															Static	Seismic	
1	RBS1	ORBS1	45/N125	80	68	43	76	Good	DRY	15	30	2.3	0.0	0.0	2.866	1.038	0.0
									SAT	7.5	20	2.4	0.1	0.10	1.479	0.505	1.008
2	RBS3	ORBS3	34/N64	80	72	47	77	Good	DRY	15	30	2.3	0.0	0.0	2.382	0.591	0.316
									SAT	7.5	20	2.4	0.1	0.10	1.279	0.306	105.732
3	RBS4	ORBS4	32/N90	80	68	43	70	Good	DRY	15	30	2.3	0.0	0.0	5.922	1.942	0.0
									SAT	7.5	20	2.4	0.1	0.10	3.009	0.957	0.023

……… contd.

S. No.	Slope Section	Program File Name	Slope Angle (°)	Slope Height (m)	RMR_{Basic}	RMR_{Adj}	SMR	Rock Mass Class	Slope Condition	C (t/m2)	Φ(°)	Unit Weight of Rock Mass (γ)	$\bar{B}$	α_h	F.O.S.		Dynamic Displacement (m)
															Static	Seismic	
4	RBS6	ORBS6	45/N90	90	65	40	66	Good	DRY	15	30	2.3	0.0	0.0	1.877	0.551	0.316
									SAT	7.5	20	2.4	0.1	0.10	1.000	0.276	105.73
5	RBS12	ORBS12	50/N150	60	70	45	63	Good	DRY	15	30	2.3	0.0	0.0	3.261	1.214	0.0
									SAT	7.5	20	2.4	0.1	0.10	1.673	0.590	0.507
6	RBS15	ORBS15	70/N17	40	59	35	43.35	Fair	DRY	15	30	2.3	0.0	0.0	1.954	0.637	0.386
									SAT	7.5	20	2.4	0.1	0.10	1.029	0.312	105.73

Table 8.4 Stability Analysis of Rock Slopes along Left Bank using "SASP"

S. No.	Slope Section	Program File Name	Slope Angle (°)	Slope Height (m)	RMR_{Basic}	RMR_{Adj}	SMR	Rock Mass Class	Slope Condition	C (t/m2)	Φ (°)	Unit Weight of Rock Mass (γ)	$\bar{B}$	α_h	FOS		Dynamic Displacement (m)
															Static	Seismic	
1	LBS5	OLBS5	45/N324	70	65	40	68.7	Good	DRY	15	30	2.3	0.0	0.0	1.878	0.497	0.582
									SAT	7.5	20	2.4	0.1	0.10	1.009	0.255	105.73

8.3.3 Remedial Measures

It is suggested in general that for all those slopes which are unstable and close to the dam axis, cable anchors be provided which will have the tendency to stitch the joints together and hence improve the stability of the slope.

8.3.3.1 Right bank

Slope Section: RBS1

The slope at section RBS1 is a moderate to steep (slope angle of 45^0) is located at about 200 m d/s of the Zero Bridge on the right bank of the reservoir. The stereo net shows the possibility of planar mode of failure. However, when the possibility of a planar slide is explored for the dry condition of the slope, it gives the factor of safety of 2.866 in static case and 1.038 in seismic case. But in saturated condition the corresponding values of factors of safety are 1.479 and 0.505 (Table 8.3). The slope is totally unsafe in seismic condition irrespective of whether it is in dry state or in saturated state. The program SASP suggests that the unreinforced slope may fail by over-toppling if continuous cross joint dips more than 2^0.

It may be noted that the slope is unlikely to be fully saturated as assumed in the stability analysis for wet condition. This slope section is far away from the dam structure and hence the slope failure is not likely to have any significant effect on the dam structure.

Slope Section: RBS3

Rock slope RBS3, which is located at about 1 km d/s of the Zero Bridge (near pumping unit) on the right bank of the reservoir, has been found to be safe both in dry condition as well as in saturated condition for planar failure and the factors of safety have been found to be 2.382 in static dry and 1.279 static saturated conditions respectively. But when analysed for seismic condition, the corresponding factors of safety for dry and saturated conditions have been found to be 0.591 and 0.306 respectively. So the slope is totally unstable in seismic condition. The program SASP has recommended that unreinforced slope may fail by over-toppling if continuous cross joint dips more than 20^0 for seismic dry condition and unreinforced slope may fail by over-toppling if continuous cross joint dips more than 10^0 for seismic wet condition respectively. It may however be noted that the analysis for wet condition has been carried out assuming that the slope is fully saturated, which is practically unlikely to happen considering the presence of jointed rock masses which allow for free drainage of trapped rain water. Since the slope is situated far away from the dam structure on the right bank of the reservoir, the slope failure may not affect the dam structure. Hence, it is suggested to provide concrete cladding up to El.645 m (MRL = 615 m), so as to protect and strengthen the toe of the slope.

Slope Section: RBS4

The slope at section RBS4, which is located at about 2 km d/s of Zero Bridge (near Dobra village) on the right bank of the reservoir, has been found to be completely stable both in dry and wet conditions and needs no remedial measures. The factors of safety are 5.922 and 1.942 in static and seismic conditions when the slope is dry. The corresponding values for the saturated condition of the slope have been found to be 3.009 and 0.957 respectively. The corresponding value of dynamic displacement is 0.023 m. As per the practice in Geotechnical Engineering, if this dynamic displacement is less than 1% of the height of the slope, the slope is considered to safe kinematically. In this case, the height of the slope is 80 m and hence the dynamic displacement is far less than 1% of its height and hence the slope in saturated condition is seismically safe.

Slope Section: RBS6

The slope at section RBS6 is located at 2.7 km away d/s of the Zero Bridge towards the dam site (just upstream of Dharamghat Village) on the right bank. At this section, the slope is somewhat steep, about 45^0 and the slope height is about 19 m. The possibility of a planar mode of failure at this slope section has been explored. The analysis using the computer program SASP gives the factors of safety of 1.877 for dry and 1.000 for saturated conditions in static case. Minimum factor of safety required in static condition, as per the Geotechnical Engineering practice, is 1.5 and hence the saturated slope is unsafe in static condition. In seismic case, the corresponding values of factors of safety are 0.551 and 0.276 for dry and saturated conditions respectively (Table 8.3). So the slope is unstable in seismic condition and the program SASP has recommended that the unreinforced slope may fail by over-toppling if continuous cross joint dips more than 10^0.

It may however be noted that the wet condition analysis has been carried out assuming fully saturated slope, which is practically unlikely to happen considering the presence of jointed rock masses which allow for free drainage of trapped rain water. Hence, it is suggested to provide concrete cladding up to El. 645 m so as to protect the toe of the slope. Since this section is far away from the dam axis, therefore failure at this section is not likely to cause any danger to the dam.

Slope Section: RBS12

The slope at section RBS12 which is quite steep (slope angle 50^0) is located at about 7.7 km d/s of Zero Bridge (near Phipalti village) on the right bank of the reservoir site. The stereo net shows the possibility of planar slide. Plane failure analysis using SASP of this has yielded values of factors of safety of 3.261 in static condition and 1.214 in seismic condition when the slope is dry. However, in saturated condition, the corresponding values of factors of safety have been found to be 1.673 and 0.590 respectively (Table 8.3). The corresponding value of dynamic displacement under saturated condition has been found to be 0.507 m. The slope height is 60 m and the dynamic displacement is less than 1% of its height and hence the slope can be treated as just stable. The program SASP recommended that the unreinforced slope may fail by over-toppling if continuous cross joint dips more than -3^0.

It may be noted that the slope is unlikely to be fully saturated as assumed in the stability analysis for wet condition. Hence it is not likely to have any significant effect on the dam structure.

Slope Section: RBS15

The rock slope at section RBS15 which is located at about 14.5 km d/s of Zero Bridge (near Pendars village) on the right bank of the reservoir site. The slope section is expected to experience planar failure as the least factors of safety in dry condition at this section have been found to be 1.954 and 0.637 in static and seismic conditions respectively. Dynamic displacement in dry state is just less than 1% of the slope height and the slope can be called as just stable. The corresponding values of factors of safety in saturated condition are 1.029 and 0.312 (Table 8.3). Hence the slope is not stable in static saturated condition as the factor of safety is less than 1.5. It is also unstable in seismic condition. The damage to the road close to the dam area may be severe and hence the slope should be closely monitored during monsoons and earthquakes. Necessary warnings should be displayed at the toe of the slope for general public safety. It is suggested that the entire area encompassing the road, the terrace above the administrative building and its surrounding areas are more prone to failure.

8.3.3.2 Left bank

Slope Section: LBS5

Rock slope at section LBS5 is located at 8.5 km d/s of Zero Bridge on the northern side of Bhashon village on the left bank. The mode of failure at this slope section is a planar failure and the analysis through SASP gives factors of safety of 1.878 and 0.497 in static and seismic condition when the slope is dry. It is therefore stable in dry condition. The value of dynamic displacement corresponding to the factor of safety of 0.497 has been found to be 0.582 m which is less than 1% of the slope height and hence the slope may be considered to be still stable in seismic dry condition. But when saturated, the corresponding values of factors of safety have been found to be 1.009 and 0.255 which makes the slope is totally unstable in saturated condition (Table 8.4). It may however be noted that the wet condition analysis has been carried out assuming fully saturated slopes, which is practically unlikely to happen considering the presence of jointed rock masses allowing for free drainage of trapped rain water.

The input parameters and the results of the analysis are given in the Appendix- XI . The computer program recommended that unreinforced slope may fail by over-toppling if continuous cross joint dips more than -1^0. Following remedial measures should be adopted for strengthening the slope thereby improving its stability:

a) The existing debris material above the rock slope shall not be disturbed for making the required new road at El. 620 m level, instead the new road may be constructed using a concrete gravity retaining wall, founded on the existing road level and rising up to El. 620 m. Moreover, the debris material below the base slab should be grouted up to a depth of 10 m and the retaining wall should be raised on the base slab supported by the grouted debris material. The slab should be monolithic with the retaining wall and should extend from the heel of the retaining wall to the edge of the lower slope.

b) The debris slope below the existing road level should be protected with suitable concrete cladding starting from the river bed.

8.4 STABILITY ANALYSIS OF ROCK SLOPES USING SOFTWARE "SASW"

The computer program, SASW (Singh and Goel, 2002) is basically for the stability analysis of reservoir slopes with tetrahedral wedge failure. The program is based on the simple solution for the computation of the factor of safety (Hoek and Bray, 1981) of translational slip of a tetrahedral wedge formed in a rock slope by two intersecting discontinuities, the slope face and the upper ground surface. The upper ground surface may have any dip and dip direction. The influence of a tension crack is not included in the solution. The solution does not take into account the rotational slip and toppling. It is assumed that the pressure varies from zero (at the free faces) to a maximum level (at some point on the line of intersection) of the two failure planes.

8.4.1 Overview of "SASW"

The software "SASW" (Singh and Goel, 2002) was checked by Deoja et al. (1991) for stability analysis of rock slopes in Kathmandu. The program SASW was evaluated by Tabatabei (1993) in Garhwal Himalaya which has also predicted that in dry season during earthquake (magnitude < 7 on the Richter scale), the rock wedges which are under study will not fail. This prediction was confirmed by the Uttarkashi Earthquake.

When a pair of discontinuities is chosen at random from a set of field data, it is not observed whether -

i) The planes could form a wedge (the line of intersection may plunge too steeply to daylight the slope face or it may be too flat to intersect the upper ground surface),

ii) One of the planes overlies the other,

iii) One of the planes lies to the right or to the left of the plane when viewed from the bottom of the slope.

To resolve these uncertainties, a simple solution (Hoek and Bray, 1981) has been derived in such a manner that either of the planes may be labeled 1 (or 2) and allowance has been made for one plane overlying the other. In addition, a check on whether both the planes do form a wedge is included in the solution at an early stage. Depending upon the configuration of the wedge and the magnitude of the water pressure acting on each plane, contact may be lost on either plane and this contingency is provided in the solution. The geometry of the wedge failure case is shown in Fig. 8.3.

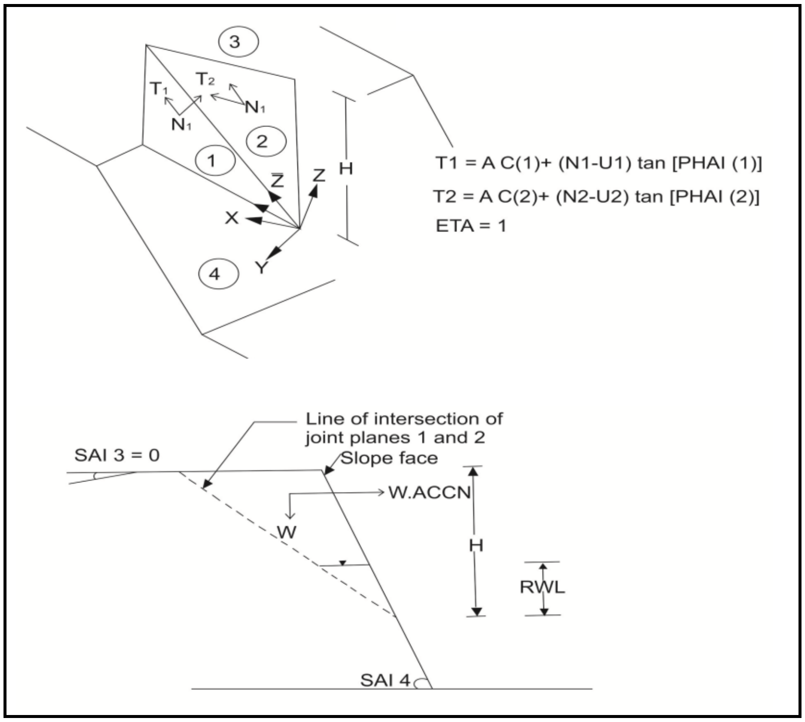


Fig. 8.6 Input variables for Stability Analysis of Rock Slopes with Wedge Failure (SASW)

The discontinuities are marked by 1 and 2; the upper ground surface is denoted by 3 and the slope face by 4. Computer program SASW was developed on basis of the principle of Hoek and Bray (1981). The input variables for the program SASW are defined below and described in Appendix - XII.

H = height of the crest of the slope above toe of intersection

GAMA = unit weight of rock mass

GAMAW = unit weight of water

C = cohesion

PHI = angle of friction

PORE = pore water pressure factor

ACCN = coefficient of horizontal acceleration of earthquake near crest of slope

EQM = corresponding earthquake magnitude on Richter's scale for seismic zone

RWL = water level above toe of intersection

ETA = slope face overhangs toe of the slope

W = weight of wedge

SAI (I) = dip of I^{th} joint plane

ALPHA (I) = dip direction of I^{th} joint plane

SAI3 = angle of slope of upper ground surface

SAI4 = angle of rock slope

The program uses the above input parameters to calculate the factor of safety of the slope. With respect to Fig. 8.3 the expression for factors of safety are given by Eq. 8.6, 8.7 and 8.8 for dry slope static analysis, saturated slope static analysis, dry slope seismic analysis, saturated slope seismic analysis respectively.

$$FOS = (R_A+R_B) \tan \Phi\} / W . \sin \psi_i \quad (8.6)$$

where, R_A and R_B are the normal reactions provided by planes A and B

$$FOS = 3 /\gamma_H (C_A . X + C_B . Y) + (A - \gamma_w /2\gamma . X) \tan \Phi_A + (B - \gamma_w /2\gamma . Y) \tan \Phi_B \quad (8.7)$$

where, C_A and C_B are the cohesive strengths of planes A and B, Φ_A and Φ_B are the angles of friction on planes A and B, and X, Y, A and B are dimensionless factors which depend upon the geometry of the wedge

$$FOS = ƛ \frac{(\cos i_a - \eta \sin (i_a+\beta) \tan \Phi}{\sin i_a + \eta \cos (i_a+\beta)} \quad (8.8)$$

where, ƛ = Wedge Factor, η = Seismic coefficient, β = inclinations of the seismic force, and i_a = Line of intersection of planes A and B

The principle given by Hoek and Bray (1981) was extended for dynamic stability analysis of a rock wedge. The rock wedge is likely to slide and experience dynamic settlement during high intensity earthquake. The dynamic settlement of rock wedge is calculated approximately using Jansen's (1990) correlation (Chapter VII). This value of dynamic settlement may be conservative as the correlation was developed on the basis of observed dynamic settlement in earth dams during an earthquake of magnitude, M on the Richter's scale causing peak ground acceleration α_h g.

The output of the program includes the factors of safety –

i) both in static and seismic conditions and

ii) dynamic settlement of the slope due to seismicity

In general, rock slopes have been analyzed for the following four conditions:

i) Dry slope, static analysis

ii) Saturated slope, static analysis

iii) Dry slope, seismic analysis, and

iv) Saturated slope, seismic analysis.

8.4.2 Stability analysis of rock slopes using "SASW"

The rock slopes around the periphery of the reservoir which have been analyzed using the computer program "SASW" are listed below in Table 8.5. The corresponding geological sections are presented in Chapter IV. There are only three rock slopes which can fail in wedge mode of failure along the right bank of the reservoir.

The dip and dip direction of slopes and joints obtained from the field studies (Appendix – I, II) have been used for the stability analysis. The shear strength parameters of various joints used in the stability analyses were obtained from Bieniawski's RMR classification system (Chapter – IV). Other input parameters used are as follows:

i) Unit weight of the rock = 2.3 t/m^3 (dry condition) and 2.4 t/m^3 (saturated condition),

ii) Magnitude of Earthquake = 7 (Richter's Scale).

In the right bank of the reservoir area, slopes at sections RBS8 (near Dandeli village), RBS10 (opposite of Bhashon village) and RBS14 (near THDCIL guest house) are the rock slopes which are analyzed using software program SASW. The output files of the stability analyses of all the rock slopes along with the suggested remedial measures are presented in Appendix - XIII. The values of the factors of safety of these sections are summarized in Table 8.6.

Table 8.5 Rock Slopes Analyzed by using "SASW"

S. No.	Bank	Rock Slopes at Sections
1	Right	RBS8
2	Right	RBS10
3	Right	RBS14

Table 8.6 Stability Analysis of Rock Slopes along Right Bank using "SASW"

S. No.	Slope Section	Program File Name	Slope Angle (°)	Slope Height (m)	RMR_{Basic}	RMR_{Adj}	SMR	Rock Mass Class	Slope Condition	C (t/m2)	Φ (°)	Unit Weight of Rock Mass (γ)	$\bar{B}$	α_h	F.O.S.		Dynamic Displacement (m)
															Static	Seismic	
1	RBS8	ORBS8	41/N150	40	68	63	83	Very good	DRY	30	35	1.7	0.0	0.0	9.327	4.436	0.0
									SAT	15	23	1.9	0.1	0.10	4.326	2.043	0.0
2	RBS10	ORBS10	60/N189	33	68	63	83	Very good	DRY	30	35	1.7	0.0	0.0	6.068	3.977	0.0
									SAT	15	23	1.9	0.1	0.10	2.747	1.790	0.0
3	RBS14	ORBS14	48/N120	55	70	45	55	Normal	DRY	30	35	1.7	0.0	0.0	7.269	4.790	0.0
									SAT	15	23	1.9	0.1	0.10	1.729	1.126	0.0

8.4.3 Remedial Measures

Slope Section: RBS8

Slope section RBS8, which is located at about 4.7 km d/s of Zero Bridge on the right bank near Dandeli village, is comprised of two regular joint sets and one foliation. The slope is quite steep, sloping at an angle of 41^0 up to a height of 40 m above the road level. The mode of failure at this slope section is a wedge failure. When the slope is analysed for the possibility of a 3D wedge failure, the slope is stable in dry state with factors of safety 9.327 and 4.436 in static and seismic conditions respectively. So in dry condition the slope section is stable statically and seismically. The corresponding values of factors of safety in saturated condition are 4.326 and 2.043. Table 8.6 suggests that the slope would therefore be stable.

Slope Section: RBS10

Slope at section RBS10 is located at 6.5 km d/s of Zero Bridge below the road (close to village Palam) on the right bank of the reservoir. At this section, the slope is somewhat steep, about 60^0 and the slope height is about 33 m. The mode of failure at this slope section is a wedge failure and when in a dry state, the factors of safety have been found to be 6.068 and 3.977 in static and seismic conditions respectively. The corresponding values in saturated condition are 2.747 and 1.790. The slope at section RBS10 is therefore completely stable (Table 8.6) and needs no remedial measures.

Slope Section: RBS14

The slope at section RBS14 is located at a distance of about 14 km d/s of Zero Bridge below the road close to village Gairogi on the right bank of the reservoir. The slope rises at an angle of about 48^0 up to a height of about 55 m. The slope mass has two regular joint sets and a foliation which shows the possibility of a 3D wedge failure. Analysis of the section using SASW give factors of safety of 7.269 and 4.790 in static and seismic conditions when the slope is dry which indicates that the slope is stable in dry condition. But when saturated, the corresponding values of factors of safety have been found to be 1.729 and 1.126 which means that the slope at RBS14 becomes completely stable (Table 8.6) and needs no remedial measures.

In all the three cases, as the factor of safety in seismic condition is always more than unity, dynamic displacement has been found to be zero.

CHAPTER – IX

COMPUTATION OF WAVE HEIGHT DUE TO LANDSLIDE

9.1 THEORETICAL BACKGROUND OF WAVE HEIGHT

One of the causes of concern, from the safety point of view of the dam, is the wave generated by a nearby deep seated landslide around the periphery and in close proximity of the reservoir. Many landslides tend to take place along the rim of the reservoir, but only a deep seated landslide / rock slide has the ability to generate a very high wave in the reservoir. It is needless to mention that submerged rotational slides may be triggered by a major earthquake during the rainy season. Slingerland and Voigt (1979) obtained an approximate correlation for the maximum height of the wave generated due to landslide in the reservoir on the basis of some case histories and presented an equation which gives the reduction in the height of wave during its travel from the landslide zone towards the dam structure (Fig. 9.1). On basis of several case studies, the authors developed the following regression equation (Eq. 9.1) for first wave height.

$$\log (\eta_{max} / d) = a + b \log (KE) \qquad (9.1)$$

Where, a and b are constant values which are - 1.25 and 0.71 respectively and are neither dependent on the site nor on the reservoir geometry and KE is the dimensionless kinetic energy which has a value ranging from 1 to 100 and is expressed by Eq. 9.2

$$KE = 0.5 \, (l \, h \, w / d^3) \, (\Upsilon s / \Upsilon) \, (v_s / g \, d) \qquad (9.2)$$

Where, l = length of landslide mass

h = thickness of landslide body

w = average landslide width

d = water depth

Υs = density of the landslide material

Υ = density of water (1.0 g cm $^{-3}$)

v_s = slide velocity

The value of KE in turn is substituted into Eq. 9.1 to yield the wave height.

Table 9.1 below gives the list of rock slopes along both left and right banks of the reservoir along with their distances from the body of the dam and which have the potential of a major landslide, especially in view of their very low factors of safety.

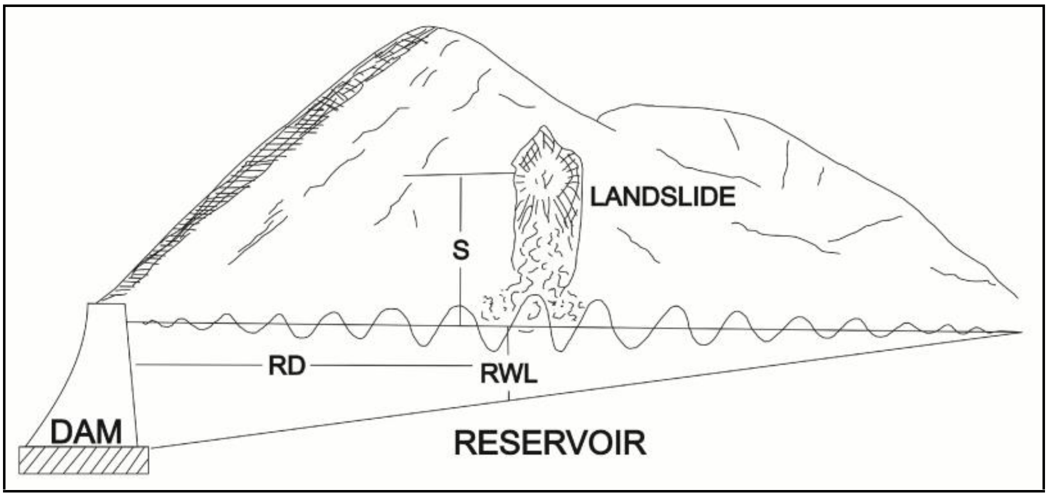


Fig. 9.1 Wave generation in Reservoir due to Landslide

9.2 COMPUTATION OF WAVE HEIGHT USING "WAVE" SOFTWARE

In the present study, computations for wave height have been made using the software - WAVE (Singh and Goel, 2002). Sample input file of the program is presented in Appendix - XIV. The output of the program WAVE is in the form of - i) maximum wave height at the location of possible landslide and ii) the corresponding height of wave at the location of concrete gravity dam (after it has traveled a distance from the location of landslide to the dam site). All the output files of WAVE have been presented in Appendix XV.

Table 9.1 Summary of Stability of Rock Slopes (close to Dam / Barrage) using SAST, SASP and SASW Software Packages

S. No.	Slope	Type of Failure	Distance from Dam (m)
1	RBS14	Serious risk of wedge failure in saturated condition	Very Close to Dam (400 m)
2	RBS15	Risk of planar wedge failure and talus failure in both dry and saturated conditions	Close to Dam (600 m)
3	RBS16	Risk of talus failure in saturated condition	Very Close to Dam (500 m)
4	RBS17	Risk of talus failure in saturated condition	Very Close to Dam (300 m)
5	LBS5	Risk of planar wedge failure in saturated condition	Away from Dam (1500 m)

9.3 RESULTS AND DISCUSSION

Using the above software package, computations have been carried out for some critical rock slopes RBS14, RBS15 along the right bank and LBS5 along the left bank of the reservoir. Computations have also been carried out for some critical debris slopes RBS16 and RBS17 along the right bank of the reservoir. These slope sections from the reservoir area are chosen for analysis as the factors of safety in saturated condition for these slopes are very close to unity (Table 9.1).

Table 9.2 gives the values of the weight of sliding wedge, mean depth of water in the reservoir and the distance of landslide from the dam body along with the maximum wave height generated at the location of landslide and the wave height at the location of the dam. Table 9.2 shows that for rock slopes RBS14 (at 400 m from dam site) and RBS15 (at 600 m from dam site) on the right bank and slope section LBS5 (approx. 1500 m from dam site) on the left bank, the maximum wave height generated at the point of landslide is 0.776 m, 1.355 m and 0.944 m respectively. As the wave travels towards the dam, this wave height reduces to 0.194 m, 0.180 m and 0.063 m respectively. No damage to the dam / barrage is therefore expected. Similarly, at debris slope section: RBS16 (approx. 500 m from dam site) on the right bank, the maximum wave height generated at the point of landslide is 1.092 m and as the wave travels towards the dam, this wave height reduces to 0.174 m.

However, at debris slope section RBS17, which is at a distance of about 300 m from the dam site, the maximum wave height at the place of landslide can be as high as 4.116 m and as this wave travels to the dam / barrage; this height would reduce to about 1.372 m.

The output result shows that the values of maximum wave height generated at the location of these slope sections range from 0.776 m to 4.116 m. When these waves travel to the dam axis, the wave height left out varies from 0.174 m to 1.372 m. It is therefore clear that the sights of potential deep seated landslides due to submergence are far away from the dam site and no danger of over-toppling of the dam is predicted. So the wave height near the dam / barrage is well within limits and wave height is not a matter of concern.

Table 9.2 Computation of Wave Height for Some Critical Slopes in the Event of a Landslide

S. No.	Slope Sections	Program File Name	Slope Height (m)	Residual Angle of Friction Φ_r (°)	Mean Depth of Reservoir (m)	Dip of Intersection of Joint Plane (°)	Distance of Landslide from Dam (m)	Weight of Sliding Wedge at Landslide (m)	Maximum Wave Height at Landslide (m)	Wave Height at Dam Axis (m)
Rock Slopes										
1	RBS14	ORBS14	55	15	25	84	400	0.05E+05	0.776	0.194
2	RBS15	ORBS15	70	15	20	90	600	0.52E+04	1.355	0.180
3	LBS5	OLBS5	80	15	25	71	1500	0.52E+04	0.944	0.063
Debris Slopes										
4	RBS16	ORBS16	80	16	20	57	500	0.05E+05	1.092	0.174
5	RBS17	ORBS17	80	16	25	59	300	0.05E+06	**4.116**	**1.372**

CHAPTER – X

SUMMARY AND CONCLUSION

10.1 SUMMARY

The problem of stability of reservoir slopes in a hydro-power project assumes importance as any major landslide in the close vicinity of the dam / barrage can be detrimental to the stability of dam / barrage itself. In the present study, case of Koteshwar hydro-electric project has been considered for detailed study. Accordingly, all the essential data of the project was collected which included:

Salient features of the project, details of regional geology and geology of the project area, choice of appropriate slope section around the periphery of the reservoir including rock slopes and debris / talus slopes, and all rock mass characteristics on the basis of actual field survey for different slope sections.

The above data was used to characterize / classify the rock mass, evaluate values of RMR and SMR and relate these to the shear strength characteristics of the slope mass. Kinematic analysis of various rock slope sections was carried out on the basis of stereographic projections in order to get a preliminary idea about the possible mode of failure at various slope sections. Initial prediction of the stability of debris / talus or rock slopes was made based on Hoek and Bray stability charts (1981).

Detail stability at various slope sections was studied based on the nature of slope mass i.e. either debris / talus or rock mass. For this purpose, appropriate software was chosen and computer runs were taken for predicting the factors of safety under static dry and saturated conditions and seismic dry and saturated conditions.

Further, an attempt was also made to compute the wave height generated due to major landslide in the close vicinity of the dam and any adverse effect that it would have on the stability of the dam.

Attempt has also been made to suggest the remedial measures for different unstable slopes.

10.2 CONCLUSIONS

i) In general, it has been observed that both debris / talus slopes and the rock slopes are stable under static condition when the slope mass is in dry state.

ii) However, upon filling of the reservoir up to its MRL and the subsequent submergence of the slopes causes degradation in the shear strength parameters and hence the stability of slopes is adversely affected.

iii) The stability is further adversely affected under seismic condition.

iv) Debris / talus slopes can be protected by constructing either one or series of toe protection walls i.e. gabions by providing toe protection and hence arrest the movement of the sliding debris / talus material.

v) Rock slopes can be protected by providing properly designed cable anchors.

vi) Slope sections RBS14, RBS15, RBS16 and RBS17 on the right bank of the reservoir are the four slope sections which are in close proximity of the dam body. Out of these four slope sections, slopes RBS14 and RBS15 are the rock slopes whereas RBS16 and RBS17 are the debris slopes. Out of these four sections, the wave height generated at the location of landslide is maximum at section RBS17 which is just 300 m away from the dam body. The corresponding wave height generated is 4.116 m and when this wave travels towards the dam body, the wave height at the structure is 1.372 m. This wave height is not really a cause of any major concern as far as the stability of the dam body is concerned.

vii) The interpretation map showing the nature of instability within Koteshwar dam reservoir is presented in Fig. 10.1.

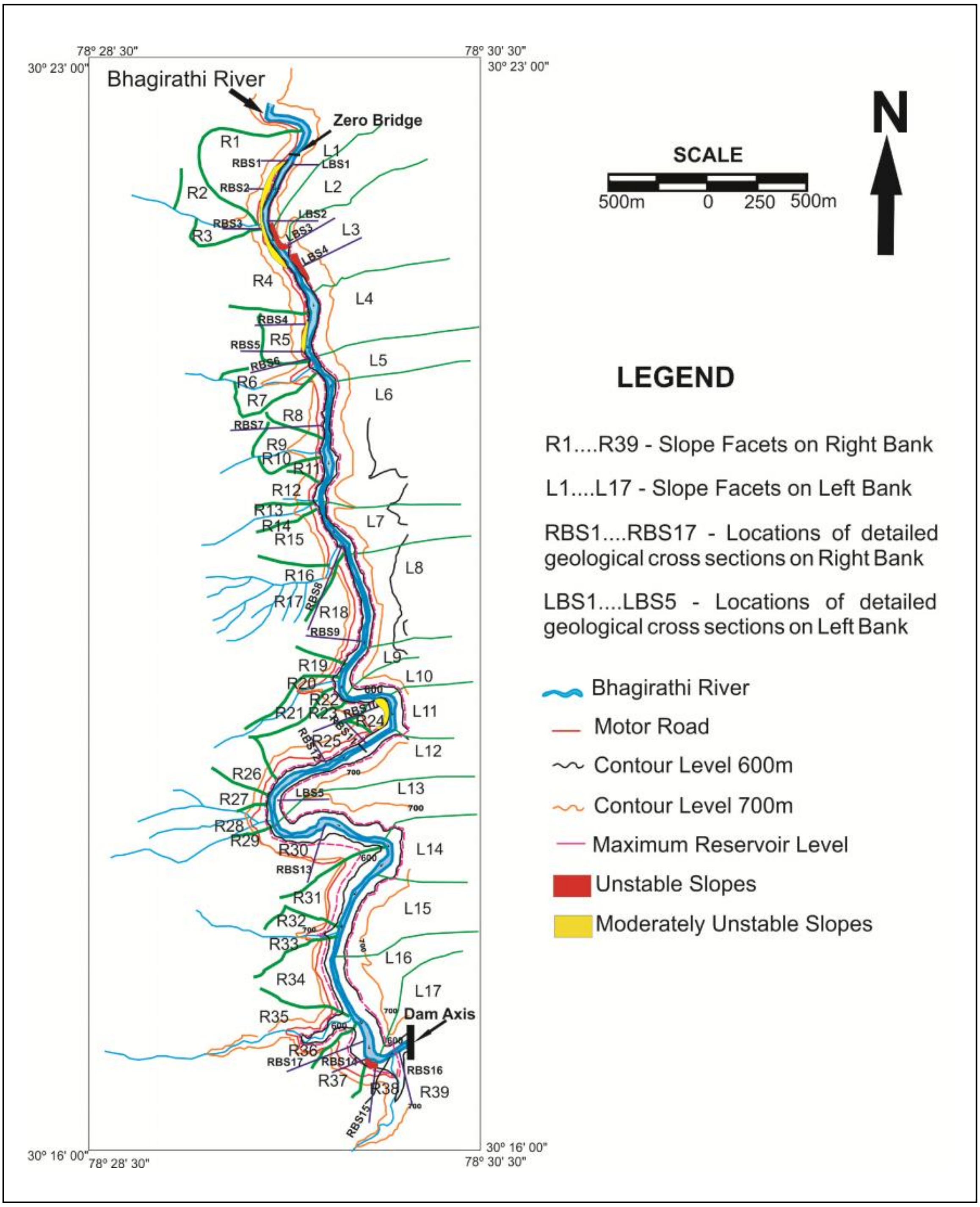


Fig. 10.1 Interpretation Map Showing Nature of Instability within Koteshwar Dam Reservoir

10.3 SUGGESTIONS FOR FURTHER RESEARCH

i) In order to further investigate in to the stability aspects of the reservoir slopes of Koteshwar hydro electric project, it is suggested that detail stability analysis be carried out for rock slopes using finite element modeling through either PHASE-II software for two dimensional modeling or through PLAXIS software for three dimensional modeling of rock slopes.

ii) For further investigation in to stability of the debris / talus slope, it is preferable to use only PLAXIS software and nonlinear modeling of the debris material.

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APPENDIX - I

DETAILS OF SLOPE PARAMETERS AND GEOLOGY COLLECTED FACET-WISE ON RIGHT BANK

Slope Identification – R 1 **River bed El – 590.6**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 40-45	N125	30	Phyllite Gr –II with 2-3m of debris cover	F J1 J2	32 60 40	N175 N40 N10	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed at the river bed level for 2 – 2.5m , above that covered with debris of 20-40 cm thickness
Above road level 45	N125	55	Phyllite Gr –II minor warping - Foliation- close to surface due to weathering	F J1 J2	32 60 40	N185 N150 N150	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Above road level rocks are exposed for about 10 -15m ht, then it has debris cover with medium vegetation

Slope Identification – R 2 **River bed El – 590.6**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 35 - 40	N100	30	Phyllite Gr–II with 1-1.5m of debris cover	F	48	N175	Undulating Fairly rough	Very long >20m	Tight	Nil	Rocks are exposed on sides of Marsh nala for 2 – 2.5m , above that debris cover of 20-40 cm thickness
				J1	65	N345	Fairly rough	1 – 1.25m	Open	Clay	
				J2	50	N170	Smooth	1 – 1.5m	Tight	Nil	
Above road level 35 - 40	N180	50	Phyllite Gr –II with 2-3m of debris cover	F	48	N175	Undulating Fairly rough	Very long >20m	Tight	Nil	Above road level rocks are exposed for about 10 -15m further above debris cover with moderate vegetation
				J1	65	N345	Fairly rough	1 – 1.25m	Open	clay	
				J2	50	N170	Smooth	1 – 1.5m	close	Nil	

Slope Identification – R 3 **River bed El – 590.6**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 30 -35	N64	30	Debris boulders - 50% Avg - Block size 1m, Some very big boulders, Matrix- clayey silt, contains some calcareous material having natural cementation	F J1 J2	75 70 25	N330 N70 N113	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Open Tight	Nil Clay Nil	Rocks are exposed at the river bed level for 2 – 2.5m , above that covered with debris of 20-40 cm thickness
Above road level 35 - 40	N20	45	- do -.	F J1 J2	75 70 25	N330 N70 N113	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Open close	Nil clay Nil	Above road huge blocks of size 3 – 4m with moderate vegetation cover

Slope Identification – R 4 **River bed El – 585.3**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 30-32	N100	22	Debris boulders - 40% Avg – max block size – 1m, few very big boulders, Matrix-clayey silt	F J1 J2	75 90 30	N335 N140 N145	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Open Tight	Nil Clay Nil	Rocks are exposed at the river bed level for 2 – 2.5m, and further above that covered with debris of 60 cm thickness.
Above road level 30-32	N100	55 - 60	Phyllite rock block of 3m-5m present with 2-3m of debris cover Mixed with clayey matrix with 25% of big boulders at places.	F J1 J2	75 90 30	N335 N140 N145	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Open Tight	Nil Clay Nil	At road level and further above rocks exposed in patches for about 10 -15m ht. Further above debris cover having moderate vegetation

Slope Identification – R 5 **River bed El – 582.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 32	N100	25	Phyllite rock of Gr II exposed at the river bed level for 2- 3m, with 2 sets of joints. Remaining slope is covered with debris – compacted with rock boulder of 2 – 3m.	F J1 J2	75 90 30	N100 N335 N140	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed at the river bed level for 2 – 2.5m , above that cover with debris of 60-80 cm thickness with dense vegetation
Above road level 32	N85	45 - 50	Slum of length 10m debris: 40-50% boulders, generally <1m size, few big boulders also seen – matrix – clayey silt	F J1 J2	75 90 30	N100 N335 N140	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Above road level rocks are exposed for about 10 -15m ht, then it has debris cover with moderate vegetation

Slope Identification – R 6 **River bed El – 580.5**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 45	N90	18	Phyllite of Gr II exposed at the river bed level for 2- 3m, with 2 sets of joints. Remaining slope is covered with debris having rock boulders of 1 - 2m	F J1 J2	30 35 90	N190 N145 N335	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Moderate vegetation – shrubs and thorny bushes
Above road level 40 - 45	N140	37	Debris cover 10-15m thick highly compacted with 1 – 2m size boulders	F J1 J2	30 35 90	N190 N145 N335	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Above road level rocks debris cover with moderate vegetation. slope is dipping towards the nala

Slope Identification – R 7 **River bed El – 578.5**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 35	N25	23	Phyllite rock of Gr II exposed at the river bed level for 2- 3m, with 2 sets of joints. Remaining slope is covered with debris.	F	28	N175	Undulating Fairly rough	Very long >20m	Tight	Nil	
				J1	30	N135	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	60	N145	Smooth	1 – 1.5m	Tight	Nil	
Above road level 35	N25	45	Debris cover of 10-15m thick - highly compacted.	F	28	N175	Undulating Fairly rough	Very long >20m	Tight	Nil	
				J1	30	N135	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	60	N145	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 8 **River bed El – 576.6**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 20	N90	24	Phyllite rock of Gr II exposed at the river bed level for 2- 3m, with 2 sets of joints. Remaining slope is covered with debris of 4 – 6m thick. Nearly 3 tension cracks were identified (Tension cracks of 10 – 12m length ,80 cm wide and 2m depth)	F	30	N135	Undulating Fairly rough	Very long >20m	Tight	Nil	Tensions cracks are seen only in debris they don't travel into the rock
				J1	60	N 270	Smooth	1 – 1.5m	Tight	Nil	
				J2	90	N140	Smooth	1 – 1.5m	Tight	Nil	
Above road level 20	N90	55	Phyllite Gr –II with 2-3m of debris cover with big rock blocks of Phyllite and Quartzites –seen scattered on surface	F	30	N135	Undulating Fairly rough	Very long >20m	Tight	Nil	Above road level debris cover with moderate vegetation
				J1	60	N 270	Smooth	1 – 1.5m	Tight	Nil	
				J2	90	N140	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 9 **River bed El – 576.3**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 35 - 40	N175	30	Phyllite Gr –II with 2-3m of debris cover	F J1 J2	25 -35 60 90	N135 N 270 N190	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed at the river bed level for 2 – 2.5m , above that cover with debris of 20-40 cm thickness
Above road level 40 - 45	N175	70	Few big rock blocks of Phyllite 6 -12m size seen on slope –with the debris cover above	F J1 J2	25 -35 60 90	N135 N 270 N190	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	

Slope Identification – R 10 **River bed El – 575.5**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 30- 35	N25	30	Phyllite Gr – II exposed at the river bed. Further above rock with 2-3m of debris cover.	F J1 J2	25 -35 60 90	N135 N 265 N175	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	
Above road level 30- 35	N25	70	Debris cover above rock for 2 – 3m – having medium to big rock blocks.	F J1 J2	25 -35 60 90	N135 N 265 N175	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Moderate vegetation – shrubs and thorny bushes

Slope Identification – R 11 **River bed El – 575.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 30-35	N90	22	Phyllite Gr –II with 2-3m of debris cover	F	25 -35	N135	Undulating Fairly rough	Very long >20m	Tight	Nil	Rocks are exposed at the river bed level for 2 – 2.5m, above that covered with debris of 60-80 cm thickness.
				J1	60	N 270	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	90	N190	Smooth	1 – 1.5m	Tight	Nil	
Above road level 40	N90	30	Debris cover of > 3m thick - well compacted, with size of boulders ranging from 10-80cm in silty clay matrix	F	25 -35	N135	Undulating Fairly rough	Very long >20m	Tight	Nil	Moderate to dense vegetation mostly of shrubs thorny bushes and scattered trees.
				J1	60	N 270	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	90	N190	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 12 **River bed El – 575**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 30 -35	N100	25 -30	Phyllite Gr –II with 2-3m of debris cover	F J1 J2	25 -35 60 90	N135 N 270 N190	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	
Above road level 40	N100	30- 35	Debris cover of > 3m thick - well compacted, with general size of boulders ranging from 10-80cm in silty clay matrix. Few big rock blocks of 1m size also seen.	F J1 J2	25 -35 60 90	N135 N 270 N190	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Moderate to dense vegetation mostly of shrubs thorny bushes and scattered trees.

Slope Identification – R 13 **River bed El – 575**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 60	N17	18 ± 2	Phyllite Gr –II with 2-3m of debris cover, slope dipping downstream towards the stream	F J1 J2	25 -35 60 90	N135 N 270 N190	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Small and linear facet trending E-W direction bounded by small stream on east - moderate vegetation cover
Above road level 65	N17	25	Debris cover of > 2m thick - well compacted, with general size of boulders ranging from 10-80cm in silty clay matrix. Few big rock blocks of 1m size also seen.	F J1 J2	25 -35 60 90	N135 N 270 N190	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Covered with debris of thickness 2 – 4-5; with moderate to dense vegetation mostly of shrubs thorny bushes and scattered trees.

Slope Identification – R 14 **River bed El – 575**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 40	N30	15 ± 3	Phyllite Gr –II exposed at the river bed level for 1.5 – 2m ht. And further above debris of 1 -2m are seen.	F J1 J2	25 -35 60 30	N100 N 170 N80	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Small and linear facet trending E-W direction bounded by small stream on west - moderate vegetation cover
Above road level 35	N30	22	Debris cover of > 2m thick - well compacted, with general size of boulders ranging from 10-80cm in silty clay matrix. Few big rock blocks of 1m size also seen.	F J1 J2	25 -35 60 30	N100 N 170 N80	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	covered with debris of thickness 2 – 4-5; with moderate to dense vegetation mostly of shrubs thorny bushes

Slope Identification – R 15 **River bed El – 574.8**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 55 ± 5	N80	22	Phyllite rocks are exposed at the river bed level for 2 – 2.5m Gr –II with 2-3m of debris cover, big rock blocks of dislocated nature	F J1 J2	25 -35 55 90	N135 N 240 N190	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Moderate vegetation
Above road level 40	N80	25	Debris cover of > 2m thick - well compacted, with general size of boulders ranging from 10-80cm in silty clay matrix. Few big rock blocks of 1m size also seen. .	F J1 J2	25 -35 55 90	N135 N 240 N190	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Slided rock mass rest on the side slopes of the facet.

Slope Identification – R 16 **River bed El – 574.5**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 40-45	N150	30	Phyllite Gr –II with 2-3m of debris cover, slope dipping downstream towards the stream	F J1 J2	20 40 30	N150 N 140 N90	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Small and linear facet trending E-W direction bounded by small stream on east - moderate vegetation cover
Above road 40-45	N150	45	Phyllite Gr –II with 2-3m of debris cover	F J1 J2	20 40 30	N150 N 140 N90	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight		Above road level rocks are exposed for about 10 - 15m ht, then its has debris cover with modearte vegetation

Slope Identification – R 17 **River bed El – 574.5**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 60 ± 5	N	23	Rocks of Phyllite Gr II 2- 4 m thickness with 2 joints set are exposed only at the river bed level	F J1 J2	25 -35 55 90	N135 N 240 N190	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Small and linear facet trending E-W direction bounded by small stream on west - moderate vegetation cover
Above road level	N	35	Debris covers of 35 m± 5m with 5% boulders ranging from 1 – 3m. 45% broken rock fragments of 2 – 6cm Phyllite and Very small pockets of RBM	F J1 J2	25 -35 55 90	N135 N 240 N190	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Above road level rocks are exposed for about 10 -15m ht, then its has debris cover with moderate vegetation

Slope Identification – R 18 **River bed El – 572.5**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 60	N104	22	Rocks are exposed at the river bed level for 2 – 2.5m, Debris of 1.5 – 4 m thickness- overlied by RBM (Pvt quarry) almost excavated 50 - 70m thickness and 250 – 300m length- overlain by debris of 6 – 8m thickness	F	50	N 80	Undulating Fairly rough	Very long >20m	Tight	Nil	Moderate vegetation.
				J1	75	N75	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	75	N160	Smooth	1 – 1.5m	Tight	Nil	
Above road level 60	N104	70	Debris compacted with boulders of Avg 50% varying size 1 – 3m.	F	50	N 80	Undulating Fairly rough	Very long >20m	Tight	Nil	Debris compacted- moderate vegetation
				J1	75	N75	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	75	N160	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 19 **River bed El – 570.6**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 40 ± 5	N110 ± 5	24	Rocks of Phyllite Gr II are seen at the bed level only 3m – 6m thick	F	60	N 80	Undulating Fairly rough	Very long >20m	Tight	Nil	Moderate vegetation An anticline seen on rocks- the axial plane marking contact of facets 19 & 20
				J1	75	N75	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	75	N150	Smooth	1 – 1.5m	Tight	Nil	
Above road level 30	N110 ± 5	35	Slided rock blocks of 4m 8m in size. Debris: compacted, rock fragments of varying size	F	60	N 80	Undulating Fairly rough	Very long >20m	Tight	Nil	Above road level debris with slided rock blocks cover with moderate vegetation
				J1	75	N75	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	75	N150	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 20 **River bed El – 566**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 45 ± 5	N175	24	Phyllite Gr –II with 2-3m of debris cover	F J1 J2	50 75 75	N 80 N75 N150	Undulating Fairly rough Fairly rough Smooth	7m -15m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Small and linear facet trending E-W direction bounded by small stream on east - one limb of anticline within this facet - axis tending in E-W direction
Above road level 35	N175	47	Phyllite – foliated dipping D/S with 2 major join sets Moderately Weathered	F J1 J2	50 75 75	N 80 N75 N150	Undulating Fairly rough Fairly rough Fairly rough	6 m - 14m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed for about 10 -15m ht, and further above debris cover with moderate vegetation

Slope Identification – R 21 **River bed El – 566**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 40 ± 5	N25	18	Phyllite Gr –II with 2 joint sets- highly foliated with small scale folds	F J1 J2	35 70 80	N128 N42 N148	Undulating Fairly rough Fairly rough Fairly rough	10m -12m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Small and linear facet trending E-W direction bounded by small stream on west - moderate vegetation cover
Above road level 30	N25	45	Phyllite Gr –II with 2-3m of debris cover	F J1 J2	35 70 80	N128 N42 N148	Undulating Fairly rough Fairly rough Fairly rough	10m -12m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Above road level Phyllite rocks are exposed within the debris cover of .5m - .8m. Moderately vegetated.

Slope Identification – R 22 **River bed El – 563.5**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 60	N189	20	Phyllite rocks Gr –II are exposed at the river bed level for 2 – 2.5m ht with 2 joint sets- highly foliated and wrapped	F	30	N220	Undulating Fairly rough	Very long >20m	Tight	Nil	Debris cover of 20-40 cm thickness - moderate vegetation
				J1	51	N239	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	41	N150	Smooth	1 – 1.5m	Tight	Nil	
Above road level 55-60	N189	30	Phyllite Gr –II with 2-3m of debris cover	F	30	N220	Undulating Fairly rough	Very long >20m	Tight	Nil	Moderately vegetated
				J1	51	N239	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	41	N150	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 23 **River bed El – 562.5**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 40	N149	28	Phyllite rocks Gr –II are exposed at the river bed level for 2 – 2.5m ht with 2 joint sets- highly foliated and wrapped	F	26	85	Undulating Fairly rough	Very long >20m	Tight	Nil	Moderately vegetation With shrubs and thorny bushes
				J1	40	180	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	85	315	Smooth	1 – 1.5m	Tight	Nil	
Above road level 35-40	N149	45	Phyllite Gr –II with 2-3m of debris cover	F	26	85	Undulating Fairly rough	Very long >20m	Tight	Nil	Moderately vegetation With shrubs and thorny bushes
				J1	40	180	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	85	315	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 24 **River bed El – 561.3**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to terrace cultivated land 48	N120	21	Phyllite Gr –II with 2-3m of debris cover	F	24	N120	Undulating Fairly rough	Very long >20m	Tight	Nil	
				J1	41	N170	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	62	N70	Smooth	1 – 1.5m	Tight	Nil	
Terrace 5 – 10	N120	12	Thick debris	F	24	N120	Undulating Fairly rough	Very long >20m	Tight	Nil	Agricultural land
Terrace to upper road level 35		17		J1	41	N170	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	62	N70	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 25 **River bed El – 560.6**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 50	N135-150	30	Phyllite Gr –II rocks are exposed at the river bed level for 2 – 2.5m ht, further above 2-3m of thickness debris cover	F J1 J2	26 40 85	N85 N180 N315	Undulating Fairly rough Fairly rough Smooth	12 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Moderate vegetation
Above road level 45-50	N135-150	30	Phyllite Gr –II with 2-3m of debris cover	F J1 J2	26 40 85	N85 N180 N315	Undulating Fairly rough Fairly rough Smooth	12 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Moderate vegetation

Slope Identification – R 26 **River bed El – 560**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 45	N140	28	Phyllite Gr –II with 2 major 50cm to 70cm debris cover	F J1 J2	30 65 80	90 220 150	Undulating Fairly rough Fairly rough Smooth	12 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Moderate vegetation
Above road level 30	N140	35	Phyllite Gr –II with 50cm - 70cm debris cover	F J1 J2	30 65 80	25 25 75	N110 N65 N295	12 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed for about 10 -15m ht, further above then it has debris cover with medium vegetation

Slope Identification – R 27 **River bed El – 559.5**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 45 - 50	N110	20	Phyllite Gr –II rocks are exposed at the river bed level for 2 – 2.5m ht, further above 60 – 80 cm of thickness debris cover	F J1 J2	25 65 80	N95 N220 N150	Undulating Fairly rough Fairly rough Smooth	12 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Moderate vegetation cover
Above road level 35 ± 5	N110	70	Highly crushed and Intensely foliated Phyllite – broken angular fragments mixed with clay.	F J1 J2	25 65 80	N95 N220 N150	Undulating Fairly rough Fairly rough Smooth	12 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed for about 10 - 15m ht, further above then it has debris cover with medium vegetation

Slope Identification – R 28 **River bed El – 558.5**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 45 -50	N80	30	Phyllite Gr –II rocks are exposed at the river bed level for 2 – 2.5m ht, further above 60 – 80 cm of thickness debris cover	F J1 J2	30 65 80	N90 N220 N150	Undulating Fairly rough Fairly rough Smooth	12 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Small and linear facet trending E-W direction bounded by small stream on east - moderate vegetation cover
Above road level 30	N80	70	Highly crushed and Intensely foliated Phyllite – broken angular fragments mixed with clay.	F J1 J2	30 65 80	N90 N220 N150	Undulating Fairly rough Fairly rough Smooth	12 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Above road level rocks are exposed for about 10 -15m ht, then it has debris cover with medium vegetation

Slope Identification – R 29 **River bed El – 558**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 35 - 40	N	26	Phyllite Gr –II with 60- 80 cm of debris cover	F	30	N90	Undulating Fairly rough	8 - 12	Tight	Nil	Small and linear facet trending E-W direction bounded by small stream on west - moderate vegetation cover
				J1	65	N220	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	80	N150	Smooth	1 – 1.5m	Tight	Nil	
Above road level 40	N	37	Highly crushed and Intensely foliated Phyllite dislocated into broken angular fragments mixed with clay.	F	30	N90	Undulating Fairly rough	8 - 12	Tight	Nil	Above road level rocks are exposed for about 10 -15m ht, then it has debris cover with medium vegetation
				J1	65	N220	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	80	N150	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 30 **River bed El – 554.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to RBM Quarry 25	N06	25 ± 5	Phyllite Gr –II at river bed for 2m thickness And above that covered with dump of 10m thick	F	35	N90	Undulating Fairly rough	8 - 12	Tight	Nil	Moderate vegetation
				J1	40	N250	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	75	N340	Smooth	1 – 1.5m	Tight	Nil	
RBM Quarry to road 25	N06	40 – 50	RBM Mixed boulder, cobbles, silt, sand and clay	F	35	N90	Undulating Fairly rough	8 - 12	Tight	Nil	RBM quarry Mined and maintained by THDC at Gairogi Village.
				J1	40	N250	Fairly rough	1 – 1.25m	Tight	Nil	
Upper road 35 - 40		40	Debris 10 - 15m thickness	J2	75	N340	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 31 **River bed El – 554.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 35 ± 5	N105	3 - 6	Phyllite Gr –II at river bed for 2m thickness	F	30	45	Undulating Fairly rough	8 - 12	Tight	Nil	RBM (mined by THDC)
				J1	65	340	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	80	180	Smooth	1 – 1.5m	Tight	Nil	
Above road level 30	N105	40 – 50	RBM Mixed boulder, cobbles, silt, sand and clay	F	30	45	Undulating Fairly rough	8 - 12	Tight	Nil	RBM quarry Mined and maintained by THDC next to Gairogi Village.
				J1	65	340	Fairly rough	1 – 1.25m	Tight	Nil	
		40	Debris 10 - 15m thickness	J2	80	180	Smooth	1 – 1.5m	Tight	Nil	Phyllite rock exposed above

Slope Identification – R 32 **River El – 554.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 35 ± 5	N185	33	Phyllite Gr –II with 2-3m of debris cover	F	28	75	Undulating Fairly rough	Very long >20m	Tight	Nil	Rocks are exposed at the river bed level for 2 – 2.5m , above that cover with debris of 20-40 cm thickness
				J1	40	200	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	60	10	Smooth	1 – 1.5m	Tight	Nil	
Above road level 45	N185	25	Phyllite Gr –II with 2-3m of debris cover	F	28	185	Undulating Fairly rough	Very long >20m	Tight	Nil	Debris with broken rock fragments – angular- varies in size from 3-5cm
				J1	30	150	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	80	150	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 33 **River El – 554.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 40 ± 5	N15	28	Phyllite Gr –II with 2-3m of debris cover	F	25	38	Undulating Fairly rough	12 -14 m	Tight	Nil	Small and linear facet trending E-W direction bounded by small stream on west - moderate vegetation cover Moderate vegetation
				J1	70	275	Fairly rough	1 – 1.25 m	Tight	Nil	
				J2	75	5	Smooth	1 – 1.5 m	Tight	Nil	
Above road level 40	N15	35	Phyllite Gr –II with 2-3m of debris cover	F	25	38	Undulating Fairly rough	12 – 14m	Tight	Nil	Rocks are highly crumbled left with strains due to shear stress. Vegetation - less
				J1	70	275	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	75	5	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 34 **River El – 554.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 45 ± 5	N85	30	Rocks are exposed at the river bed level for 2 – 2.5m , above that cover – clay + broken rock fragments varies in size – 10cm, 25cm, 50cm – angular, sub angular.	F	25	38	Undulating Fairly rough	12 – 14m	Tight	Nil	Moderate vegetation
				J1	70	275	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	75	5	Smooth	1 – 1.5m	Tight	Nil	
Above road 35 - 40	N85	70	Phyllite Gr –II with 2-3m of debris cover	F	25	38	Undulating Fairly rough	12 – 14m	Tight	Nil	Debris mass – broken rock fragments – angular-with clayey silt matrix
				J1	70	275	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	75	5	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 35 **River bed El – 554.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 60 ± 5	N170 ± 5	30	Rocks are exposed at the river bed level for 2 – 2.5m , above that cover of clay + broken rock fragments varies in size – 10cm, 25cm, 50cm – angular, sub angular	F	44	65	Undulating Fairly rough	Very long >20m	Tight	Nil	Moderate vegetation.
				J1	80	75	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	50	280	Smooth	1 – 1.5m	Tight	Nil	
Above road level 35 ± 5	N170 ± 5	70	Phyllite Gr –II with 2-3m of debris cover	F	44	65	Undulating Fairly rough	Very long >20m	Tight	Nil	Debris mass – broken rock angular rock fragments of varying size with clayey silt matrix
				J1	80	75	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	50	280	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 36 **River bed El – 554.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 28	N73	30	Rocks are exposed at the river bed level for 2 – 2.5m , above that cover of clay + broken rock fragments varying in size from 10 - 50cm –angular to sub angular.	F	30	N80	Undulating Fairly rough	Very long >20m	Tight	Nil	Moderate vegetation.
				J1	47	N30	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	65	N260	Smooth	1 – 1.5m	Tight	Nil	
Above road level 28-30	N73	70	Phyllite Gr –II with 2-3m of debris cover	F	30	N80	Undulating Fairly rough	Very long >20m	Tight	Nil	Debris mass – broken rock angular rock fragments of varying size with clayey silt matrix
				J1	47	N30	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	65	N260	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 37 **River bed El – 554.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 70	N17	30	Phyllite Rocks are exposed at the river bed level for 2 – 2.5m ht , above that covered with debris of 1.5 - 2m thickness Weathered crumbled with intense foliations	F	25	N75	Undulating Fairly rough	Very long >20m	Tight	Nil	Moderate weathering
				J1	40	N260	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	65	N260	Smooth	1 – 1.5m	Tight	Nil	
Above road level 65-70	N17	70	Debris having broken angular rock fragments in silty matrix	F	25	N75	Undulating Fairly rough	Very long >20m	Tight	Nil	Above road level rocks are exposed for about 10 - 15m , with debris cover above - moderate vegetation
				J1	40	N260	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	65	N260	Smooth	1 – 1.5m	Tight	Nil	

Slope Identification – R 38 **River bed El – 553.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 48	N120	45	Phyllite Gr –II Rocks are exposed at the river bed level for 2 – 2.5m ht , above that covered with debris of 20-40 cm thickness	F J1 J2	24 41 62	N120 N170 N70	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Moderate Vegetation.
Above road 40 - 45-50	N120	45	Phyllite Gr –II with 2-3m of debris cover	F J1 J2	24 41 62	N120 N170 N70	Undulating Fairly rough Fairly rough Smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Above road level rocks are exposed for about 10 -15m ht, above that RBM pockets are observed

Slope Identification – R 39 **River bed El – 553.2**

Slope Angle (Degree)	Slope direction (Degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction (Degree)	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 45	N120	45	Phyllite Gr –II Rocks are exposed at the river bed level for 2 – 2.5m ht , above that covered with debris of 20-40 cm thickness	F	25	N120	Undulating Fairly rough	Very long >20m	Tight	Nil	Moderate Vegetation.
				J1	40	N170	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	60	N70	Smooth	1 – 1.5m	Tight	Nil	
Above road 40 - 45	N120	47	Phyllite Gr –II with 2-3m of debris cover	F	25	N120	Undulating Fairly rough	Very long >20m	Tight	Nil	Above road level rocks are exposed for about 10 -15m ht, above that RBM pockets are observed
				J1	40	N170	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	60	N70	Smooth	1 – 1.5m	Tight	Nil	

APPENDIX - II

DETAILS OF SLOPE PARAMETERS AND GEOLOGY COLLECTED FACET-WISE ON LEFT BANK

Left Bank L1 …..L17

Slope identification: L-1 **River bed El – 590.6m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 46	N280	30	Phyllite Gr –II At lower level muck Pile containing debris fine silty matrix with boulders	F J1 J2	50 65 73	N170 N345 N072	Undulating Fairly rough Fairly rough Undulating Smooth	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed at the river bed level for 30m. No vegetation. Muck pile (55 m high) at the downstream end of the section.
Above road level 46	N280	200	Phyllite Gr –II	F J1 J2	50 65 73	N170 N345 N072	Undulating Fairly rough Fairly rough Planar smooth	Very long >20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Above road level rocks are exposed for about 10 -15m ht, then it has debris cover with medium vegetation

Slope identification: L-2 **River bed El – 590 m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 50	N210	50	Phyllite Gr –II -,	F	50	N170	Undulating Fairly rough	>20m	Tight	Nil	
				J1	65	N345	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	73	N072	Undulating Smooth	1 – 1.5m	Tight	Nil	
Above road level 60	N210	200	Phyllite Gr –II	F	50	N170	Undulating Fairly rough	Very long >20m	Tight	Nil	Above road level rocks are exposed for about 5 m, then it has debris cover with medium vegetation
				J1	65	N345	Fairly rough	1 – 1.25m	Tight	Nil	
				J2	73	N072	Planar smooth	1 – 1.5m	Tight	Nil	

Slope identification: L-3. **River bed El – 587.5 m.**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to upper road level 47	N244	15	Muck Pile containing debris fine silty matrix with boulders -, contains some calcareous material causing cementation	F J1 J2	25 75 70	N115 N335 N65	Undulating Fairly rough Fairly rough Undulating Smooth	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Muck dump loose and unstable in nature
Above road level 34	N244	20	Debris- highly compacted With 10% of big rock blocks of sine 3 - 6m.	F J1 J2	25 75 70	N115 N335 N65	Undulating Fairly rough Fairly rough Undulating Smooth	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Village Chopra is located in this area.

Slope identification: L-4 **River bed El – 585 m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to MRL 40	N261	28	RBM-Debris - Boulders - silty Matrix	F J1 J2	75 70 30	N332 N170 N145	Undulating Fairly rough Fairly rough Undulating Smooth	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed at the river bed level for 7 to 10 m , above that RBM is present in small pocket with 10-15 m thickness. Debris(<5m thick) is present above this upto MRL.
MRL to 700m 30	N261	87		F J1 J2	75 70 30	N332 N170 N145	Undulating Fairly rough Fairly rough Undulating Smooth	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Above MRL Debris (<5m thick) are exposed to El 655m. Above this a pocket of RBM with 15 m thickness is present.

Slope identification: L-5 **River bed El – 583m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to MRL 65	N220	30	Phyllite Gr –II	F J1 J2	35 70 75	N145 N070 N330	Undulating Fairly rough Fairly rough Undulating Smooth	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	
MRL to 700m 30	N210	87	Phyllite Gr –II with ± 3m debris present from EL. ± 640m 3m thick RBM present at El. ±710m.	F J1 J2	35 70 75	N145 N070 N330	Undulating Fairly rough Fairly rough Undulating Smooth	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	

Slope identification: L-6 **River El – 580.7m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to MRL	N276	49m	Phyllite Gr –II	F	30	N145	Planar rough	>20m	Tight	Nil	Hard phyllite cliff. No vegetation.
70				J1	80	N270	Planar Rough	1 – 1.25m	Tight	Nil	
				J2	75	N330	Planar rough	1 – 1.5m	Tight	Nil	
MRL to 700m	N276	87m	Phyllite Gr –II	F	30	N145	Planar rough	>20m	Tight	Nil	Thin vegetation.
30				J1	80	N270	Planar Rough	1 – 1.25m	Tight	Nil	
				J2	75	N330	Planar rough	1 – 1.5m	Tight	Nil	

Slope identification: L-7 **River bed El – 574.55m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to MRL 75	N220	49m	Phyllite Gr –II	F J1 J2	25 80 80	N100 N230 N320	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	
MRL to 750m 50	N220	137m	Phyllite Gr –II with ± 3m debris present from EL. ± 640m 3m thick RBM present at El. ±710m.	F J1 J2	25 80 80	N100 N230 N320	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Debris is thinly vegetated. Terrace is present above 710m.

Slope identification: L-8 **River El – 570.2m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to MRL 40	N250	42.8m	Debris present up to MRL.	F J1 J2	25 75 85	N070 N260 N330	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Medium to high vegetation.
MRL to 900m 70	N250	287m	Phyllite Gr –II	F J1 J2	25 75 85	N070 N260 N330	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Above MRL debris cover with medium vegetation. Debris – highly compacted.

Slope identification: L9 **River bed El – 569 m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to MRL 48	N315	49m	Phyllite Gr –II with ±2 m of debris cover.	F	25	N070	Planar rough	>20m	Tight	Nil	Rocks are exposed at the river bed level for 1– 2m , above that cover with debris consisting angular fragments. Very thin vegetation cover
				J1	75	N260	Planar Rough	1 – 1.25m	Tight	Nil	
				J2	85	N330	Planar rough	1 – 1.5m	Tight	Nil	
Above MRL to El. 700m. 48	N175	87m	Phyllite Gr –II up to El.±650m with ±2 m of debris cover. RBM with debris present above El.±650m.	F	25	N070	Planar rough	>20m	Tight	Nil	Terrace at El. 665m.
				J1	75	N260	Planar Rough	1 – 1.25m	Tight	Nil	
				J2	85	N330	Planar rough	1 – 1.5m	Tight	Nil	

Slope identification: L-10 **River bed El – 564.4m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to MRL 40	N175	49m	Phyllite Gr –II with ±2 m of debris cover.	F	40	N135	Planar rough	>20m	Tight	Nil	Rocks are exposed at the river bed level for 1– 2m , above that cover with debris of 60 - 80 cm thickness with angular fragments with very thin vegetation cover
				J1	30	N180	Planar Rough	1 – 1.25m	Tight	Nil	
				J2	85	N340	Planar rough	1 – 1.5m	Tight	Nil	
Above MRL to El. 700m. 40	N175	87m	Phyllite Gr –II up to El.±650m with ±2 m of debris cover. RBM with debris seen above El.±650m.	F	35	N90	Planar rough	>20m	Tight	Nil	Debris of 60 - 80 cm thickness with angular fragments having thin vegetation cover
				J1	30	N180	Planar Rough	1 – 1.25m	Tight	Nil	
				J2	85	N340	Planar rough	1 – 1.5m	Tight	Nil	

Slope identification: L-11 **River El – 567.5 m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to MRL 40	N268	57m	Phyllite Gr –II with ±2 m of debris cover.	F J1 J2	35 40 75	N90 N250 N340	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed at the river bed level for 1– 2m , above that cover with debris of 60 - 80 cm thickness with angular fragments with very thin vegetation cover
Above MRL to El. 700m. 40	N268	-	Phyllite Gr –II with ±2 m of debris cover.	F J1 J2	35 40 75	N90 N250 N340	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Debris of 60 - 80 cm thickness with angular fragments with very thin vegetation cover

Slope identification: L-12. **River Bed El – 561.3m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to MRL (El. 613 m) 45	N324	61	Phyllite Gr –II with < 1m of debris cover.	F J1 J2	20 30 85	N105 N180 N320	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed at the river bed level upto El. 610m. above that covered with debris of 60-80 cm thickness.
Above MRL 40	N324	30	Debris:- well compacted, varying size of boulders in clayey silt matrix	F J1 J2	20 30 85	N105 N180 N320	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Bhason Village is located here. The area has very thin vegetation.

Slope identification: L-13 **River bed El – 556.7m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River level to MRL 40	N200	56.3	Phyllite Gr –II with ±1m of debris cover.	F J1 J2	35 40 75	N90 N250 N340	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rock exposed at river bed level for 1– 2m , above that covered with debris of 60 - 80 cm thickness with angular fragments with very thin vegetation cover
MRL to El.700 m 65	N200	87	RBM from El.619-650m Above El. 630m phyllites are present.	F J1 J2	35 40 75	N90 N250 N340	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	30m highly compacted RBM.

Slope identification: L-14. **River El. – 556 m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to MRL 30	N270	57m	Phyllite Gr –II with ±2 m of debris cover.	F J1 J2	35 40 75	N90 N250 N340	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed at the river bed level for 1– 2m , above that cover with debris of 60 - 80 cm thickness with angular fragments having thin vegetation cover
Above MRL to El. 700m. 46	N270	-	Phyllite Gr –II with ±2 m of debris cover.	F J1 J2	35 40 75	N90 N250 N340	Planar rough Planar Rough Planar rough	>20m 1 – 1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Debris of 60 - 80 cm thickness with angular fragments having thin vegetation cover

Slope identification: L-15. **River El ± 555.6 m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River level to El. ±660 m 58	N306	104 m	Phyllite Gr –II with less than .5m of debris pockets.	F J1 J2	35 40 75	N090 N250 N340	Rough Undulating Rough Planar Rough Planar	>20m 1 –1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Rocks are exposed at the river bed level for 2 – 2.5m , above that cover with debris of 0-50 cm thickness. Very thin vegetation.
El. 660-710m 15±5	N306	40m	Debris	F J1 J2	35 40 75	N090 N250 N340	Rough Undulating Rough Planar Rough Planar	>20m 1 –1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Villages Halijent and Ali are located nearby Cultivated Land.

Slope identification: L-16 **River bed El – 554.2 m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River to MRL 55	N250	59m	El. 585m muck pile is present. Above 585m is phyllite rock exposed	F J1	35 68	N075 N170	Rough Undulating Rough Planar Rough Planar	>20m 1 –1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	No vegetation over Muck Pile. Very thin vegetation on the Phyllites.
MRL to 665m	N80	52m	Phyllite Gr-II exposed upto full height of the slope. RBM pockets (1-3 m thick) present at the downstream end of the facet.	F J1	35 68	N075 N170	Rough Undulating Rough Planar Rough Planar	>20m 1 –1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Very thin vegetation on the Phyllites.

Slope identification: L-17 **River El – 553.2 m**

Slope Angle (degree)	Slope direction (degree)	Slope Height (m)	Rock Type	Joint No.	Dip (Degree)	Dip Direction	Joint Roughness	Continuity	Aperture	In-Filling	Remarks
River level to MRL 60	N150	65	Upto El. 585m muck pile is present. Above 585m is phyllite rock exposed	F J1	35 68	N075 N170	Rough Undulating Rough Planar Rough Planar	>20m 1 –1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	No vegetation over Muck Pile. Very thin vegetation on the Phyllites.
MRL to El. 700m 40	N150	87	Phyllite Gr-II exposed . RBM pockets (1-3 m thick) present within 10 m above the dam crest.	F J1	35 68	N075 N170	Rough Undulating Rough Planar Rough Planar	>20m 1 –1.25m 1 – 1.5m	Tight Tight Tight	Nil Nil Nil	Very thin vegetation on the Phyllites.

APPENDIX - III

RMR CALCULATIONS FOR ROCK SLOPE SECTIONS

RMR$_{Basic}$ CALCULATION FOR RIGHT BANK SLOPE SECTIONS

Sl. No.	Section		Uniaxial Compressive Strength (UCS)	Drill Core Quality RQD (%)	Spacing of discontinuities (m)	Condition of Discontinuities	Ground water	RMR$_{Basic}$	RMR$_{adj}$	Description	C_{mass} (t/m^2)	Φ_{mass} (^{0})
1	RBS-1	Values	10-25	50-75	0.6-2	Slightly Rough	Completely Dry	68	43	Fair	70	20
		Ratings	2	13	15	23	15					
2	RBS-3	Values	10-25	50-75	0.6-2	Slightly Rough	Completely Dry	72	47	Fair	70	20
		Ratings	2	13	15	27	15					
3	RBS-4	Values	10-25	50-75	0.6-2	Slightly Rough	Completely Dry	68	43	Fair	70	20
		Ratings	2	13	15	23	15					
4	RBS-6	Values	10-25	25-50	0.6-2	Slightly Rough	Completely Dry	65	40	Poor	70	20
		Ratings	2	8	15	25	15					
5	RBS-8	Values	10-25	50-75	0.6-2	Slightly Rough	Completely Dry	68	63	Good	150	23
		Ratings	2	13	15	23	15					
6	RBS-10	Values	10-25	50-75	0.6-2	Slightly Rough	Completely Dry	68	63	Good	150	23
		Ratings	2	13	15	23	15					
7	RBS-12	Values	10-25	50-75	0.6-2	Slightly Rough	Completely Dry	70	45	Fair	70	20
		Ratings	2	13	15	25	15					

8	RBS-14	Values	10-25	50-75	0.6-2	Slightly Rough	Completely Dry	70	45	Fair	150	23
		Ratings	2	13	15	25	15					
9	RBS-15	Values	10-25	50-75	0.2-0.6	Slightly Rough	Completely Dry	59	35	Poor	70	20
		Ratings	2	13	10	19	15					

RMR$_{Basic}$ CALCULATION FOR LEFT BANK SLOPE SECTIONS

Sl. No.	Section		Uniaxial Compressive Strength (UCS)	Drill Core Quality RQD (%)	Spacing of discontinuities (m)	Condition of Discontinuities	Ground water	RMR$_{Basic}$	RMR$_{adj}$	Description	C_{mass} (t/m^2)	Φ_{mass} (^{0})
1	LBS-5	Values	10-25	50-75	0.2-0.6	Slightly Rough	Completely Dry	65	40	Poor	70	20
		Ratings	2	13	10	25	15					

APPENDIX - IV

SMR FOR PLANAR FAILURE MODE OF BOTH RIGHT AND LEFT BANKS OF RESERVOIR

Section Name		Dip	Dip Direction	Strike	Trend	Plunge	F1		F2		F3		F1.F2.F3	SMR
RBS1	S	45	125	35	332	33							0	83
	J1	60	40	310	332	33	275	0.15	60	1	15	0	0	83
	J2	40	10	280	332	33	245	0.15	40	0.85	-5	-50	-6.375	76.625
	J1&J2	0	0	270	332	33	153	0.15	33	0.7	-12	-60	-6.3	76.7
RBS3	S	34	64	334	153	20							0	80
	J1	70	70	340	153	20	6	0.85	70	1	36	0	0	80
	J2	25	113	23	153	20	311	0.15	25	0.4	-9	-50	-3	77
	J1&J2	0	0	270	153	20	89	0.15	20	0.4	-14	-60	-3.6	76.4
RBS4	S	32	90	0	230	4							0	76
	J1	90	140	50	230	4	50	0.15	90	1	58	0	0	76
	J2	30	145	55	230	4	55	0.15	30	0.7	-2	-50	-5.25	70.75
	J1&J2	0	0	270	230	4	140	0.15	4	0.15	-28	-60	-1.35	74.65
RBS6	S	45	90	0	50	10							0	73
	J1	35	335	245	50	10	245	0.15	35	0.85	-10	-50	-6.375	66.625
	J2	90	140	50	50	10	50	0.15	90	1	45	0	0	73
	J1&J2	0	0	270	50	10	40	0.15	10	0.15	-35	-60	-1.35	71.65
RBS12	S	50	150	60	228	29							0	80
	J1	40	180	90	228	29	30	0.4	40	0.85	-10	-50	-17	63
	J2	85	315	225	228	29	165	0.15	85	1	35	0	0	80
	J1&J2	0	0	270	228	29	78	0.15	29	0.4	-21	-60	-3.6	76.4
RBS15	S	70	17	287	172	2							0	51
	J1	40	260	170	172	2	117	0.15	40	0.85	-30	-60	-7.65	43.35
	J2	65	260	170	172	2	117	0.15	65	1	-5	-50	-7.5	43.5
	J1&J2	0	0	270	172	2	155	0.15	2	0.15	-68	-60	-1.35	49.65
LBS5	S	45	324	234	233	20							0	75
	J1	30	180	90	233	20	144	0.15	30	0.7	-15	-60	-6.3	68.7
	J2	85	320	230	233	20	4	1	85	1	40	0	0	75
	J1&J2	0	0	270	233	20	91	0.15	20	0.4	-25	-60	-3.6	71.4

APPENDIX - V

SMR FOR WEDGE FAILURE MODE OF RIGHT BANK OF RESERVOIR

Section Name		Dip	Dip Direction	Strike	Trend	Plunge	F1		F2		F3		F1.F2.F3	SMR
RBS8	S	41	150	60	201	29							0	83
	J1	40	90	0	201	29	60	0.4	40	1	-1	0	0	83
	J2	30	220	130	201	29	70	0.15	30	1	-11	0	0	83
	J1&J2	0	0	270	201	29	51	0.15	29	1	-12	0	0	83
RBS10	S	60	189	99	201	29							0	83
	J1	51	239	149	201	29	50	0.15	51	0.7	-9	0	0	83
	J2	41	150	60	201	29	39	0.15	41	1	-19	0	0	83
	J1&J2	0	0	270	184	35	12	0.4	29	0.15	-31	0	0	83
RBS14	S	50	120	30	332	6							0	62
	J1	30	50	320	332	6	290	0.15	30	0.7	-20	-60	-6.3	55.7
	J2	70	60	330	332	6	300	0.15	70	1	20	0	0	62
	J1&J2	0	0	270	332	6	148	0.15	6	0.15	-44	-60	-1.35	60.65

APPENDIX - VI

SAMPLE INPUT FILES FOR EXECUTION OF PROGRAM SARC

SARC
THIS PROGRAM IS FOR THE STABILITY ANALYSISOFRESERVOIR OR SUBMERGED SLOPES WITH CIRCULAR WEDGE MODE OF FAILURE

NAME OF PROGRAM -> SARC.FOR
UNITS USED -> TONNE-METER-DEGREE
GIVE DATA IN THE FOLLOWING SEQUENCE ->
TITLE OF PROBLEM IN ONE LINE (< 80 CHARACTERS)
N
X (I), Z (I), I=1 to N
ROCK, RWL, XS, WI, ZC, ZWR
C, PHI, GAMA, GAMAW,BBAR,AH, AVR, EQM
NENP, (ENTX(I), ENTY(I), I=1 to NENP
NEP, NOPT
XEXITI, XEXITL, GAP -> This line is needed only when nep=0
-> This line is needed only when NEP>0
End of block 1
Block 1 is represented NENP number of times.
XEXITI, XEXITL, GAP

ENTER 0 FOR TERMINATION
1 FOR FURTHER HELP REGARDING EXPLANATION OF TERMS IN INPUT DATA
2 FOR EXECUTION OF PROGRAMME

ENTER 0 FOR TERMINATION
1 FOR FURTHER HELP 2 FOR EXECUTION

N = Number of profile coordinates (<50)
(X,Z) = Coordinates of profile points (X (I) < X (I +1))
ROCK = Reduced level of hard strata w.r.t. origin
RWL = Reduced level of gwt / reservoir water w.r.t. origin
XS = X- Coordinate of point from where surcharge starts
WI = Uniform surcharge intensity
ZC = Depth of tension crack
ZWR = Depth of water in tension crack / ZC
C = Cohesion of soil / rock
PHI = Angle of internal friction (Degree) of soil / rock
GAMA = Unit weight of soil / rock
GAMAW = Unit weight of pore water

BBAR = Pore water pressure/ (GAMMA* Average height of slices)
AH = Horizontal component of EQ. acceleration near crest of slope
AVR = Vertical component of EQ. acceleration / AH
EQM = Corresponding EQ. magnitude on Richter Scale

NENP	= Number of entry points of slip circles (<10)
ENTX	= X- Coordinate of entry point of circle
ENTY	= Y- Coordinate of entry point of circle
NOPT	= 0, when only minimum factor of safety is required
	= 1, when all F.S. corresponding to all exit points are also required
NEP	= Number of exit points (<50)
	= 0, When no individual point is given
XEXITI	= X- Coordinates of first exit point of circle
XEXITL	= X- Coordinates of last exit point of circle
GAP	= Horizontal distance between consecutive exit points
XEXIT	= X- Coordinates of exit point of circle

ENTER	0 For Termination
	2 For Execution

APPENDIX - VII

OUTPUT FILES FOR STABILITY ANALYSIS OF DEBRIS SLOPES USING PROGRAM SARC

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS9-STATIC DRY CONDITION

```
STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
    UNITS USED          -> TONNE - METER - DEGREE
    INPUT FILE NAME     ->IRBS9.DAT
    OUTPUT FILE NAME    ->OSARC.DAT
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 COORDINATES OF POINTS ALONG SLOPE ->
    X( 1)=    .00000    Z( 1)=    .00000
    X( 2)=  11.00000    Z( 2)=  18.00000
    X( 3)=  20.00000    Z( 3)=  16.00000
    X( 4)=  28.00000    Z( 4)=  17.00000
    X( 5)=  32.00000    Z( 5)=  25.00000
    X( 6)=  38.00000    Z( 6)=  25.00000
    X( 7)=  40.00000    Z( 7)=  28.00000
    X( 8)=  45.00000    Z( 8)=  28.00000
    X( 9)=  48.00000    Z( 9)=  32.00000
    X(10)=  58.00000    Z(10)=  33.00000
    X(11)=  65.00000    Z(11)=  45.00000
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ROCK =   -30.000    RWL  =    26.000    XS   =      .000    WI   =      .000
 ZC   =      .000    ZWR  =      .000
 C    =      .000    PHI  =    40.000    GAMA =     1.700    GAMAW=     1.000
 BBAR =      .000    AH   =      .000    AVR  =      .000    EQM  =      .000
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ENTX =      .000    ENTY =      .000
 NEP  = 0            NOPT = 0
 XEXITI=    20.000    XEXITL=    65.000    GAP   =     5.000
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 F.S   : DYN. :WEIGHT OF:AH CRI : COORDINATES OF   : COORDINATES OF    :RADIUS
*******:DIS(M):WEDGE(T) :TICAL  : CENTER(XC,YC)    : EXIT POINT        :R(M)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
 COORDINATES OF CENTRE =      -3.19,     36.48
 PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

 SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
 COORDINATES OF CENTRE =     -24.43,     71.20
 PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

 SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
 COORDINATES OF CENTRE =     -15.86,     65.23
 PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

 SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
 COORDINATES OF CENTRE =    -467.30,    801.18
 PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

 SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
```

COORDINATES OF CENTRE = -90.61, 195.62
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -1.55, 70.18
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -6.47, 78.79
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

1.0477 .000 .67E+02 .009 (-228.49, 306.11) (20.00, 16.00) 381.99
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS9-STATIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
~~~~~~

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS9.DAT
OUTPUT FILE NAME ->OSARC.DAT
~~~~~~

COORDINATES OF POINTS ALONG SLOPE ->
X(1)= .00000 Z(1)= .00000
X(2)= 11.00000 Z(2)= 18.00000
X(3)= 20.00000 Z(3)= 16.00000
X(4)= 28.00000 Z(4)= 17.00000
X(5)= 32.00000 Z(5)= 25.00000
X(6)= 38.00000 Z(6)= 25.00000
X(7)= 40.00000 Z(7)= 28.00000
X(8)= 45.00000 Z(8)= 28.00000
X(9)= 48.00000 Z(9)= 32.00000
X(10)= 58.00000 Z(10)= 33.00000
X(11)= 65.00000 Z(11)= 45.00000
~~~~~~

ROCK = -30.000 RWL = 26.000 XS = .000 WI = .000
ZC = .000 ZWR = .000
C = .000 PHI = 30.000 GAMA = 1.900 GAMAW= 1.000
BBAR = 1.000 AH = .000 AVR = .000 EQM = .000
~~~~~~

ENTX = .000 ENTY = .000
NEP = 0 NOPT = 0
XEXITI= 20.000 XEXITL= 65.000 GAP = 5.000
~~~~~~

F.S : DYN. :WEIGHT OF:AH CRI : COORDINATES OF : COORDINATES OF :RADIUS
*******:DIS(M):WEDGE(T) :TICAL : CENTER(XC,YC) : EXIT POINT :R(M)
~~~~~~

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -3.19, 36.48
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.
~~~~~~

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -24.43, 71.20
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -15.86, 65.23
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -467.30, 801.18
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -90.61, 195.62
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -1.55, 70.18
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -6.47, 78.79
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

.7158 .000 .25E+03 -.068 (-621.44, 1107.84) (55.00, 32.70) 1270.23
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS9-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
~~~~~~
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS9.DAT
OUTPUT FILE NAME ->OSARC.DAT
~~~~~~
COORDINATES OF POINTS ALONG SLOPE ->
X(1)= .00000 Z(1)= .00000
X(2)= 11.00000 Z(2)= 18.00000
X(3)= 20.00000 Z(3)= 16.00000
X(4)= 28.00000 Z(4)= 17.00000
X(5)= 32.00000 Z(5)= 25.00000
X(6)= 38.00000 Z(6)= 25.00000
X(7)= 40.00000 Z(7)= 28.00000
X(8)= 45.00000 Z(8)= 28.00000
X(9)= 48.00000 Z(9)= 32.00000
X(10)= 58.00000 Z(10)= 33.00000
X(11)= 65.00000 Z(11)= 45.00000
~~~~~~
ROCK = -30.000 RWL = 26.000 XS = .000 WI = .000

```
ZC   =     .000    ZWR  =     .000
C    =     .000    PHI  =   40.000    GAMA =    1.700    GAMAW=    1.000
BBAR =     .000    AH   =     .100    AVR  =     .500    EQM  =    7.000

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
ENTX =     .000    ENTY =     .000
NEP  = 0           NOPT = 0
XEXITI=   20.000   XEXITL=   65.000    GAP  =    5.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
CHECK F.S. FOR -AVR ALSO
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
F.S   : DYN. :WEIGHT OF:AH CRI : COORDINATES OF   : COORDINATES OF    :RADIUS
*******:DIS(M):WEDGE(T) :TICAL  : CENTER(XC,YC)    : EXIT POINT       :R(M)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE =     -3.19,    36.48
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE =    -24.43,    71.20
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE =    -15.86,    65.23
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE =   -467.30,   801.18
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE =    -90.61,   195.62
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE =     -1.55,    70.18
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE =     -6.47,    78.79
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

 .6817   .310   .67E+02   .010 ( -240.00,  320.50) (   20.00,   16.00)  400.40
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS9-SEISMIC SATURATED CONDITION

```
STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
    UNITS USED          -> TONNE - METER - DEGREE
    INPUT FILE NAME      ->IRBS9.DAT
    OUTPUT FILE NAME     ->OSARC.DAT
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 COORDINATES OF POINTS ALONG SLOPE ->
    X( 1)=    .00000    Z( 1)=    .00000
    X( 2)=  11.00000    Z( 2)=  18.00000
    X( 3)=  20.00000    Z( 3)=  16.00000
    X( 4)=  28.00000    Z( 4)=  17.00000
    X( 5)=  32.00000    Z( 5)=  25.00000
    X( 6)=  38.00000    Z( 6)=  25.00000
    X( 7)=  40.00000    Z( 7)=  28.00000
    X( 8)=  45.00000    Z( 8)=  28.00000
    X( 9)=  48.00000    Z( 9)=  32.00000
    X(10)=  58.00000    Z(10)=  33.00000
    X(11)=  65.00000    Z(11)=  45.00000
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ROCK =   -30.000    RWL  =    26.000    XS   =     .000    WI   =     .000
 ZC   =      .000    ZWR  =      .000
 C    =      .000    PHI  =    30.000    GAMA =    1.900    GAMAW=    1.000
 BBAR =      .100    AH   =      .100    AVR  =     .500    EQM  =    7.000
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ENTX =      .000    ENTY =      .000
 NEP  = 0            NOPT = 0
 XEXITI=    20.000    XEXITL=    65.000    GAP   =     5.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 CHECK F.S. FOR -AVR ALSO
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 F.S   : DYN. :WEIGHT OF:AH CRI : COORDINATES OF   : COORDINATES OF    :RADIUS
*******:DIS(M):WEDGE(T) :TICAL  : CENTER(XC,YC)    : EXIT POINT        :R(M)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
 COORDINATES OF CENTRE =      -3.19,     36.48
 PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

 SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
 COORDINATES OF CENTRE =     -24.43,     71.20
 PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

 SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
 COORDINATES OF CENTRE =     -15.86,     65.23
 PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

 SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
 COORDINATES OF CENTRE =    -467.30,    801.18
```

PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -90.61, 195.62
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -1.55, 70.18
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -6.47, 78.79
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

.4931 10.572 .86E+02 .000 (-240.00, 320.50) (20.00, 16.00) 400.40
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS13-STATIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
~~~~~~

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS13.DAT
OUTPUT FILE NAME ->OSARC.DAT
~~~~~~

COORDINATES OF POINTS ALONG SLOPE ->
X(1)= .00000 Z(1)= .00000
X(2)= 10.00000 Z(2)= 8.00000
X(3)= 14.00000 Z(3)= 13.00000
X(4)= 20.00000 Z(4)= 13.00000
X(5)= 30.00000 Z(5)= 14.00000
X(6)= 40.00000 Z(6)= 15.00000
X(7)= 50.00000 Z(7)= 16.00000
X(8)= 60.00000 Z(8)= 16.00000
X(9)= 70.00000 Z(9)= 20.00000
X(10)= 80.00000 Z(10)= 28.00000
X(11)= 82.00000 Z(11)= 31.00000
X(12)= 90.00000 Z(12)= 33.00000
X(13)= 100.00000 Z(13)= 37.00000
X(14)= 110.00000 Z(14)= 40.00000
~~~~~~

ROCK = -30.000 RWL = 23.000 XS = .000 WI = .000
ZC = .000 ZWR = .000
C = .000 PHI = 40.000 GAMA = 1.700 GAMAW= 1.000
BBAR = .000 AH = .000 AVR = .000 EQM = .000
~~~~~~

ENTX = .000 ENTY = .000
NEP = 0 NOPT = 0
XEXITI= 20.000 XEXITL= 110.000 GAP = 10.000
~~~~~~

~~~~~~
F.S : DYN. :WEIGHT OF:AH CRI : COORDINATES OF : COORDINATES OF :RADIUS
*******:DIS(M):WEDGE(T) :TICAL : CENTER(XC,YC) : EXIT POINT :R(M)
~~~~~~

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -49.41, 305.43
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = 4.14, 116.47
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

1.2468 .000 .31E+02 .044 (-31.46, 70.29) (20.00, 13.00) 77.01
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS13-STATIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
~~~~~~
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS13.DAT
OUTPUT FILE NAME ->OSARC.DAT
~~~~~~
COORDINATES OF POINTS ALONG SLOPE ->
X(1)= .00000 Z(1)= .00000
X(2)= 10.00000 Z(2)= 8.00000
X(3)= 14.00000 Z(3)= 13.00000
X(4)= 20.00000 Z(4)= 13.00000
X(5)= 30.00000 Z(5)= 14.00000
X(6)= 40.00000 Z(6)= 15.00000
X(7)= 50.00000 Z(7)= 16.00000
X(8)= 60.00000 Z(8)= 16.00000
X(9)= 70.00000 Z(9)= 20.00000
X(10)= 80.00000 Z(10)= 28.00000
X(11)= 82.00000 Z(11)= 31.00000
X(12)= 90.00000 Z(12)= 33.00000
X(13)= 100.00000 Z(13)= 37.00000
X(14)= 110.00000 Z(14)= 40.00000
~~~~~~
ROCK = -30.000 RWL = 23.000 XS = .000 WI = .000
ZC = .000 ZWR = .000
C = .000 PHI = 30.000 GAMA = 1.900 GAMAW= 1.000
BBAR = 1.000 AH = .000 AVR = .000 EQM = .000
~~~~~~
ENTX = .000 ENTY = .000
NEP = 0 NOPT = 0
XEXITI= 20.000 XEXITL= 110.000 GAP = 10.000
~~~~~~
F.S : DYN. :WEIGHT OF:AH CRI : COORDINATES OF : COORDINATES OF :RADIUS
*******:DIS(M):WEDGE(T) :TICAL : CENTER(XC,YC) : EXIT POINT :R(M)

~~~~~~

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -49.41, 305.43
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.
SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = 4.14, 116.47
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

.8578 .000 .40E+02 -.033 (-31.46, 70.29) (20.00, 13.00) 77.01

~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS13-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE

~~~~~~

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS13.DAT
OUTPUT FILE NAME ->OSARC.DAT

~~~~~~

COORDINATES OF POINTS ALONG SLOPE ->
X(1)= .00000 Z(1)= .00000
X(2)= 10.00000 Z(2)= 8.00000
X(3)= 14.00000 Z(3)= 13.00000
X(4)= 20.00000 Z(4)= 13.00000
X(5)= 30.00000 Z(5)= 14.00000
X(6)= 40.00000 Z(6)= 15.00000
X(7)= 50.00000 Z(7)= 16.00000
X(8)= 60.00000 Z(8)= 16.00000
X(9)= 70.00000 Z(9)= 20.00000
X(10)= 80.00000 Z(10)= 28.00000
X(11)= 82.00000 Z(11)= 31.00000
X(12)= 90.00000 Z(12)= 33.00000
X(13)= 100.00000 Z(13)= 37.00000
X(14)= 110.00000 Z(14)= 40.00000

~~~~~~

ROCK = -30.000 RWL = 23.000 XS = .000 WI = .000
ZC = .000 ZWR = .000
C = .000 PHI = 40.000 GAMA = 1.700 GAMAW= 1.000
BBAR = .000 AH = .100 AVR = .500 EQM = 7.000

~~~~~~

ENTX = .000 ENTY = .000
NEP = 0 NOPT = 0
XEXITI= 20.000 XEXITL= 110.000 GAP = 10.000

~~~~~~

CHECK F.S. FOR -AVR ALSO

~~~~~~

F.S : DYN. :WEIGHT OF:AH CRI : COORDINATES OF : COORDINATES OF :RADIUS
*******:DIS(M):WEDGE(T) :TICAL : CENTER(XC,YC) : EXIT POINT :R(M)

~~~~~~

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
~~~~~~

COORDINATES OF CENTRE = -49.41, 305.43
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = 4.14, 116.47
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -10.34, 167.43
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.
.8073 .083 .30E+02 .046 (-35.67, 76.77) (20.00, 13.00) 84.65
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS13-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
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UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS13.DAT
OUTPUT FILE NAME ->OSARC.DAT
~~~~~~

COORDINATES OF POINTS ALONG SLOPE ->
X(1)= .00000 Z(1)= .00000
X(2)= 10.00000 Z(2)= 8.00000
X(3)= 14.00000 Z(3)= 13.00000
X(4)= 20.00000 Z(4)= 13.00000
X(5)= 30.00000 Z(5)= 14.00000
X(6)= 40.00000 Z(6)= 15.00000
X(7)= 50.00000 Z(7)= 16.00000
X(8)= 60.00000 Z(8)= 16.00000
X(9)= 70.00000 Z(9)= 20.00000
X(10)= 80.00000 Z(10)= 28.00000
X(11)= 82.00000 Z(11)= 31.00000
X(12)= 90.00000 Z(12)= 33.00000
X(13)= 100.00000 Z(13)= 37.00000
X(14)= 110.00000 Z(14)= 40.00000
~~~~~~

ROCK = -30.000 RWL = 23.000 XS = .000 WI = .000
ZC = .000 ZWR = .000
C = .000 PHI = 30.000 GAMA = 1.900 GAMAW= 1.000
BBAR = .100 AH = .100 AVR = .500 EQM = 7.000
~~~~~~

ENTX = .000 ENTY = .000
NEP = 0 NOPT = 0
XEXITI= 20.000 XEXITL= 110.000 GAP = 10.000
~~~~~~

CHECK F.S. FOR -AVR ALSO
~~~~~~

F.S : DYN. :WEIGHT OF:AH CRI : COORDINATES OF : COORDINATES OF :RADIUS
*******:DIS(M):WEDGE(T) :TICAL : CENTER(XC,YC) : EXIT POINT :R(M)
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~~~~~~

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -49.41, 305.43
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = 4.14, 116.47
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

SLIP CIRCLE IS ABOVE PROFILE OF SLOPE FOR
COORDINATES OF CENTRE = -10.34, 167.43
PLEASE REVISE INPUT DATA IF WEIGHT OF WEGDE IS ZERO.

.5833 10.572 .39E+02 .000 (-34.44, 74.87) (20.00, 13.00) 82.42

~~~~~~

STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS1-STATIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE

~~~~~~

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->ILBS1.DAT
OUTPUT FILE NAME ->OSARC.DAT

~~~~~~

COORDINATES OF POINTS ALONG SLOPE ->
X(1)= .00000 Z(1)= .00000
X(2)= 10.00000 Z(2)= 10.00000
X(3)= 19.00000 Z(3)= 20.00000
X(4)= 20.00000 Z(4)= 21.00000
X(5)= 30.00000 Z(5)= 32.00000
X(6)= 40.00000 Z(6)= 43.00000
X(7)= 50.00000 Z(7)= 48.00000
X(8)= 60.00000 Z(8)= 58.00000

~~~~~~

ROCK = -20.000 RWL = 13.000 XS = .000 WI = .000
ZC = .000 ZWR = .000
C = 10.000 PHI = 30.000 GAMA = 1.700 GAMAW= 1.000
BBAR = .000 AH = .000 AVR = .000 EQM = .000

~~~~~~

ENTX = .000 ENTY = .000
NEP = 0 NOPT = 0
XEXITI= 30.000 XEXITL= 60.000 GAP = 5.000

~~~~~~

F.S : DYN. :WEIGHT OF:AH CRI : COORDINATES OF : COORDINATES OF :RADIUS
*******:DIS(M):WEDGE(T) :TICAL : CENTER(XC,YC) : EXIT POINT :R(M)

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1.6886 .000 .15E+04 .315 (.33, 59.69) (60.00, 58.00) 59.69

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STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS1-STATIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE

~~~~~~

```
   UNITS USED          -> TONNE - METER - DEGREE
   INPUT FILE NAME      ->ILBS1.DAT
   OUTPUT FILE NAME     ->OSARC.DAT
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 COORDINATES OF POINTS ALONG SLOPE ->
   X( 1)=    .00000    Z( 1)=    .00000
   X( 2)=  10.00000    Z( 2)=  10.00000
   X( 3)=  19.00000    Z( 3)=  20.00000
   X( 4)=  20.00000    Z( 4)=  21.00000
   X( 5)=  30.00000    Z( 5)=  32.00000
   X( 6)=  40.00000    Z( 6)=  43.00000
   X( 7)=  50.00000    Z( 7)=  48.00000
   X( 8)=  60.00000    Z( 8)=  58.00000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ROCK =   -20.000    RWL  =    13.000    XS   =      .000    WI   =      .000
 ZC   =      .000    ZWR  =      .000
 C    =     5.000    PHI  =    20.000    GAMA =     1.900    GAMAW=     1.000
 BBAR =      .100    AH   =      .000    AVR  =      .000    EQM  =      .000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ENTX =      .000    ENTY =      .000
 NEP  = 0            NOPT = 0
 XEXITI=    30.000    XEXITL=    60.000    GAP  =     5.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 F.S   : DYN. :WEIGHT OF:AH CRI : COORDINATES OF   : COORDINATES OF    :RADIUS
*******:DIS(M):WEDGE(T) :TICAL  : CENTER(XC,YC)    : EXIT POINT        :R(M)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
  .8508   .000   .16E+04  -.083 (   -5.59,   65.81) (   60.00,   58.00)   66.05
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS1-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE

~~~~~~

```
   UNITS USED          -> TONNE - METER - DEGREE
   INPUT FILE NAME      ->ILBS1.DAT
   OUTPUT FILE NAME     ->OSARC.DAT
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 COORDINATES OF POINTS ALONG SLOPE ->
   X( 1)=    .00000    Z( 1)=    .00000
   X( 2)=  10.00000    Z( 2)=  10.00000
   X( 3)=  19.00000    Z( 3)=  20.00000
   X( 4)=  20.00000    Z( 4)=  21.00000
   X( 5)=  30.00000    Z( 5)=  32.00000
   X( 6)=  40.00000    Z( 6)=  43.00000
   X( 7)=  50.00000    Z( 7)=  48.00000
   X( 8)=  60.00000    Z( 8)=  58.00000
```

```
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
ROCK =   -20.000    RWL  =    13.000    XS   =     .000    WI   =     .000
ZC   =     .000    ZWR  =     .000
C    =   10.000    PHI  =    30.000    GAMA =     1.700    GAMAW=     1.000
BBAR =     .000    AH   =     .100    AVR  =     .500    EQM  =     7.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
ENTX =     .000    ENTY =     .000
NEP  = 0           NOPT = 0
XEXITI=    30.000    XEXITL=    60.000    GAP   =     5.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
CHECK F.S. FOR -AVR ALSO
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
F.S   : DYN. :WEIGHT OF:AH CRI : COORDINATES OF   : COORDINATES OF    :RADIUS
*******:DIS(M):WEDGE(T) :TICAL  : CENTER(XC,YC)    : EXIT POINT        :R(M)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
1.3813   .000   .16E+04   .304 (    1.13,    58.87) (    60.00,    58.00)   58.88
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS1-SEISMIC SATURATED CONDITION

```
STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
   UNITS USED          -> TONNE - METER - DEGREE
   INPUT FILE NAME      ->ILBS1.DAT
   OUTPUT FILE NAME     ->OSARC.DAT
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
COORDINATES OF POINTS ALONG SLOPE ->
   X( 1)=     .00000    Z( 1)=     .00000
   X( 2)=   10.00000    Z( 2)=   10.00000
   X( 3)=   19.00000    Z( 3)=   20.00000
   X( 4)=   20.00000    Z( 4)=   21.00000
   X( 5)=   30.00000    Z( 5)=   32.00000
   X( 6)=   40.00000    Z( 6)=   43.00000
   X( 7)=   50.00000    Z( 7)=   48.00000
   X( 8)=   60.00000    Z( 8)=   58.00000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
ROCK =   -20.000    RWL  =    13.000    XS   =     .000    WI   =     .000
ZC   =     .000    ZWR  =     .000
C    =    5.000    PHI  =    20.000    GAMA =     1.900    GAMAW=     1.000
BBAR =     .100    AH   =     .100    AVR  =     .500    EQM  =     7.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
ENTX =     .000    ENTY =     .000
NEP  = 0           NOPT = 0
XEXITI=    30.000    XEXITL=    60.000    GAP   =     5.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
CHECK F.S. FOR -AVR ALSO
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
F.S   : DYN. :WEIGHT OF:AH CRI : COORDINATES OF   : COORDINATES OF    :RADIUS
*******:DIS(M):WEDGE(T) :TICAL  : CENTER(XC,YC)    : EXIT POINT        :R(M)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

```
 .6998 10.572   .16E+04   .000 (   -5.59,   65.81) (   60.00,   58.00)   66.05
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS2-STATIC DRY CONDITION

```
STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
   UNITS USED          -> TONNE - METER - DEGREE
   INPUT FILE NAME     ->ILBS2.DAT
   OUTPUT FILE NAME    ->OSARC.DAT
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 COORDINATES OF POINTS ALONG SLOPE ->
   X( 1)=    .00000   Z( 1)=    .00000
   X( 2)=  10.00000   Z( 2)=  10.00000
   X( 3)=  19.00000   Z( 3)=  20.00000
   X( 4)=  20.00000   Z( 4)=  21.00000
   X( 5)=  30.00000   Z( 5)=  32.00000
   X( 6)=  40.00000   Z( 6)=  43.00000
   X( 7)=  50.00000   Z( 7)=  48.00000
   X( 8)=  60.00000   Z( 8)=  58.00000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ROCK =   -50.000    RWL  =    18.000    XS   =     .000    WI   =     .000
 ZC   =      .000    ZWR  =      .000
 C    =    10.000    PHI  =    30.000    GAMA =    1.700    GAMAW=    1.000
 BBAR =      .000    AH   =      .000    AVR  =     .000    EQM  =     .000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ENTX =      .000    ENTY =      .000
 NEP  = 0            NOPT = 0
 XEXITI=    30.000   XEXITL=    80.000   GAP  =    5.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 F.S   : DYN. :WEIGHT OF:AH CRI : COORDINATES OF   : COORDINATES OF    :RADIUS
*******:DIS(M):WEDGE(T) :TICAL  : CENTER(XC,YC)    : EXIT POINT        :R(M)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 1.5119   .000   .25E+04   .233 (   -1.38,   81.44) (   80.00,   78.00)   81.45
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS2-STATIC SATURATED CONDITION

```
STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
   UNITS USED          -> TONNE - METER - DEGREE
   INPUT FILE NAME     ->ILBS2.DAT
   OUTPUT FILE NAME    ->OSARC.DAT
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 COORDINATES OF POINTS ALONG SLOPE ->
   X( 1)=    .00000   Z( 1)=    .00000
   X( 2)=  10.00000   Z( 2)=  10.00000
   X( 3)=  19.00000   Z( 3)=  20.00000
   X( 4)=  20.00000   Z( 4)=  21.00000
   X( 5)=  30.00000   Z( 5)=  32.00000
```

X(6)= 40.00000   Z(6)= 43.00000
X(7)= 50.00000   Z(7)= 48.00000
X(8)= 60.00000   Z(8)= 58.00000
~~~~~~
ROCK =   -50.000   RWL =   18.000   XS   =   .000   WI   =   .000
ZC   =   .000   ZWR =   .000
C   =   5.000   PHI =   20.000   GAMA =   1.900   GAMAW=   1.000
BBAR =   .100   AH   =   .000   AVR =   .000   EQM =   .000
~~~~~~
ENTX =   .000   ENTY =   .000
NEP = 0   NOPT = 0
XEXITI=   30.000   XEXITL=   80.000   GAP =   5.000
~~~~~~
F.S   : DYN. :WEIGHT OF:AH CRI : COORDINATES OF   : COORDINATES OF   :RADIUS
*******:DIS(M):WEDGE(T) :TICAL : CENTER(XC,YC)   : EXIT POINT   :R(M)
~~~~~~
.7701   .000   .26E+04 -.125 (-7.86,   88.09) (80.00,   78.00)   88.44
~~~~~~

STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS2-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
~~~~~~
UNITS USED   -> TONNE - METER - DEGREE
INPUT FILE NAME   ->ILBS2.DAT
OUTPUT FILE NAME   ->OSARC.DAT
~~~~~~
COORDINATES OF POINTS ALONG SLOPE ->
X(1)=   .00000   Z(1)=   .00000
X(2)= 10.00000   Z(2)= 10.00000
X(3)= 19.00000   Z(3)= 20.00000
X(4)= 20.00000   Z(4)= 21.00000
X(5)= 30.00000   Z(5)= 32.00000
X(6)= 40.00000   Z(6)= 43.00000
X(7)= 50.00000   Z(7)= 48.00000
X(8)= 60.00000   Z(8)= 58.00000
~~~~~~
ROCK =   -50.000   RWL =   18.000   XS   =   .000   WI   =   .000
ZC   =   .000   ZWR =   .000
C   =   10.000   PHI =   30.000   GAMA =   1.700   GAMAW=   1.000
BBAR =   .000   AH   =   .100   AVR =   .500   EQM =   7.000
~~~~~~
ENTX =   .000   ENTY =   .000
NEP = 0   NOPT = 0
XEXITI=   30.000   XEXITL=   80.000   GAP =   5.000
~~~~~~
CHECK F.S. FOR -AVR ALSO
~~~~~~
F.S   : DYN. :WEIGHT OF:AH CRI : COORDINATES OF   : COORDINATES OF   :RADIUS
*******:DIS(M):WEDGE(T) :TICAL : CENTER(XC,YC)   : EXIT POINT   :R(M)
~~~~~~

~~~~~~
1.2363 .000 .25E+04 .226 (-1.38, 81.44) (80.00, 78.00) 81.45
~~~~~~

STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS2-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
~~~~~~
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->ILBS2.DAT
OUTPUT FILE NAME ->OSARC.DAT
~~~~~~
COORDINATES OF POINTS ALONG SLOPE ->
X(1)= .00000 Z(1)= .00000
X(2)= 10.00000 Z(2)= 10.00000
X(3)= 19.00000 Z(3)= 20.00000
X(4)= 20.00000 Z(4)= 21.00000
X(5)= 30.00000 Z(5)= 32.00000
X(6)= 40.00000 Z(6)= 43.00000
X(7)= 50.00000 Z(7)= 48.00000
X(8)= 60.00000 Z(8)= 58.00000
~~~~~~
ROCK = -50.000 RWL = 18.000 XS = .000 WI = .000
ZC = .000 ZWR = .000
C = 5.000 PHI = 20.000 GAMA = 1.900 GAMAW= 1.000
BBAR = .100 AH = .100 AVR = .500 EQM = 7.000
~~~~~~
ENTX = .000 ENTY = .000
NEP = 0 NOPT = 0
XEXITI= 30.000 XEXITL= 80.000 GAP = 5.000
~~~~~~
CHECK F.S. FOR -AVR ALSO
~~~~~~
F.S : DYN. :WEIGHT OF:AH CRI : COORDINATES OF : COORDINATES OF :RADIUS
*******:DIS(M):WEDGE(T) :TICAL : CENTER(XC,YC) : EXIT POINT :R(M)
~~~~~~
.6312 10.572 .26E+04 .000 (-7.86, 88.09) (80.00, 78.00) 88.44
~~~~~~

STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS3-STATIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
~~~~~~
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->ILBS3.DAT
OUTPUT FILE NAME ->OSARC.DAT
~~~~~~
COORDINATES OF POINTS ALONG SLOPE ->
X(1)= .00000 Z(1)= .00000
X(2)= 10.00000 Z(2)= 13.00000

```
    X( 3)=  20.00000    Z( 3)=  24.00000
    X( 4)=  23.00000    Z( 4)=  26.00000
    X( 5)=  30.00000    Z( 5)=  33.00000
    X( 6)=  40.00000    Z( 6)=  44.00000
    X( 7)=  50.00000    Z( 7)=  52.00000
    X( 8)=  60.00000    Z( 8)=  59.00000
    X( 9)=  70.00000    Z( 9)=  70.00000
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ROCK =   -40.000     RWL  =    16.000     XS   =      .000    WI   =      .000
 ZC   =      .000     ZWR  =      .000
 C    =    10.000     PHI  =    30.000     GAMA =     1.700    GAMAW=     1.000
 BBAR =      .000     AH   =      .000     AVR  =      .000    EQM  =      .000
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ENTX =      .000     ENTY =      .000
 NEP  = 0             NOPT = 0
 XEXITI=    30.000    XEXITL=    70.000    GAP  =     5.000
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 F.S   : DYN. :WEIGHT OF:AH CRI : COORDINATES OF   : COORDINATES OF    :RADIUS
*******:DIS(M):WEDGE(T) :TICAL  : CENTER(XC,YC)    : EXIT POINT        :R(M)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 1.5497   .000   .21E+04   .249 (    -2.14,    72.14) (    70.00,    70.00)   72.17
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS3-STATIC SATURATED CONDITION

```
STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
    UNITS USED          -> TONNE - METER - DEGREE
    INPUT FILE NAME      ->ILBS3.DAT
    OUTPUT FILE NAME     ->OSARC.DAT
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 COORDINATES OF POINTS ALONG SLOPE ->
    X( 1)=    .00000    Z( 1)=    .00000
    X( 2)=  10.00000    Z( 2)=  13.00000
    X( 3)=  20.00000    Z( 3)=  24.00000
    X( 4)=  23.00000    Z( 4)=  26.00000
    X( 5)=  30.00000    Z( 5)=  33.00000
    X( 6)=  40.00000    Z( 6)=  44.00000
    X( 7)=  50.00000    Z( 7)=  52.00000
    X( 8)=  60.00000    Z( 8)=  59.00000
    X( 9)=  70.00000    Z( 9)=  70.00000
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ROCK =   -40.000     RWL  =    16.000     XS   =      .000    WI   =      .000
 ZC   =      .000     ZWR  =      .000
 C    =     5.000     PHI  =    20.000     GAMA =     1.900    GAMAW=     1.000
 BBAR =      .100     AH   =      .000     AVR  =      .000    EQM  =      .000
 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 ENTX =      .000     ENTY =      .000
 NEP  = 0             NOPT = 0
 XEXITI=    30.000    XEXITL=    70.000    GAP  =     5.000
```

~~~~~~

F.S : DYN. :WEIGHT OF:AH CRI : COORDINATES OF : COORDINATES OF :RADIUS
*******:DIS(M):WEDGE(T) :TICAL : CENTER(XC,YC) : EXIT POINT :R(M)

~~~~~~

.7888 .000 .23E+04 -.113 (-6.17, 76.17) (70.00, 70.00) 76.42

~~~~~~

STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS3-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE

~~~~~~

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->ILBS3.DAT
OUTPUT FILE NAME ->OSARC.DAT

~~~~~~

COORDINATES OF POINTS ALONG SLOPE ->
X(1)= .00000 Z(1)= .00000
X(2)= 10.00000 Z(2)= 13.00000
X(3)= 20.00000 Z(3)= 24.00000
X(4)= 23.00000 Z(4)= 26.00000
X(5)= 30.00000 Z(5)= 33.00000
X(6)= 40.00000 Z(6)= 44.00000
X(7)= 50.00000 Z(7)= 52.00000
X(8)= 60.00000 Z(8)= 59.00000
X(9)= 70.00000 Z(9)= 70.00000

~~~~~~

ROCK = -40.000 RWL = 16.000 XS = .000 WI = .000
ZC = .000 ZWR = .000
C = 10.000 PHI = 30.000 GAMA = 1.700 GAMAW= 1.000
BBAR = .000 AH = .100 AVR = .500 EQM = 7.000

~~~~~~

ENTX = .000 ENTY = .000
NEP = 0 NOPT = 0
XEXITI= 30.000 XEXITL= 70.000 GAP = 5.000

~~~~~~

CHECK F.S. FOR -AVR ALSO

~~~~~~

F.S : DYN. :WEIGHT OF:AH CRI : COORDINATES OF : COORDINATES OF :RADIUS
*******:DIS(M):WEDGE(T) :TICAL : CENTER(XC,YC) : EXIT POINT :R(M)

~~~~~~

1.2669 .000 .21E+04 .242 (-2.14, 72.14) (70.00, 70.00) 72.17

~~~~~~

STABILITY ANALYSIS OF LEFT BANK RESERVOIR SLOPE-LBS3-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH CIRCULAR SLIP SURFACE

~~~~~~

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->ILBS3.DAT

```
   OUTPUT FILE NAME     ->OSARC.DAT
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
COORDINATES OF POINTS ALONG SLOPE ->
   X( 1)=    .00000    Z( 1)=    .00000
   X( 2)=  10.00000    Z( 2)=  13.00000
   X( 3)=  20.00000    Z( 3)=  24.00000
   X( 4)=  23.00000    Z( 4)=  26.00000
   X( 5)=  30.00000    Z( 5)=  33.00000
   X( 6)=  40.00000    Z( 6)=  44.00000
   X( 7)=  50.00000    Z( 7)=  52.00000
   X( 8)=  60.00000    Z( 8)=  59.00000
   X( 9)=  70.00000    Z( 9)=  70.00000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
ROCK =   -40.000     RWL  =    16.000     XS   =      .000    WI   =      .000
ZC   =      .000     ZWR  =      .000
C    =     5.000     PHI  =    20.000     GAMA =     1.900    GAMAW=     1.000
BBAR =      .100     AH   =      .100     AVR  =      .500    EQM  =     7.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
ENTX =      .000     ENTY =      .000
NEP  = 0             NOPT = 0
XEXITI=    30.000    XEXITL=    70.000    GAP   =     5.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
CHECK F.S. FOR -AVR ALSO
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
F.S   : DYN. :WEIGHT OF:AH CRI : COORDINATES OF   : COORDINATES OF    :RADIUS
*******:DIS(M):WEDGE(T) :TICAL  : CENTER(XC,YC)    : EXIT POINT        :R(M)
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 .6459 10.572   .23E+04   .000 (   -6.53,   76.53) (   70.00,   70.00)   76.81
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

APPENDIX - VIII

SAMPLE INPUT FILES FOR EXECUTION OF PROGRAM SAST

PROGRAM - STABILITY ANALYSIS OF SLOPE WITH TALUS DEPOSIT

NAME OF PROGRAM -> SAST.FOR
UNITS USED -> TONNE-METER-DEGREE

GIVE INPUT DATA IN THE FOLLOWING SEQUENCE ->
NO. OF SLOPES
TITLE OF PROBLEM IN ONE LINE (< 80 CHARACTERS)
C, PHI, GAMA, GAMAW, Z, ZW, SIF, AH,Q, FS, EFFCY, EQM
(Number of above two lines = No. of slopes)

ENTER 0 FOR TERMINATION
1 FOR FURTHER HELP
2 FOR EXECUTION

AV = Coefficient of vertical earthquake acceleration
AH = Coefficient of horiz. earthquake acceleration
EQM = Corresponding EQ. magnitude on Richter Scale
C = Cohesion of talus deposit
EFFCY = Efficiency of drains (generally observed to be 0.50)
It is more for higher K (horz.) / K (vert.)
FS = Allowable factor of safety in static condition
GAMA = Unit weight of talus (saturated)
GAMAW = Unit weight of water
No = Number of cases to be analysed
PHI = Angle of internal friction of talus deposit
Q = Surcharge on slope (live)
SAI = Dip of slope face = dip of rock slope
Z = Average vertical depth of talus / debris deposit
ZW = Vertical depth of ground water during (worst)
rainy season below slope surface
= depth of wet soil below slope in off season

NOTE = = > THIS PROGRAM MAY ALSO BE USED FOR DEBRIS / DIP/ REGOLITH SLOPES USING STRENGTH PARAMETERSOF PLANE SLIP.
FOR SURFICIAL SLIDING IN SILTY SOIL DUE TO LONG SPELL OF RAINS, ASSUME Zw = 0. AND Z = OBSERVED DEPTH OF SATURATION BELOW SLOPE SURFACE

ENTER 0 FOR TERMINATION
2 FOR EXECUTION

APPENDIX - IX

OUTPUT FILES FOR STABILITY ANALYSIS OF TALUS SLOPES USING PROGRAM SAST

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS2-STATIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 8.000 SIF = 40.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.024
FS2(With Surcharge & W.T.,But No E.Q.) =1.024
FS3(No Surcharge & E.Q. , But W.T.) =1.024
FS4(No Surcharge , With E.Q. & Dry) =1.024 .012 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.024 .012 .00

~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = .000 SIF = 40.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.024
FS2(With Surcharge & W.T.,But No E.Q.) = .586
FS3(No Surcharge & E.Q. , But W.T.) = .586
FS4(No Surcharge , With E.Q. & Dry) =1.024 .012 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .586 -.213 .00

~~~~~~

Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 4.778 FOR FACTOR OF SAFETY(3)= 1.00

****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT

****
CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 4.000 SIF = 40.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.024
FS2(With Surcharge & W.T.,But No E.Q.) = .805
FS3(No Surcharge & E.Q. , But W.T.) = .805
FS4(No Surcharge , With E.Q. & Dry) =1.024 .012 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .805 -.100 .00
~~~~~~
Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 4.778 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS2-STATIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = 8.000 SIF = 40.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .582
FS2(With Surcharge & W.T.,But No E.Q.) = .582
FS3(No Surcharge & E.Q. , But W.T.) = .582
FS4(No Surcharge , With E.Q. & Dry) = .582 -.226 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .582 -.226 .00
~~~~~~
Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 6.158 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = .000 SIF = 40.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .582
FS2(With Surcharge & W.T.,But No E.Q.) = .342
FS3(No Surcharge & E.Q. , But W.T.) = .342
FS4(No Surcharge , With E.Q. & Dry) = .582 -.226 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .342 -.356 .00
~~~~~~
Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 6.724 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = 4.000 SIF = 40.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .582
FS2(With Surcharge & W.T.,But No E.Q.) = .462
FS3(No Surcharge & E.Q. , But W.T.) = .462
FS4(No Surcharge , With E.Q. & Dry) = .582 -.226 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .462 -.291 .00
~~~~~~
Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 6.724 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS2-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1

C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 8.000 SIF = 40.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.024
FS2(With Surcharge & W.T.,But No E.Q.) =1.024
FS3(No Surcharge & E.Q. , But W.T.) =1.024
FS4(No Surcharge , With E.Q. & Dry) = .864 .012 .26
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .864 .012 .26
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = .000 SIF = 40.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.024
FS2(With Surcharge & W.T.,But No E.Q.) = .586
FS3(No Surcharge & E.Q. , But W.T.) = .586
FS4(No Surcharge , With E.Q. & Dry) = .864 .012 .26
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .455 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 4.778 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 4.000 SIF = 40.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.024
~~~~~~

FS2(With Surcharge & W.T.,But No E.Q.) = .805
FS3(No Surcharge & E.Q. , But W.T.) = .805
FS4(No Surcharge , With E.Q. & Dry) = .864 .012 .26
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .660 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 4.778 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS2-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = 8.000 SIF = 40.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .582
FS2(With Surcharge & W.T.,But No E.Q.) = .582
FS3(No Surcharge & E.Q. , But W.T.) = .582
FS4(No Surcharge , With E.Q. & Dry) = .487 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .487 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 6.158 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = .000 SIF = 40.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .582
FS2(With Surcharge & W.T.,But No E.Q.) = .342

FS3(No Surcharge & E.Q. , But W.T.) = .342
FS4(No Surcharge , With E.Q. & Dry) = .487 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .262 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 6.724 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS2.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = 4.000 SIF = 40.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .582
FS2(With Surcharge & W.T.,But No E.Q.) = .462
FS3(No Surcharge & E.Q. , But W.T.) = .462
FS4(No Surcharge , With E.Q. & Dry) = .487 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .375 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 6.724 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS4-STATIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 5.000 ZW = 5.000 SIF = 27.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******
CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.770

FS2(With Surcharge & W.T.,But No E.Q.)   =1.770
FS3(No Surcharge & E.Q. , But W.T.)   =1.770
FS4(No Surcharge , With E.Q. & Dry)   =1.770   .311   .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.770   .311   .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED   -> TONNE - METER - DEGREE
INPUT FILE NAME   ->IRBS4.DAT
OUTPUT FILE NAME   ->OSAST.DAT
****
CASE NUMBER =   2
C   =   1.870   PHI =   32.000   GAMA =   1.700   GAMAW =   1.000
Z   =   5.000   ZW   =   .000   SIF   =   27.000   AH   =   .000
AV   =   .000   EQM =   .000   Q   =   .000   FS   =   1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******   CRITICAL   DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)   =1.770
FS2(With Surcharge & W.T.,But No E.Q.)   =1.049
FS3(No Surcharge & E.Q. , But W.T.)   =1.049
FS4(No Surcharge , With E.Q. & Dry)   =1.770   .311   .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.049   .020   .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED   -> TONNE - METER - DEGREE
INPUT FILE NAME   ->IRBS4.DAT
OUTPUT FILE NAME   ->OSAST.DAT
****
CASE NUMBER =   3
C   =   1.870   PHI =   32.000   GAMA =   1.700   GAMAW =   1.000
Z   =   5.000   ZW   =   2.500   SIF   =   27.000   AH   =   .000
AV   =   .000   EQM =   .000   Q   =   .000   FS   =   1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******   CRITICAL   DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)   =1.770
FS2(With Surcharge & W.T.,But No E.Q.)   =1.410
FS3(No Surcharge & E.Q. , But W.T.)   =1.410
FS4(No Surcharge , With E.Q. & Dry)   =1.770   .311   .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.410   .166   .00
~~~~~~
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS4-STATIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 5.000 ZW = 5.000 SIF = 27.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .997
FS2(With Surcharge & W.T.,But No E.Q.) = .997
FS3(No Surcharge & E.Q. , But W.T.) = .997
FS4(No Surcharge , With E.Q. & Dry) = .997 -.001 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .997 -.001 .00

~~~~~~

Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = .067 FOR FACTOR OF SAFETY(3)= 1.00

****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 5.000 ZW = .000 SIF = 27.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .997
FS2(With Surcharge & W.T.,But No E.Q.) = .600
FS3(No Surcharge & E.Q. , But W.T.) = .600
FS4(No Surcharge , With E.Q. & Dry) = .997 -.001 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .600 -.162 .00

~~~~~~

Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 3.108 FOR FACTOR OF SAFETY(3)= 1.00

****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M

****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 5.000 ZW = 2.500 SIF = 27.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .997
FS2(With Surcharge & W.T.,But No E.Q.) = .798
FS3(No Surcharge & E.Q. , But W.T.) = .798
FS4(No Surcharge , With E.Q. & Dry) = .997 -.001 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .798 -.082 .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 3.108 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS4-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 5.000 ZW = 5.000 SIF = 27.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.770
FS2(With Surcharge & W.T.,But No E.Q.) =1.770
FS3(No Surcharge & E.Q. , But W.T.) =1.770
FS4(No Surcharge , With E.Q. & Dry) =1.436 .311 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.436 .311 .00

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
~~~~~~

OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 2

C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000

Z = 5.000 ZW = .000 SIF = 27.000 AH = .100

AV = -.050 EQM = 7.000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)

FS1(No Surcharge & E.Q.,But Dry) =1.770

FS2(With Surcharge & W.T.,But No E.Q.) =1.049

FS3(No Surcharge & E.Q. , But W.T.) =1.049

FS4(No Surcharge , With E.Q. & Dry) =1.436 .311 .00

FS5(No Surcharge , With E.Q. & W.T.[WORST]= .807 .020 .19

~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M

****

UNITS USED -> TONNE - METER - DEGREE

INPUT FILE NAME ->IRBS4.DAT

OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 3

C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000

Z = 5.000 ZW = 2.500 SIF = 27.000 AH = .100

AV = -.050 EQM = 7.000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)

FS1(No Surcharge & E.Q.,But Dry) =1.770

FS2(With Surcharge & W.T.,But No E.Q.) =1.410

FS3(No Surcharge & E.Q. , But W.T.) =1.410

FS4(No Surcharge , With E.Q. & Dry) =1.436 .311 .00

FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.122 .166 .00

~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS4-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M

****

UNITS USED -> TONNE - METER - DEGREE

INPUT FILE NAME ->IRBS4.DAT

OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 1

C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000

Z = 5.000 ZW = 5.000 SIF = 27.000 AH = .100

AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .997
FS2(With Surcharge & W.T.,But No E.Q.) = .997
FS3(No Surcharge & E.Q. , But W.T.) = .997
FS4(No Surcharge , With E.Q. & Dry) = .803 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .803 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = .067 FOR FACTOR OF SAFETY(3)= 1.00
****
STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 5.000 ZW = .000 SIF = 27.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .997
FS2(With Surcharge & W.T.,But No E.Q.) = .600
FS3(No Surcharge & E.Q. , But W.T.) = .600
FS4(No Surcharge , With E.Q. & Dry) = .803 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .457 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 3.108 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 5.000 ZW = 2.500 SIF = 27.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
~~~~~~

ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .997
FS2(With Surcharge & W.T.,But No E.Q.) = .798
FS3(No Surcharge & E.Q. , But W.T.) = .798
FS4(No Surcharge , With E.Q. & Dry) = .803 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .630 .000 10.57
~~~~~~

Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 3.108 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS5-STATIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS5.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = 6.000 SIF = 32.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.408
FS2(With Surcharge & W.T.,But No E.Q.) =1.408
FS3(No Surcharge & E.Q. , But W.T.) =1.408
FS4(No Surcharge , With E.Q. & Dry) =1.408 .183 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.408 .183 .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS5.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = .000 SIF = 32.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.408
FS2(With Surcharge & W.T.,But No E.Q.) = .820
FS3(No Surcharge & E.Q. , But W.T.) = .820
FS4(No Surcharge , With E.Q. & Dry) =1.408 .183 .00

FS5(No Surcharge , With E.Q. & W.T.[WORST]= .820 -.081 .00
~~~~~~

Measure adopted to get required factor of safety ->
SPACING OF DRAIN = 18.39
DEPTH OF DRAIN = 3.68
EFFICIENCY OF DRAIN = .50
AVERAGE VERTICAL DEPTH OF W.T.= 1.84
PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS5.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = 3.000 SIF = 32.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.408
FS2(With Surcharge & W.T.,But No E.Q.) =1.114
FS3(No Surcharge & E.Q. , But W.T.) =1.114
FS4(No Surcharge , With E.Q. & Dry) =1.408 .183 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.114 .051 .00
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS5-STATIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS5.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 6.000 ZW = 6.000 SIF = 32.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .797
FS2(With Surcharge & W.T.,But No E.Q.) = .797

FS3(No Surcharge & E.Q. , But W.T.)   = .797
FS4(No Surcharge , With E.Q. & Dry)   = .797   -.093   .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .797   -.093   .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED =   3.161 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED   -> TONNE - METER - DEGREE
INPUT FILE NAME   ->IRBS5.DAT
OUTPUT FILE NAME   ->OSAST.DAT
****
CASE NUMBER =   2
C   =   .935   PHI =   21.000   GAMA =   1.900   GAMAW =   1.000
Z   =   6.000   ZW   =   .000   SIF   =   32.000   AH   =   .000
AV   =   .000   EQM =   .000   Q   =   .000   FS   =   1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******   CRITICAL   DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)   = .797
FS2(With Surcharge & W.T.,But No E.Q.)   = .473
FS3(No Surcharge & E.Q. , But W.T.)   = .473
FS4(No Surcharge , With E.Q. & Dry)   = .797   -.093   .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .473   -.242   .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED =   4.456 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED   -> TONNE - METER - DEGREE
INPUT FILE NAME   ->IRBS5.DAT
OUTPUT FILE NAME   ->OSAST.DAT
****
CASE NUMBER =   3
C   =   .935   PHI =   21.000   GAMA =   1.900   GAMAW =   1.000
Z   =   6.000   ZW   =   3.000   SIF   =   32.000   AH   =   .000
AV   =   .000   EQM =   .000   Q   =   .000   FS   =   1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******   CRITICAL   DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)   = .797
FS2(With Surcharge & W.T.,But No E.Q.)   = .635
FS3(No Surcharge & E.Q. , But W.T.)   = .635
FS4(No Surcharge , With E.Q. & Dry)   = .797   -.093   .00

FS5(No Surcharge , With E.Q. & W.T.[WORST]= .635 -.168 .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 4.456 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS5-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS5.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = 6.000 SIF = 32.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.408
FS2(With Surcharge & W.T.,But No E.Q.) =1.408
FS3(No Surcharge & E.Q. , But W.T.) =1.408
FS4(No Surcharge , With E.Q. & Dry) =1.167 .183 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.167 .183 .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS5.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = .000 SIF = 32.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.408
FS2(With Surcharge & W.T.,But No E.Q.) = .820
FS3(No Surcharge & E.Q. , But W.T.) = .820
FS4(No Surcharge , With E.Q. & Dry) =1.167 .183 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .637 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->
~~~~~~

SPACING OF DRAIN = 18.39
DEPTH OF DRAIN = 3.68
EFFICIENCY OF DRAIN = .50
AVERAGE VERTICAL DEPTH OF W.T.= 1.84

PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .

****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS5.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = 3.000 SIF = 32.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.408
FS2(With Surcharge & W.T.,But No E.Q.) =1.114
FS3(No Surcharge & E.Q. , But W.T.) =1.114
FS4(No Surcharge , With E.Q. & Dry) =1.167 .183 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .902 .051 .07

~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS5-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS5.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 6.000 ZW = 6.000 SIF = 32.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .797
FS2(With Surcharge & W.T.,But No E.Q.) = .797
FS3(No Surcharge & E.Q. , But W.T.) = .797
FS4(No Surcharge , With E.Q. & Dry) = .656 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .656 .000 10.57
~~~~~~

~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 3.161 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS5.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 6.000 ZW = .000 SIF = 32.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .797
FS2(With Surcharge & W.T.,But No E.Q.) = .473
FS3(No Surcharge & E.Q. , But W.T.) = .473
FS4(No Surcharge , With E.Q. & Dry) = .656 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .364 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 4.456 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 5.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS5.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 6.000 ZW = 3.000 SIF = 32.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .797
FS2(With Surcharge & W.T.,But No E.Q.) = .635
FS3(No Surcharge & E.Q. , But W.T.) = .635
FS4(No Surcharge , With E.Q. & Dry) = .656 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .510 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->
~~~~~~

DEPTH OF EXCAVATION REQUIRED = 4.456 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS6-STATIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 8.000 SIF = 30.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.400
FS2(With Surcharge & W.T.,But No E.Q.) =1.400
FS3(No Surcharge & E.Q. , But W.T.) =1.400
FS4(No Surcharge , With E.Q. & Dry) =1.400 .173 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.400 .173 .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = .000 SIF = 30.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.400
FS2(With Surcharge & W.T.,But No E.Q.) = .763
FS3(No Surcharge & E.Q. , But W.T.) = .763
FS4(No Surcharge , With E.Q. & Dry) =1.400 .173 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .763 -.102 .00
~~~~~~
Measure adopted to get required factor of safety ->

SPACING OF DRAIN = 29.76
DEPTH OF DRAIN = 5.95

EFFICIENCY OF DRAIN = .50
AVERAGE VERTICAL DEPTH OF W.T.= 2.98

PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 4.000 SIF = 30.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.400
FS2(With Surcharge & W.T.,But No E.Q.) =1.082
FS3(No Surcharge & E.Q. , But W.T.) =1.082
FS4(No Surcharge , With E.Q. & Dry) =1.400 .173 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.082 .035 .00
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS6-STATIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = 8.000 SIF = 30.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .807
FS2(With Surcharge & W.T.,But No E.Q.) = .807
FS3(No Surcharge & E.Q. , But W.T.) = .807
FS4(No Surcharge , With E.Q. & Dry) = .807 -.085 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .807 -.085 .00
~~~~~~

~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 4.609 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = .000 SIF = 30.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .807
FS2(With Surcharge & W.T.,But No E.Q.) = .457
FS3(No Surcharge & E.Q. , But W.T.) = .457
FS4(No Surcharge , With E.Q. & Dry) = .807 -.085 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .457 -.238 .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 6.341 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = 4.000 SIF = 30.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .807
FS2(With Surcharge & W.T.,But No E.Q.) = .632
FS3(No Surcharge & E.Q. , But W.T.) = .632
FS4(No Surcharge , With E.Q. & Dry) = .807 -.085 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .632 -.161 .00
~~~~~~
Measure adopted to get required factor of safety ->
~~~~~~

DEPTH OF EXCAVATION REQUIRED = 6.341 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS6-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 8.000 SIF = 30.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.400
FS2(With Surcharge & W.T.,But No E.Q.) =1.400
FS3(No Surcharge & E.Q. , But W.T.) =1.400
FS4(No Surcharge , With E.Q. & Dry) =1.142 .173 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.142 .173 .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = .000 SIF = 30.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.400
FS2(With Surcharge & W.T.,But No E.Q.) = .763
FS3(No Surcharge & E.Q. , But W.T.) = .763
FS4(No Surcharge , With E.Q. & Dry) =1.142 .173 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .576 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->
SPACING OF DRAIN = 29.76
DEPTH OF DRAIN = 5.95
EFFICIENCY OF DRAIN = .50

AVERAGE VERTICAL DEPTH OF W.T.=   2.98

PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .
****
STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 4.000 SIF = 30.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.400
FS2(With Surcharge & W.T.,But No E.Q.) =1.082
FS3(No Surcharge & E.Q. , But W.T.) =1.082
FS4(No Surcharge , With E.Q. & Dry) =1.142 .173 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .859 .035 .12
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS6-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = 8.000 SIF = 30.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .807
FS2(With Surcharge & W.T.,But No E.Q.) = .807
FS3(No Surcharge & E.Q. , But W.T.) = .807
FS4(No Surcharge , With E.Q. & Dry) = .655 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .655 .000 10.57
~~~~~~

Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 4.609 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = .000 SIF = 30.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .807
FS2(With Surcharge & W.T.,But No E.Q.) = .457
FS3(No Surcharge & E.Q. , But W.T.) = .457
FS4(No Surcharge , With E.Q. & Dry) = .655 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .343 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 6.341 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = 4.000 SIF = 30.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .807
FS2(With Surcharge & W.T.,But No E.Q.) = .632
FS3(No Surcharge & E.Q. , But W.T.) = .632
FS4(No Surcharge , With E.Q. & Dry) = .655 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .499 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 6.341 FOR FACTOR OF SAFETY(3)= 1.00

****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS7-STATIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS7.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = 6.000 SIF = 20.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =2.287
FS2(With Surcharge & W.T.,But No E.Q.) =2.287
FS3(No Surcharge & E.Q. , But W.T.) =2.287
FS4(No Surcharge , With E.Q. & Dry) =2.287 .427 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=2.287 .427 .00

~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS7.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = .000 SIF = 20.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =2.287
FS2(With Surcharge & W.T.,But No E.Q.) =1.277
FS3(No Surcharge & E.Q. , But W.T.) =1.277
FS4(No Surcharge , With E.Q. & Dry) =2.287 .427 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.277 .092 .00

~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS7.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = 3.000 SIF = 20.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =2.287
FS2(With Surcharge & W.T.,But No E.Q.) =1.782
FS3(No Surcharge & E.Q. , But W.T.) =1.782
FS4(No Surcharge , With E.Q. & Dry) =2.287 .427 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.782 .260 .00
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS7-STATIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS7.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 6.000 ZW = 6.000 SIF = 20.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.310
FS2(With Surcharge & W.T.,But No E.Q.) =1.310
FS3(No Surcharge & E.Q. , But W.T.) =1.310
FS4(No Surcharge , With E.Q. & Dry) =1.310 .100 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.310 .100 .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS7.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 6.000 ZW = .000 SIF = 20.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
~~~~~~

FS1(No Surcharge & E.Q.,But Dry) =1.310
FS2(With Surcharge & W.T.,But No E.Q.) = .755
FS3(No Surcharge & E.Q. , But W.T.) = .755
FS4(No Surcharge , With E.Q. & Dry) =1.310 .100 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .755 -.079 .00
~~~~~~
Measure adopted to get required factor of safety ->
SPACING OF DRAIN = 26.51
DEPTH OF DRAIN = 5.30
EFFICIENCY OF DRAIN = .50
AVERAGE VERTICAL DEPTH OF W.T.= 2.65
PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS7.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 6.000 ZW = 3.000 SIF = 20.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.310
FS2(With Surcharge & W.T.,But No E.Q.) =1.032
FS3(No Surcharge & E.Q. , But W.T.) =1.032
FS4(No Surcharge , With E.Q. & Dry) =1.310 .100 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.032 .010 .00
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS7-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS7.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = 6.000 SIF = 20.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~

~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =2.287
FS2(With Surcharge & W.T.,But No E.Q.) =2.287
FS3(No Surcharge & E.Q. , But W.T.) =2.287
FS4(No Surcharge , With E.Q. & Dry) =1.746 .427 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.746 .427 .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS7.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = .000 SIF = 20.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =2.287
FS2(With Surcharge & W.T.,But No E.Q.) =1.277
FS3(No Surcharge & E.Q. , But W.T.) =1.277
FS4(No Surcharge , With E.Q. & Dry) =1.746 .427 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .922 .092 .01
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS7.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 6.000 ZW = 3.000 SIF = 20.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =2.287
FS2(With Surcharge & W.T.,But No E.Q.) =1.782
FS3(No Surcharge & E.Q. , But W.T.) =1.782
FS4(No Surcharge , With E.Q. & Dry) =1.746 .427 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.334 .260 .00
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS7-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS7.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 6.000 ZW = 6.000 SIF = 20.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000

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FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)

FS1(No Surcharge & E.Q.,But Dry) =1.310
FS2(With Surcharge & W.T.,But No E.Q.) =1.310
FS3(No Surcharge & E.Q. , But W.T.) =1.310
FS4(No Surcharge , With E.Q. & Dry) = .995 .100 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .995 .100 .00

~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS7.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 6.000 ZW = .000 SIF = 20.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)

FS1(No Surcharge & E.Q.,But Dry) =1.310
FS2(With Surcharge & W.T.,But No E.Q.) = .755
FS3(No Surcharge & E.Q. , But W.T.) = .755
FS4(No Surcharge , With E.Q. & Dry) = .995 .100 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .542 .000 10.57

~~~~~~

Measure adopted to get required factor of safety ->

SPACING OF DRAIN = 26.51
DEPTH OF DRAIN = 5.30
EFFICIENCY OF DRAIN = .50
AVERAGE VERTICAL DEPTH OF W.T.= 2.65

PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.

```
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .
*******************************************************************************
STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
 ******************************************************************************
    UNITS USED          -> TONNE - METER - DEGREE
    INPUT FILE NAME      ->IRBS7.DAT
    OUTPUT FILE NAME     ->OSAST.DAT
 ******************************************************************************
 CASE NUMBER =    3
C     =     .935    PHI   =    21.000    GAMA  =     1.900    GAMAW =    1.000
Z     =    6.000    ZW    =     3.000    SIF   =    20.000    AH    =     .100
AV    =    -.050    EQM   =     7.000    Q     =      .000    FS    =    1.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******     CRITICAL     DYNAMIC
                                          ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)          =1.310
FS2(With Surcharge & W.T.,But No E.Q.)    =1.032
FS3(No Surcharge & E.Q. , But W.T.)       =1.032
FS4(No Surcharge , With E.Q. & Dry)       = .995       .100             .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .768       .010             .29
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS11-STATIC DRY CONDITION

```
STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M
 ******************************************************************************
    UNITS USED          -> TONNE - METER - DEGREE
    INPUT FILE NAME      ->IRBS11.DAT
    OUTPUT FILE NAME     ->OSAST.DAT
 ******************************************************************************
 CASE NUMBER =    1
C     =    4.000    PHI   =    32.000    GAMA  =     1.700    GAMAW =    1.000
Z     =   10.000    ZW    =    10.000    SIF   =    35.000    AH    =     .000
AV    =     .000    EQM   =      .000    Q     =      .000    FS    =    1.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******     CRITICAL     DYNAMIC
                                          ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)          =1.393
FS2(With Surcharge & W.T.,But No E.Q.)    =1.393
FS3(No Surcharge & E.Q. , But W.T.)       =1.393
FS4(No Surcharge , With E.Q. & Dry)       =1.393       .187             .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.393       .187             .00
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M
  ******************************************************************************
    UNITS USED          -> TONNE - METER - DEGREE
    INPUT FILE NAME      ->IRBS11.DAT
```

```
   OUTPUT FILE NAME     ->OSAST.DAT
 ******************************************************************************
 CASE NUMBER =    2
C     =     4.000    PHI   =    32.000    GAMA  =     1.700    GAMAW =    1.000
Z     =    10.000    ZW    =      .000    SIF   =    35.000    AH    =     .000
AV    =      .000    EQM   =      .000    Q     =      .000    FS    =    1.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******     CRITICAL     DYNAMIC
                                        ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)          =1.393
FS2(With Surcharge & W.T.,But No E.Q.)    = .868
FS3(No Surcharge & E.Q. , But W.T.)       = .868
FS4(No Surcharge , With E.Q. & Dry)       =1.393       .187             .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .868      -.063             .00
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Measure adopted to get required factor of safety ->
 SPACING OF DRAIN              =  25.10
DEPTH OF DRAIN                 =   5.02
EFFICIENCY OF DRAIN            =    .50
AVERAGE VERTICAL DEPTH OF W.T.=   2.51

 PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .
******************************************************************************


  STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M
 ******************************************************************************
   UNITS USED          -> TONNE - METER - DEGREE
   INPUT FILE NAME      ->IRBS11.DAT
   OUTPUT FILE NAME     ->OSAST.DAT
 ******************************************************************************
 CASE NUMBER =    3
C     =     4.000    PHI   =    32.000    GAMA  =     1.700    GAMAW =    1.000
Z     =    10.000    ZW    =     5.000    SIF   =    35.000    AH    =     .000
AV    =      .000    EQM   =      .000    Q     =      .000    FS    =    1.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******     CRITICAL     DYNAMIC
                                        ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)          =1.393
FS2(With Surcharge & W.T.,But No E.Q.)    =1.131
FS3(No Surcharge & E.Q. , But W.T.)       =1.131
FS4(No Surcharge , With E.Q. & Dry)       =1.393       .187             .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.131       .062             .00
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
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STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS11-STATIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS11.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 10.000 ZW = 10.000 SIF = 35.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .653
FS2(With Surcharge & W.T.,But No E.Q.) = .653
FS3(No Surcharge & E.Q. , But W.T.) = .653
FS4(No Surcharge , With E.Q. & Dry) = .653 -.170 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .653 -.170 .00

~~~~~~

Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 7.682 FOR FACTOR OF SAFETY(3)= 1.00

****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS11.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 10.000 ZW = .000 SIF = 35.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .653
FS2(With Surcharge & W.T.,But No E.Q.) = .364
FS3(No Surcharge & E.Q. , But W.T.) = .364
FS4(No Surcharge , With E.Q. & Dry) = .653 -.170 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .364 -.312 .00

~~~~~~

Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 8.585 FOR FACTOR OF SAFETY(3)= 1.00

****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS11.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 10.000 ZW = 5.000 SIF = 35.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .653
FS2(With Surcharge & W.T.,But No E.Q.) = .509
FS3(No Surcharge & E.Q. , But W.T.) = .509
FS4(No Surcharge , With E.Q. & Dry) = .653 -.170 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .509 -.241 .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 8.585 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS11-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS11.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = 4.000 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 10.000 ZW = 10.000 SIF = 35.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.393
FS2(With Surcharge & W.T.,But No E.Q.) =1.393
FS3(No Surcharge & E.Q. , But W.T.) =1.393
FS4(No Surcharge , With E.Q. & Dry) =1.177 .187 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.177 .187 .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M
****
UNITS USED -> TONNE - METER - DEGREE

```
    INPUT FILE NAME      ->IRBS11.DAT
    OUTPUT FILE NAME     ->OSAST.DAT
 ********************************************************************************
 CASE NUMBER =    2
C     =     4.000    PHI   =    32.000    GAMA  =     1.700    GAMAW =    1.000
Z     =    10.000    ZW    =      .000    SIF   =    35.000    AH    =     .100
AV    =     -.050    EQM   =     7.000    Q     =      .000    FS    =    1.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******     CRITICAL     DYNAMIC
                                       ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)           =1.393
FS2(With Surcharge & W.T.,But No E.Q.)    = .868
FS3(No Surcharge & E.Q. , But W.T.)       = .868
FS4(No Surcharge , With E.Q. & Dry)       =1.177       .187              .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .696       .000            10.57
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Measure adopted to get required factor of safety ->
 SPACING OF DRAIN              =  25.10
DEPTH OF DRAIN                 =   5.02
EFFICIENCY OF DRAIN            =    .50
AVERAGE VERTICAL DEPTH OF W.T.=   2.51

 PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .
*********************************************************************************

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M
  ********************************************************************************
    UNITS USED           -> TONNE - METER - DEGREE
    INPUT FILE NAME      ->IRBS11.DAT
    OUTPUT FILE NAME     ->OSAST.DAT
 ********************************************************************************
CASE NUMBER =    3
C     =     4.000    PHI   =    32.000    GAMA  =     1.700    GAMAW =    1.000
Z     =    10.000    ZW    =     5.000    SIF   =    35.000    AH    =     .100
AV    =     -.050    EQM   =     7.000    Q     =      .000    FS    =    1.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******     CRITICAL     DYNAMIC
                                       ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)           =1.393
FS2(With Surcharge & W.T.,But No E.Q.)    =1.131
FS3(No Surcharge & E.Q. , But W.T.)       =1.131
FS4(No Surcharge , With E.Q. & Dry)       =1.177       .187              .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .937       .062              .05
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
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STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS11-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS11.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 10.000 ZW = 10.000 SIF = 35.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .653
FS2(With Surcharge & W.T.,But No E.Q.) = .653
FS3(No Surcharge & E.Q. , But W.T.) = .653
FS4(No Surcharge , With E.Q. & Dry) = .537 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .537 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 7.682 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS11.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 10.000 ZW = .000 SIF = 35.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .653
FS2(With Surcharge & W.T.,But No E.Q.) = .364
FS3(No Surcharge & E.Q. , But W.T.) = .364
FS4(No Surcharge , With E.Q. & Dry) = .537 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .273 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 8.585 FOR FACTOR OF SAFETY(3)= 1.00
****
STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 6.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS11.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 10.000 ZW = 5.000 SIF = 35.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS15-STATIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = 5.000 PHI = 35.000 GAMA = 1.700 GAMAW = 1.000
Z = 15.000 ZW = 15.000 SIF = 70.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .865
FS2(With Surcharge & W.T.,But No E.Q.) = .865
FS3(No Surcharge & E.Q. , But W.T.) = .865
FS4(No Surcharge , With E.Q. & Dry) = .865 -.094 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .865 -.094 .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 2.719 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = 5.000 PHI = 35.000 GAMA = 1.700 GAMAW = 1.000
Z = 15.000 ZW = .000 SIF = 70.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .865
~~~~~~

FS2(With Surcharge & W.T.,But No E.Q.) = .715
FS3(No Surcharge & E.Q. , But W.T.) = .715
FS4(No Surcharge , With E.Q. & Dry) = .865 -.094 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .715 -.198 .00
~~~~~~

Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 4.776 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 3
C = 5.000 PHI = 35.000 GAMA = 1.700 GAMAW = 1.000
Z = 15.000 ZW = 7.500 SIF = 70.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .865
FS2(With Surcharge & W.T.,But No E.Q.) = .790
FS3(No Surcharge & E.Q. , But W.T.) = .790
FS4(No Surcharge , With E.Q. & Dry) = .865 -.094 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .790 -.146 .00
~~~~~~

Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 4.228 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS15-STATIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 1

C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 15.000 ZW = 15.000 SIF = 70.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC

ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .242
FS2(With Surcharge & W.T.,But No E.Q.) = .242
FS3(No Surcharge & E.Q. , But W.T.) = .242
FS4(No Surcharge , With E.Q. & Dry) = .242 -.644 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .242 -.644 .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 13.220 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 15.000 ZW = .000 SIF = 70.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .242
FS2(With Surcharge & W.T.,But No E.Q.) = .168
FS3(No Surcharge & E.Q. , But W.T.) = .168
FS4(No Surcharge , With E.Q. & Dry) = .242 -.644 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .168 -.706 .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 13.360 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 15.000 ZW = 7.500 SIF = 70.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .242

FS2(With Surcharge & W.T.,But No E.Q.) = .205
FS3(No Surcharge & E.Q. , But W.T.) = .205
FS4(No Surcharge , With E.Q. & Dry) = .242 -.644 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .205 -.675 .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 13.360 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS15-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = 5.000 PHI = 35.000 GAMA = 1.700 GAMAW = 1.000
Z = 15.000 ZW = 15.000 SIF = 70.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .865
FS2(With Surcharge & W.T.,But No E.Q.) = .865
FS3(No Surcharge & E.Q. , But W.T.) = .865
FS4(No Surcharge , With E.Q. & Dry) = .793 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .793 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 2.719 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = 5.000 PHI = 35.000 GAMA = 1.700 GAMAW = 1.000
Z = 15.000 ZW = .000 SIF = 70.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)

FS1(No Surcharge & E.Q.,But Dry) = .865
FS2(With Surcharge & W.T.,But No E.Q.) = .715
FS3(No Surcharge & E.Q. , But W.T.) = .715
FS4(No Surcharge , With E.Q. & Dry) = .793 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .641 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 4.776 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = 5.000 PHI = 35.000 GAMA = 1.700 GAMAW = 1.000
Z = 15.000 ZW = 7.500 SIF = 70.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .865
FS2(With Surcharge & W.T.,But No E.Q.) = .790
FS3(No Surcharge & E.Q. , But W.T.) = .790
FS4(No Surcharge , With E.Q. & Dry) = .793 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .717 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 4.228 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS15-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 15.000 ZW = 15.000 SIF = 70.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC

```
                                        ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)          = .242
FS2(With Surcharge & W.T.,But No E.Q.)    = .242
FS3(No Surcharge & E.Q. , But W.T.)       = .242
FS4(No Surcharge , With E.Q. & Dry)       = .199       .000           10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .199       .000           10.57
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED =  13.220  FOR FACTOR OF SAFETY(3)= 1.00
****************************************************************************

 STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
  ***************************************************************************
    UNITS USED          -> TONNE - METER - DEGREE
    INPUT FILE NAME     ->IRBS15.DAT
    OUTPUT FILE NAME    ->OSAST.DAT
 ***************************************************************************
CASE NUMBER =    2
C     =     .935    PHI  =    21.000    GAMA  =     1.900    GAMAW =    1.000
Z     =   15.000    ZW   =      .000    SIF   =    70.000    AH    =     .100
AV    =    -.050    EQM  =     7.000    Q     =      .000    FS    =    1.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******     CRITICAL     DYNAMIC
                                        ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)          = .242
FS2(With Surcharge & W.T.,But No E.Q.)    = .168
FS3(No Surcharge & E.Q. , But W.T.)       = .168
FS4(No Surcharge , With E.Q. & Dry)       = .199       .000           10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .125       .000           10.57
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED =  13.360  FOR FACTOR OF SAFETY(3)= 1.00
****************************************************************************

 STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 15.00 M
  ***************************************************************************
    UNITS USED          -> TONNE - METER - DEGREE
    INPUT FILE NAME     ->IRBS15.DAT
    OUTPUT FILE NAME    ->OSAST.DAT
 ***************************************************************************
CASE NUMBER =    3
C     =     .935    PHI  =    21.000    GAMA  =     1.900    GAMAW =    1.000
Z     =   15.000    ZW   =     7.500    SIF   =    70.000    AH    =     .100
AV    =    -.050    EQM  =     7.000    Q     =      .000    FS    =    1.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******     CRITICAL     DYNAMIC
                                        ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)          = .242
```

FS2(With Surcharge & W.T.,But No E.Q.) = .205
FS3(No Surcharge & E.Q. , But W.T.) = .205
FS4(No Surcharge , With E.Q. & Dry) = .199 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .162 .000 10.57
~~~~~~

Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 13.360 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS16-STATIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS16.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 8.000 SIF = 31.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.351
FS2(With Surcharge & W.T.,But No E.Q.) =1.351
FS3(No Surcharge & E.Q. , But W.T.) =1.351
FS4(No Surcharge , With E.Q. & Dry) =1.351 .155 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.351 .155 .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS16.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = .000 SIF = 31.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.351
FS2(With Surcharge & W.T.,But No E.Q.) = .740
FS3(No Surcharge & E.Q. , But W.T.) = .740
FS4(No Surcharge , With E.Q. & Dry) =1.351 .155 .00

FS5(No Surcharge , With E.Q. & W.T.[WORST]= .740 -.115 .00
~~~~~~

Measure adopted to get required factor of safety ->
SPACING OF DRAIN = 34.04
DEPTH OF DRAIN = 6.81
EFFICIENCY OF DRAIN = .50
AVERAGE VERTICAL DEPTH OF W.T.= 3.40

PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS16.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 4.000 SIF = 31.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.351
FS2(With Surcharge & W.T.,But No E.Q.) =1.046
FS3(No Surcharge & E.Q. , But W.T.) =1.046
FS4(No Surcharge , With E.Q. & Dry) =1.351 .155 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.046 .020 .00
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS16-STATIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS16.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = 8.000 SIF = 31.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .778

FS2(With Surcharge & W.T.,But No E.Q.) = .778
FS3(No Surcharge & E.Q. , But W.T.) = .778
FS4(No Surcharge , With E.Q. & Dry) = .778 -.100 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .778 -.100 .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 4.913 FOR FACTOR OF SAFETY(3)= 1.00
****
STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS16.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = .000 SIF = 31.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .778
FS2(With Surcharge & W.T.,But No E.Q.) = .442
FS3(No Surcharge & E.Q. , But W.T.) = .442
FS4(No Surcharge , With E.Q. & Dry) = .778 -.100 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .442 -.250 .00
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 6.402 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS16.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 8.000 ZW = 4.000 SIF = 31.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .778
FS2(With Surcharge & W.T.,But No E.Q.) = .610
FS3(No Surcharge & E.Q. , But W.T.) = .610
FS4(No Surcharge , With E.Q. & Dry) = .778 -.100 .00

FS5(No Surcharge , With E.Q. & W.T.[WORST]= .610 -.175 .00
~~~~~~

Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 6.402 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS16-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS16.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 8.000 SIF = 31.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.351
FS2(With Surcharge & W.T.,But No E.Q.) =1.351
FS3(No Surcharge & E.Q. , But W.T.) =1.351
FS4(No Surcharge , With E.Q. & Dry) =1.108 .155 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.108 .155 .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS16.DAT
OUTPUT FILE NAME ->OSAST.DAT
****

CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = .000 SIF = 31.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.351
FS2(With Surcharge & W.T.,But No E.Q.) = .740
FS3(No Surcharge & E.Q. , But W.T.) = .740
FS4(No Surcharge , With E.Q. & Dry) =1.108 .155 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .560 .000 10.57
~~~~~~

Measure adopted to get required factor of safety ->
~~~~~~

SPACING OF DRAIN = 34.04
DEPTH OF DRAIN = 6.81
EFFICIENCY OF DRAIN = .50
AVERAGE VERTICAL DEPTH OF W.T.= 3.40

PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .
****
STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 8.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS16.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 8.000 ZW = 4.000 SIF = 31.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.351
FS2(With Surcharge & W.T.,But No E.Q.) =1.046
FS3(No Surcharge & E.Q. , But W.T.) =1.046
FS4(No Surcharge , With E.Q. & Dry) =1.108 .155 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .834 .020 .19
~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS16-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 12.000 ZW = 12.000 SIF = 28.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .821
FS2(With Surcharge & W.T.,But No E.Q.) = .821
~~~~~~

FS3(No Surcharge & E.Q. , But W.T.) = .821
FS4(No Surcharge , With E.Q. & Dry) = .656 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .656 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 7.730 FOR FACTOR OF SAFETY(3)= 1.00
****
STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 12.000 ZW = .000 SIF = 28.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .821
FS2(With Surcharge & W.T.,But No E.Q.) = .441
FS3(No Surcharge & E.Q. , But W.T.) = .441
FS4(No Surcharge , With E.Q. & Dry) = .656 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .322 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 10.196 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 12.000 ZW = 6.000 SIF = 28.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .821
FS2(With Surcharge & W.T.,But No E.Q.) = .631
FS3(No Surcharge & E.Q. , But W.T.) = .631
FS4(No Surcharge , With E.Q. & Dry) = .656 .000 10.57
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .489 .000 10.57

~~~~~~

Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 10.196 FOR FACTOR OF SAFETY(3)= 1.00

****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS17-STATIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 12.000 ZW = 12.000 SIF = 28.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.396
FS2(With Surcharge & W.T.,But No E.Q.) =1.396
FS3(No Surcharge & E.Q. , But W.T.) =1.396
FS4(No Surcharge , With E.Q. & Dry) =1.396 .164 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.396 .164 .00

~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 12.000 ZW = .000 SIF = 28.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.396
FS2(With Surcharge & W.T.,But No E.Q.) = .705
FS3(No Surcharge & E.Q. , But W.T.) = .705
FS4(No Surcharge , With E.Q. & Dry) =1.396 .164 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .705 -.122 .00

~~~~~~

Measure adopted to get required factor of safety ->

SPACING OF DRAIN = 51.20
~~~~~~

DEPTH OF DRAIN = 10.24
EFFICIENCY OF DRAIN = .50
AVERAGE VERTICAL DEPTH OF W.T.= 5.12
PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .

```
*******************************************************************************
  STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M
*******************************************************************************
   UNITS USED         -> TONNE - METER - DEGREE
   INPUT FILE NAME    ->IRBS17.DAT
   OUTPUT FILE NAME   ->OSAST.DAT
*******************************************************************************
 CASE NUMBER =    3
C    =    1.870   PHI  =   32.000   GAMA  =    1.700   GAMAW =    1.000
Z    =   12.000   ZW   =    6.000   SIF   =   28.000   AH    =     .000
AV   =     .000   EQM  =     .000   Q     =     .000   FS    =    1.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******   CRITICAL    DYNAMIC
                                      ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)         =1.396
FS2(With Surcharge & W.T.,But No E.Q.)   =1.051
FS3(No Surcharge & E.Q. , But W.T.)      =1.051
FS4(No Surcharge , With E.Q. & Dry)      =1.396      .164         .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.051     .021         .00
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS17-STATIC SATURATED CONDITION

```
STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M
*******************************************************************************
   UNITS USED         -> TONNE - METER - DEGREE
   INPUT FILE NAME    ->IRBS17.DAT
   OUTPUT FILE NAME   ->OSAST.DAT
*******************************************************************************
 CASE NUMBER =    1
C    =     .935   PHI  =   21.000   GAMA  =    1.900   GAMAW =    1.000
Z    =   12.000   ZW   =   12.000   SIF   =   28.000   AH    =     .000
AV   =     .000   EQM  =     .000   Q     =     .000   FS    =    1.000
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS******   CRITICAL    DYNAMIC
                                      ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry)         = .821
FS2(With Surcharge & W.T.,But No E.Q.)   = .821
FS3(No Surcharge & E.Q. , But W.T.)      = .821
FS4(No Surcharge , With E.Q. & Dry)      = .821     -.075         .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .821    -.075         .00
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 7.730 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 2
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 12.000 ZW = .000 SIF = 28.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .821
FS2(With Surcharge & W.T.,But No E.Q.) = .441
FS3(No Surcharge & E.Q. , But W.T.) = .441
FS4(No Surcharge , With E.Q. & Dry) = .821 -.075 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .441 -.233 .00

~~~~~~

Measure adopted to get required factor of safety ->
DEPTH OF EXCAVATION REQUIRED = 10.196 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 3
C = .935 PHI = 21.000 GAMA = 1.900 GAMAW = 1.000
Z = 12.000 ZW = 6.000 SIF = 28.000 AH = .000
AV = .000 EQM = .000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) = .821
FS2(With Surcharge & W.T.,But No E.Q.) = .631
FS3(No Surcharge & E.Q. , But W.T.) = .631
FS4(No Surcharge , With E.Q. & Dry) = .821 -.075 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .631 -.154 .00

~~~~~~

Measure adopted to get required factor of safety ->

DEPTH OF EXCAVATION REQUIRED = 10.196 FOR FACTOR OF SAFETY(3)= 1.00
****

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS17-SEISMIC DRY CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 12.000 ZW = 12.000 SIF = 28.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.396
FS2(With Surcharge & W.T.,But No E.Q.) =1.396
FS3(No Surcharge & E.Q. , But W.T.) =1.396
FS4(No Surcharge , With E.Q. & Dry) =1.120 .164 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.120 .164 .00
~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 12.000 ZW = .000 SIF = 28.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.396
FS2(With Surcharge & W.T.,But No E.Q.) = .705
FS3(No Surcharge & E.Q. , But W.T.) = .705
FS4(No Surcharge , With E.Q. & Dry) =1.120 .164 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .513 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->
SPACING OF DRAIN = 51.20
DEPTH OF DRAIN = 10.24
EFFICIENCY OF DRAIN = .50
AVERAGE VERTICAL DEPTH OF W.T.= 5.12
PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .

****

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 12.000 ZW = 6.000 SIF = 28.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.396
FS2(With Surcharge & W.T.,But No E.Q.) =1.051
FS3(No Surcharge & E.Q. , But W.T.) =1.051
FS4(No Surcharge , With E.Q. & Dry) =1.120 .164 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .817 .021 .18

~~~~~~

STABILITY ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS17-SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 1
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 12.000 ZW = 12.000 SIF = 28.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000

~~~~~~

FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.396
FS2(With Surcharge & W.T.,But No E.Q.) =1.396
FS3(No Surcharge & E.Q. , But W.T.) =1.396
FS4(No Surcharge , With E.Q. & Dry) =1.120 .164 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]=1.120 .164 .00

~~~~~~

STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT

****

CASE NUMBER = 2
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 12.000 ZW = .000 SIF = 28.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.396
FS2(With Surcharge & W.T.,But No E.Q.) = .705
FS3(No Surcharge & E.Q. , But W.T.) = .705
FS4(No Surcharge , With E.Q. & Dry) =1.120 .164 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .513 .000 10.57
~~~~~~
Measure adopted to get required factor of safety ->
SPACING OF DRAIN = 51.20
DEPTH OF DRAIN = 10.24
EFFICIENCY OF DRAIN = .50
AVERAGE VERTICAL DEPTH OF W.T.= 5.12

PROVIDE CARPET OF GREEN GRASS AND BUSHES OVER HILL
TO REDUCE THE RATE OF INFILTRATION INSIDE THE SLOPE MATERIAL.
BUSHES WILL ALSO REDUCE EROSION AND ARE EASY TO MAINTAIN.
BUSHES OF ROOT DEPTH > Z SHOULD BE CHOSEN .
****
STABILITY ANALYSIS OF TALUS SLOPE OF DEPTH 12.00 M
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OSAST.DAT
****
CASE NUMBER = 3
C = 1.870 PHI = 32.000 GAMA = 1.700 GAMAW = 1.000
Z = 12.000 ZW = 6.000 SIF = 28.000 AH = .100
AV = -.050 EQM = 7.000 Q = .000 FS = 1.000
~~~~~~
FACTOR OF SAFETY WITH DIFFERENT CONDITIONS****** CRITICAL DYNAMIC
ACCELERATION DISPLACEMENT(M)
FS1(No Surcharge & E.Q.,But Dry) =1.396
FS2(With Surcharge & W.T.,But No E.Q.) =1.051
FS3(No Surcharge & E.Q. , But W.T.) =1.051
FS4(No Surcharge , With E.Q. & Dry) =1.120 .164 .00
FS5(No Surcharge , With E.Q. & W.T.[WORST]= .817 .021 .18
~~~~~~

APPENDIX - X

SAMPLE INPUT FILES FOR EXECUTION OF PROGRAM SASP

SAMPLE INPUT FILE FOR EXECUTION OF PROGRAM - SASP

THIS PROGRAM IS FOR THE STABILITY ANALYSIS OF ROCK WITH PLANE WEDGE FAILURE AND ROCK REINFORCEMENT (FIG.8.2)

~~~~~~

NAME OF PROGRAM -> SASP.FOR
UNITS USED -> TONNE-METER-DEGREE
GIVE INPUT DATA IN THE FOLLOWING SEQUENCE ->
NO
TITLE OF PROBLEM IN ONE LINE (< 80 CHARACTERS)
H, SIP, ZWR, AH, GAMA, GAMAW, ZC, SIF, ANCH, EQM
CJ, PHIR, JRC, JCS
FU, FW, FPHI, FC, THETA, P, FAL, QA, DS
REPEAT ABOVE FOUR LINES NO TIMES
****
DO YOU WANT HELP REGARDING DEFINATIONS OF VARIABLES USED
ENTER 0 FOR TERMINATION
1 FOR FURTHER HELP
2 FOR EXECUTION
****

NO	= NUMBER OF SLOPES
H	= HEIGHT OF SLOPE
SIP	=DIP OF JOINT PLANE
ZWR	=ZW/ZC
ZW	=DEPTH OF WATER IN TENSION CRACK
AH	= COEFF. OF HORIZONTAL ACCELERATION OF EARTHQUAKE NEAR CREST OF SLOPE
EQM	= CORRESPONDING EARTHQUAKE MAGNITUDE (RICHTER SCALE)
GAMA	= UNIT WEIGHT OF ROCK
GAMAW	= UNIT WEIGHT OF WATER
SIF	= SLOPE ANGLE
ZC	= DEPTH OF TENSION CRACK (IF 0 , PROGRAM WILL CALCULATE IT)
ANCH	= 0.0 MEANS THAT ANCHOR SUSTEM IS NOT TO BE DESIGNED
	= 1.0 MEANS RATIONAL DESIGN OF ANCHORS
	= 2.0 RECOMMENDATION FOR CONSTRUCTION
CJ	= COHESION ALONG JOINT PLANE
PHIR	= RESIDUAL SLIDING ANGLE OF FRICTION ALONG JOINT
	+ AVERAGE ANGLE OF LARGE SCALE ROUGHNESS (0X-6X)
JRC	= JOINT ROUGHNESS COEFF. (SMALLER SCALE ROUGHNESS)
JCS	= JOINT- WALL COMPRESSIVE STRENGTH
FU	= FACTOR OF SAFETY FOR HYDRULIC FORCES
FW	= FACTOR OF SAFETY FOR WEIGHT
FPHI	= FACTOR OF SAFETY FOR FRICTION
FC	= FACTOR OF SAFETY FOR COHESION
THETA	= ANGLE OF ANCHOR W.R.T. NORMAL OF JOINT PLANE
~~~~~~

P	= SAFE ANCHOR CAPACITY
FAL	= FIXED ANCHOR LENGTH
QA	= ALLOWABLE BEARING PRESSURE
DS	= DIAMETER OF ANCHOR

ENTER 0 FOR TERMINATION
2 FOR EXECUTION

APPENDIX - XI

OUTPUT FILES FOR STABILITY ANALYSIS OF ROCK SLOPES USING PROGRAM SASP

PLANAR WEDGE ANALYSIS OF SLOPE RBS1 (RIGHT BANK) IN STATIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS1.DAT
OUTPUT FILE NAME ->OSASP.DAT

****

CASE NO. 1

****

COHESION = 15.0000
RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000
DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 15.5015
SLOPE ANGLE = 45.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 75. DEGREES

****

STATIC FACTOR OF SAFETY = 2.8661
DYNAMIC FACTOR OF SAFETY = 2.8661
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = 1.5658
FACTOR OF SAFETY - DRAINED SLOPE = 2.8661
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 2.8661
SLIDING ANGLE OF FRICTION = 30.4981

****

PLANAR WEDGE ANALYSIS OF SLOPE RBS1 (RIGHT BANK) IN STATIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS1.DAT
OUTPUT FILE NAME ->OSASP.DAT

****

CASE NO. 1

****

COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000

DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 15.5015
SLOPE ANGLE = 45.0000

UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 65. DEGREES
****
STATIC FACTOR OF SAFETY = 1.4799
DYNAMIC FACTOR OF SAFETY = 1.4799
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = .4027
FACTOR OF SAFETY - DRAINED SLOPE = 1.4799
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.4799
SLIDING ANGLE OF FRICTION = 20.3872
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS1 (RIGHT BANK) IN SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS1.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 15.0000
RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000
DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 15.5015
SLOPE ANGLE = 45.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 12. DEGREES
****
STATIC FACTOR OF SAFETY = 2.8661
DYNAMIC FACTOR OF SAFETY = 1.0389
DYNAMIC SETTLEMENT IN METER = .0000

CRITICAL ACCELERATION = 1.0716
FACTOR OF SAFETY - DRAINED SLOPE = 2.8661
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.0389
SLIDING ANGLE OF FRICTION = 30.4981
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS1 (RIGHT BANK) IN SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS1.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000
DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 15.5015
SLOPE ANGLE = 45.0000

UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 2. DEGREES
****
STATIC FACTOR OF SAFETY = 1.4799
DYNAMIC FACTOR OF SAFETY = .5056
DYNAMIC SETTLEMENT IN METER = 1.0086
CRITICAL ACCELERATION = .0908
FACTOR OF SAFETY - DRAINED SLOPE = 1.4799
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = .5056
SLIDING ANGLE OF FRICTION = 20.3872
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS3 (RIGHT BANK) IN STATIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS3.DAT
OUTPUT FILE NAME ->OSASP.DAT
****

CASE NO. 1
****
COHESION = 15.0000
RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000
DIP OF JOINT PLANE = 25.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 13.4830
SLOPE ANGLE = 34.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 84. DEGREES
****
STATIC FACTOR OF SAFETY = 2.3822
DYNAMIC FACTOR OF SAFETY = 2.3822
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = .6445
FACTOR OF SAFETY - DRAINED SLOPE = 2.3822
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 2.3822
SLIDING ANGLE OF FRICTION = 27.5636
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS3 (RIGHT BANK) IN STATIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS3.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000
DIP OF JOINT PLANE = 25.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 13.4830
SLOPE ANGLE = 34.0000

UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 73. DEGREES
****
STATIC FACTOR OF SAFETY = 1.2793
DYNAMIC FACTOR OF SAFETY = 1.2793
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = .1303
FACTOR OF SAFETY - DRAINED SLOPE = 1.2793
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.2793
SLIDING ANGLE OF FRICTION = 17.4527
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS3 (RIGHT BANK) IN SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS3.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 15.0000
RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000
DIP OF JOINT PLANE = 25.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 13.4830
SLOPE ANGLE = 34.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 20. DEGREES
****
STATIC FACTOR OF SAFETY = 2.3822
DYNAMIC FACTOR OF SAFETY = .5916
DYNAMIC SETTLEMENT IN METER = .3161
CRITICAL ACCELERATION = .4011
FACTOR OF SAFETY - DRAINED SLOPE = 2.3822
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = .5916
SLIDING ANGLE OF FRICTION = 27.5636
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS3 (RIGHT BANK) IN SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS3.DAT
OUTPUT FILE NAME ->OSASP.DAT

****

CASE NO. 1

****

COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000
DIP OF JOINT PLANE = 25.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 13.4830
SLOPE ANGLE = 34.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 10. DEGREES

****

STATIC FACTOR OF SAFETY = 1.2793
DYNAMIC FACTOR OF SAFETY = .3069
DYNAMIC SETTLEMENT IN METER = 105.7324
CRITICAL ACCELERATION = .0000
FACTOR OF SAFETY - DRAINED SLOPE = 1.2793
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = .3069
SLIDING ANGLE OF FRICTION = 17.4527

****

PLANAR WEDGE ANALYSIS OF SLOPE RBS4 (RIGHT BANK) IN STATIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
OUTPUT FILE NAME ->OSASP.DAT

****

CASE NO. 1

****

COHESION = 15.0000
RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000
DIP OF JOINT PLANE = 30.0000

DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 3.1020
SLOPE ANGLE = 32.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 90. DEGREES
****
STATIC FACTOR OF SAFETY = 5.9221
DYNAMIC FACTOR OF SAFETY = 5.9221
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = 2.8418
FACTOR OF SAFETY - DRAINED SLOPE = 5.9221
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 5.9221
SLIDING ANGLE OF FRICTION = 31.6294
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS4 (RIGHT BANK) IN STATIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000
DIP OF JOINT PLANE = 30.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 3.1020
SLOPE ANGLE = 32.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 80. DEGREES
****
STATIC FACTOR OF SAFETY = 3.0094
DYNAMIC FACTOR OF SAFETY = 3.0094
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = 1.1602
FACTOR OF SAFETY - DRAINED SLOPE = 3.0094

DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 3.0094
SLIDING ANGLE OF FRICTION = 21.5185
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS4 (RIGHT BANK) IN SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 15.0000
RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000
DIP OF JOINT PLANE = 30.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 3.1020
SLOPE ANGLE = 32.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 26. DEGREES
****
STATIC FACTOR OF SAFETY = 5.9221
DYNAMIC FACTOR OF SAFETY = 1.9422
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = 2.4862
FACTOR OF SAFETY - DRAINED SLOPE = 5.9221
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.9422
SLIDING ANGLE OF FRICTION = 31.6294

****

PLANAR WEDGE ANALYSIS OF SLOPE RBS4 (RIGHT BANK) IN SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS4.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****

COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 80.0000
DIP OF JOINT PLANE = 30.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 3.1020
SLOPE ANGLE = 32.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 16. DEGREES
****
STATIC FACTOR OF SAFETY = 3.0094
DYNAMIC FACTOR OF SAFETY = .9572
DYNAMIC SETTLEMENT IN METER = .0234
CRITICAL ACCELERATION = .9325
FACTOR OF SAFETY - DRAINED SLOPE = 3.0094
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = .9572
SLIDING ANGLE OF FRICTION = 21.5185
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS6 (RIGHT BANK) IN STATIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 15.0000
RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 90.0000
DIP OF JOINT PLANE = 35.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 30.7254
SLOPE ANGLE = 45.0000

UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF

CONTINUOUS CROSS JOINT DIPS MORE THAN 73. DEGREES
****
STATIC FACTOR OF SAFETY = 1.8771
DYNAMIC FACTOR OF SAFETY = 1.8771
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = .6142
FACTOR OF SAFETY - DRAINED SLOPE = 1.8771
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.8771
SLIDING ANGLE OF FRICTION = 28.2836
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS6 (RIGHT BANK) IN STATIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS6.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 90.0000
DIP OF JOINT PLANE = 35.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 30.7254
SLOPE ANGLE = 45.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 63. DEGREES
****
STATIC FACTOR OF SAFETY = 1.0000
DYNAMIC FACTOR OF SAFETY = 1.0000
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = .0000
FACTOR OF SAFETY - DRAINED SLOPE = 1.0000
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.0000
SLIDING ANGLE OF FRICTION = 18.1727
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS6 (RIGHT BANK) IN SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

```
************************************************************
UNITS USED          -> TONNE - METER - DEGREE
INPUT FILE NAME      ->IRBS6.DAT
OUTPUT FILE NAME     ->OSASP.DAT
************************************************************
          CASE NO.    1
************************************************************
COHESION                          =   15.0000
RESIDUAL ANGLE OF FRICTION            =   30.0000
JOINT ROUGHNESS COEFFICIENT           =    6.0000
JOINT WALL COMP. STRENGTH             =   10.0000
HEIGHT                         =   90.0000
DIP OF JOINT PLANE                   =   35.0000
DEPTH OF WATER IN TENSION CRACK        =     .0000
COEFF. OF HORIZONTAL ACCELERATION      =    1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)=    7.0000
UNIT WEIGHT OF ROCK                  =    2.3000
UNIT WEIGHT OF WATER                  =    1.0000
DEPTH OF TENSION CRACK               =   30.7254
SLOPE ANGLE                          =   45.0000
 UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN   10. DEGREES
************************************************************
STATIC FACTOR OF SAFETY              =    1.8771
DYNAMIC FACTOR OF SAFETY              =    .5515
DYNAMIC SETTLEMENT IN METER            =    .5234
CRITICAL ACCELERATION                =    .2374
FACTOR OF SAFETY - DRAINED SLOPE       =    1.8771
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE =     .5515
SLIDING ANGLE OF FRICTION             =   28.2836
************************************************************
```

PLANAR WEDGE ANALYSIS OF SLOPE RBS6 (RIGHT BANK) IN SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

```
************************************************************
UNITS USED          -> TONNE - METER - DEGREE
INPUT FILE NAME      ->IRBS6.DAT
OUTPUT FILE NAME     ->OSASP.DAT
************************************************************
          CASE NO.    1
************************************************************
COHESION                          =    7.5000
RESIDUAL ANGLE OF FRICTION            =   20.0000
JOINT ROUGHNESS COEFFICIENT           =    6.0000
JOINT WALL COMP. STRENGTH             =   10.0000
HEIGHT                         =   90.0000
DIP OF JOINT PLANE                   =   35.0000
DEPTH OF WATER IN TENSION CRACK        =     .0000
COEFF. OF HORIZONTAL ACCELERATION      =    1.0000
```

FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 30.7254
SLOPE ANGLE = 45.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 0. DEGREES
****
STATIC FACTOR OF SAFETY = 1.0000
DYNAMIC FACTOR OF SAFETY = .2767
DYNAMIC SETTLEMENT IN METER = 105.7324
CRITICAL ACCELERATION = .0000
FACTOR OF SAFETY - DRAINED SLOPE = 1.0000
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = .2767
SLIDING ANGLE OF FRICTION = 18.1727
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS12 (RIGHT BANK) IN STATIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS12.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 15.0000
RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 60.0000
DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 26.8418
SLOPE ANGLE = 50.0000

UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 71. DEGREES
****
STATIC FACTOR OF SAFETY = 3.2613
DYNAMIC FACTOR OF SAFETY = 3.2613
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = 1.8974
FACTOR OF SAFETY - DRAINED SLOPE = 3.2613

DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 3.2613
SLIDING ANGLE OF FRICTION = 30.9229
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS12 (RIGHT BANK) IN STATIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS12.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 60.0000
DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 26.8418
SLOPE ANGLE = 50.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 61. DEGREES
****
STATIC FACTOR OF SAFETY = 1.6736
DYNAMIC FACTOR OF SAFETY = 1.6736
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = .5652
FACTOR OF SAFETY - DRAINED SLOPE = 1.6736
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.6736
SLIDING ANGLE OF FRICTION = 20.8120
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS12 (RIGHT BANK) IN SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS12.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 15.0000

RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 60.0000
DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 26.8418
SLOPE ANGLE = 50.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 7. DEGREES

****
STATIC FACTOR OF SAFETY = 3.2613
DYNAMIC FACTOR OF SAFETY = 1.2147
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = 1.3948
FACTOR OF SAFETY - DRAINED SLOPE = 3.2613
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.2147
SLIDING ANGLE OF FRICTION = 30.9229
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS12 (RIGHT BANK) IN SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS12.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 60.0000
DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 26.8418
SLOPE ANGLE = 50.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN -3. DEGREES

****
STATIC FACTOR OF SAFETY = 1.6736
DYNAMIC FACTOR OF SAFETY = .5902
DYNAMIC SETTLEMENT IN METER = .5078
CRITICAL ACCELERATION = .2463
FACTOR OF SAFETY - DRAINED SLOPE = 1.6736
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = .5902
SLIDING ANGLE OF FRICTION = 20.8120
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS15 (RIGHT BANK) IN STATIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 15.0000
RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
DEPTH OF TENSION CRACK WORKS OUT TO BE UNREALISTIC AND IT WILL BE BETTER IF IT IS ASSIGNED A PROPER VALUE BY JUDGEMENT
HEIGHT = 40.0000
DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 30.1501
SLOPE ANGLE = 70.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF CONTINUOUS CROSS JOINT DIPS MORE THAN 49. DEGREES
****
STATIC FACTOR OF SAFETY = 1.9543
DYNAMIC FACTOR OF SAFETY = 1.9543
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = .8007
FACTOR OF SAFETY - DRAINED SLOPE = 1.9543
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.9543
SLIDING ANGLE OF FRICTION = 29.1491
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS15 (RIGHT BANK) IN STATIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSASP.DAT

****

CASE NO. 1

****

COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000

DEPTH OF TENSION CRACK WORKS OUT TO BE UNREALISTIC AND IT WILL BE BETTER IF IT IS ASSIGNED A PROPER VALUE BY JUDGEMENT

HEIGHT = 40.0000
DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 30.1501
SLOPE ANGLE = 70.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF CONTINUOUS CROSS JOINT DIPS MORE THAN 39. DEGREES

****

STATIC FACTOR OF SAFETY = 1.0292
DYNAMIC FACTOR OF SAFETY = 1.0292
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = .0245
FACTOR OF SAFETY - DRAINED SLOPE = 1.0292
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.0292
SLIDING ANGLE OF FRICTION = 19.0382

****

PLANAR WEDGE ANALYSIS OF SLOPE RBS15 (RIGHT BANK) IN SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSASP.DAT

****

CASE NO. 1

****

COHESION = 15.0000

RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
DEPTH OF TENSION CRACK WORKS OUT TO BE UNREALISTIC AND
IT WILL BE BETTER IF IT IS ASSIGNED A PROPER VALUE BY
JUDGEMENT
HEIGHT = 40.0000
DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 30.1501
SLOPE ANGLE = 70.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN -14. DEGREES
****
STATIC FACTOR OF SAFETY = 1.9543
DYNAMIC FACTOR OF SAFETY = .6372
DYNAMIC SETTLEMENT IN METER = .3868
CRITICAL ACCELERATION = .3328
FACTOR OF SAFETY - DRAINED SLOPE = 1.9543
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = .6372
SLIDING ANGLE OF FRICTION = 29.1491
****

PLANAR WEDGE ANALYSIS OF SLOPE RBS15 (RIGHT BANK) IN SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
DEPTH OF TENSION CRACK WORKS OUT TO BE UNREALISTIC AND
IT WILL BE BETTER IF IT IS ASSIGNED A PROPER VALUE BY
JUDGEMENT
HEIGHT = 40.0000
DIP OF JOINT PLANE = 40.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.4000

UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 30.1501
SLOPE ANGLE = 70.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN -24. DEGREES
****
STATIC FACTOR OF SAFETY = 1.0292
DYNAMIC FACTOR OF SAFETY = .3121
DYNAMIC SETTLEMENT IN METER = 105.7324
CRITICAL ACCELERATION = .0000
FACTOR OF SAFETY - DRAINED SLOPE = 1.0292
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = .3121
SLIDING ANGLE OF FRICTION = 19.0382
****

PLANAR WEDGE ANALYSIS OF SLOPE LBS5 (LEFT BANK) IN STATIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->ILBS5.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 15.0000
RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 70.0000
DIP OF JOINT PLANE = 30.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 27.7691
SLOPE ANGLE = 45.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 72. DEGREES
****
STATIC FACTOR OF SAFETY = 1.8786
DYNAMIC FACTOR OF SAFETY = 1.8786
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = .5073
FACTOR OF SAFETY - DRAINED SLOPE = 1.8786
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.8786
SLIDING ANGLE OF FRICTION = 27.4558

****

PLANAR WEDGE ANALYSIS OF SLOPE LBS5 (LEFT BANK) IN STATIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->ILBS5.DAT
OUTPUT FILE NAME ->OSASP.DAT

****

CASE NO. 1

****

COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 70.0000
DIP OF JOINT PLANE = 30.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = .0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= .0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 27.7691
SLOPE ANGLE = 45.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 62. DEGREES

****

STATIC FACTOR OF SAFETY = 1.0099
DYNAMIC FACTOR OF SAFETY = 1.0099
DYNAMIC SETTLEMENT IN METER = .0000
CRITICAL ACCELERATION = .0057
FACTOR OF SAFETY - DRAINED SLOPE = 1.0099
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = 1.0099
SLIDING ANGLE OF FRICTION = 17.3449

****

PLANAR WEDGE ANALYSIS OF SLOPE LBS5 (LEFT BANK) IN SEISMIC DRY CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->ILBS5.DAT
OUTPUT FILE NAME ->OSASP.DAT

****

CASE NO. 1

****

COHESION = 15.0000
RESIDUAL ANGLE OF FRICTION = 30.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000

HEIGHT = 70.0000
DIP OF JOINT PLANE = 30.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.3000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 27.7691
SLOPE ANGLE = 45.0000

UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN 9. DEGREES
****
STATIC FACTOR OF SAFETY = 1.8786
DYNAMIC FACTOR OF SAFETY = .4974
DYNAMIC SETTLEMENT IN METER = .5822
CRITICAL ACCELERATION = .2073
FACTOR OF SAFETY - DRAINED SLOPE = 1.8786
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = .4974
SLIDING ANGLE OF FRICTION = 27.4558
****

PLANAR WEDGE ANALYSIS OF SLOPE LBS5 (LEFT BANK) IN SEISMIC SATURATED CONDITION

STABILITY ANALYSIS OF ROCK SLOPE WITH PLANAR FAILURE
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->ILBS5.DAT
OUTPUT FILE NAME ->OSASP.DAT
****
CASE NO. 1
****
COHESION = 7.5000
RESIDUAL ANGLE OF FRICTION = 20.0000
JOINT ROUGHNESS COEFFICIENT = 6.0000
JOINT WALL COMP. STRENGTH = 10.0000
HEIGHT = 70.0000
DIP OF JOINT PLANE = 30.0000
DEPTH OF WATER IN TENSION CRACK = .0000
COEFF. OF HORIZONTAL ACCELERATION = 1.0000
FOR EARTHQUAKE MAGNITUDE(RICHTER SCALE)= 7.0000
UNIT WEIGHT OF ROCK = 2.4000
UNIT WEIGHT OF WATER = 1.0000
DEPTH OF TENSION CRACK = 27.7691
SLOPE ANGLE = 45.0000
UNREINFORCED SLOPE MAY FAIL BY OVERTOPPLING IF
CONTINUOUS CROSS JOINT DIPS MORE THAN -1. DEGREES
****
STATIC FACTOR OF SAFETY = 1.0099
DYNAMIC FACTOR OF SAFETY = .2553

DYNAMIC SETTLEMENT IN METER = 105.7324
CRITICAL ACCELERATION = .0000
FACTOR OF SAFETY - DRAINED SLOPE = 1.0099
DYNAMIC FACTOR OF SAFETY-DRAINED SLOPE = .2553
SLIDING ANGLE OF FRICTION = 17.3449
****

APPENDIX - XII

SAMPLE INPUT FILES FOR EXECUTION OF PROGRAM SASW

SAMPLE INPUT FILE FOR EXECUTION OF PROGRAM - SASW
THIS PROGRAM IS CALCULATES THE FACTOR OF SAFETY OF TETRAHEDRAL WEDGE WITH HORIZONTAL SLOPE CREST AND WITH NO TENSION CRACK (FIG.8.3)
~~~~~~

NAME OF PROGRAM -> SASW.FOR
UNITS USED -> TONNE-METER-DEGREE
GIVE INPUT DATA IN THE FOLLOWING SEQUENCE ->
NO
(PLEASE REPEAT ALL FOLLOWING LINES NO TIMES FOR NO SLOPES)
TITLE OF PROBLEM IN ONE LINE (<80 CHARACTERS)
NJT, NCASE
SAI3, ALPHA3, SAI4, ALPHA4
H,GAMA, GAMAW, ETA, ACCN, RWL,PORE, EQM
(PLEASE REPEAT ABOVE LINE NCASE TIMES)

DO YOU WANT HELP REGARDING DEFINATIONS OF VARIABLES USED
ENTER 0 FOR TERMINATION
1 FOR FURTHER HELP
2 FOR EXECUTION

THE DISCONTINUITIES ARE DENOTED BY 1 AND 2 , THE UPPER GROUND SURFACE BY 3 AND THE SLOPE FACE BY 4

NO	= NUMBER OF SLOPES
NJT	= NUMBER OF JOINT SETS
NCASE	=NO OF CASES
SAI (1)	=DIP OF I TH JOINT PLANE (DEG.)
ALPHA (I)	= DIP DIRECTION OF I TH JOINT PLANE (DEG.)
C (I)	= COHESION OF I TH JOINT PLANE (T/SQ.M)
PHAI (I)	= FRICTION ANGLE OF I TH JOINT PLANE (DEG.)
	= ARC TAN (Jr / Ja) FOR CLAY COATED JOINTS
SAI3	= ANGLE OF SLOPE OF UPPER GROUND SURFACE
ALPHA3	= DIP DIRECTION OF THE UPPER GROUND SURFACE
SAI4	= ANGLE OF ROCK SLOPE
ALPHA4	= DIP DIRECTION OF THE ROCK SLOPE
H	= HEIGHT OF THE CREST OF THE SLOPE ABOVE TOE OF INTERSECTION
GAMA	= UNIT WEIGHT OF ROCK (T/CU.M)
GAMAW	= UNIT WEIGHT OF WATER (T/CU.M)
ETA	= -1 MEANS SLOPE FACE OVERHANGS TOE OF THE SLOPE
	= +1 MEANS SLOPE FACE DOES NOT OVERHANG
ACCN	= COEFFICIENT OF HORIZONTAL ACCELERATION OF EARTHQUAKE NEAR CREST OF SLOPE
EQM	= CORRESPONDING EARTHQUAKE MAGNITUDE (RICHTER SCALE)
RWL	= WATER LEVEL ABOVE TOE OF INTERSECTION
PORE	= PORE WATER PRESSURE FACTOR
	= 0. (FOR DRY SLOPE) OR 1. (FOR WET SLOPE)

ENTER 0 FOR TERMINATION
2 FOR EXECUTION
~~~~~~

APPENDIX - XIII

OUTPUT FILES FOR STABILITY ANALYSIS OF ROCK SLOPES USING PROGRAM SASW

WEDGE ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS8-STATIC/SEISMIC DRY

STABILITY ANALYSIS OF ROCK SLOPE WITH WEDGE FAILURE/OVER TOPPLING

```
************************************************************
UNITS USED          -> TONNE - METER - DEGREE
INPUT FILE NAME      ->IRBS8.DAT
OUTPUT FILE NAME     ->OSASW.DAT
************************************************************
            SLOPE NO.  1     CASE NO.  1
************************************************************
PLANE           1           2           3           4
SAI(DEGREE)     40.0        30.0          .0        41.0
ALPHA(DEGREE)   90.0       220.0          .0       150.0
H          =    40.000 M
GAMA       =     2.300 T/CU.M
C1         =    30.000 T/SQ.M
C2         =    30.000 T/SQ.M
PHAI1      =    35.000 DEG.
PHAI2      =    35.000 DEG.
U1         =      .000 T/SQ.M
U2         =      .000 T/SQ.M
EQ.ACCN    =      .000
EQM        =      .000
RWL        =      .000 M
* SLOPE DOES NOT OVERHANG *
*THERE IS CONTACT ON BOTH PLANES  1 AND  2 *
DYNAMIC SETTLEMENT   =     .0000 M
CRITICAL ACCLERATION =     .9900
FACTOR OF SAFETY     =    9.3273
* HENCE THE SLOPE IS STABLE IN SLIDING *
************************************************************
            SLOPE NO.  1     CASE NO.  2
************************************************************
PLANE           1           2           3           4
SAI(DEGREE)     40.0        30.0          .0        41.0
ALPHA(DEGREE)   90.0       220.0          .0       150.0
H          =    40.000 M
GAMA       =     2.300 T/CU.M
C1         =    30.000 T/SQ.M
C2         =    30.000 T/SQ.M
PHAI1      =    35.000 DEG.
PHAI2      =    35.000 DEG.
U1         =      .000 T/SQ.M
U2         =      .000 T/SQ.M
EQ.ACCN    =      .300
EQM        =     7.000
RWL        =      .000 M
* SLOPE DOES NOT OVERHANG *
*THERE IS CONTACT ON BOTH PLANES  1 AND  2 *
DYNAMIC SETTLEMENT   =     .0000 M
```

CRITICAL ACCLERATION = .9900
FACTOR OF SAFETY = 4.4367
* HENCE THE SLOPE IS STABLE IN SLIDING *
****

WEDGE ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS10-STATIC/SEISMIC DRY

STABILITY ANALYSIS OF ROCK SLOPE WITH WEDGE FAILURE/OVER TOPPLING
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS10.DAT
OUTPUT FILE NAME ->OSASW.DAT
****
SLOPE NO. 1 CASE NO. 1
****
PLANE 1 2 3 4
SAI(DEGREE) 51.0 41.0 .0 60.0
ALPHA(DEGREE) 239.0 150.0 .0 189.0
H = 33.000 M
GAMA = 2.300 T/CU.M
C1 = 30.000 T/SQ.M
C2 = 30.000 T/SQ.M
PHAI1 = 35.000 DEG.
PHAI2 = 35.000 DEG.
U1 = .000 T/SQ.M
U2 = .000 T/SQ.M
EQ.ACCN = .000
EQM = .000
RWL = .000 M
* SLOPE DOES NOT OVERHANG *
*THERE IS CONTACT ON BOTH PLANES 1 AND 2 *
DYNAMIC SETTLEMENT = .0000 M
CRITICAL ACCLERATION = .9900
FACTOR OF SAFETY = 6.0687
* HENCE THE SLOPE IS STABLE IN SLIDING *
****
SLOPE NO. 1 CASE NO. 2
****
PLANE 1 2 3 4
SAI(DEGREE) 51.0 41.0 .0 60.0
ALPHA(DEGREE) 239.0 150.0 .0 189.0
H = 33.000 M
GAMA = 2.300 T/CU.M
C1 = 30.000 T/SQ.M
C2 = 30.000 T/SQ.M
PHAI1 = 35.000 DEG.
PHAI2 = 35.000 DEG.
U1 = .000 T/SQ.M
U2 = .000 T/SQ.M
EQ.ACCN = .300

EQM = 7.000
RWL = .000 M
* SLOPE DOES NOT OVERHANG *
*THERE IS CONTACT ON BOTH PLANES 1 AND 2 *
DYNAMIC SETTLEMENT = .0000 M
CRITICAL ACCLERATION = .9900
FACTOR OF SAFETY = 3.9778
* HENCE THE SLOPE IS STABLE IN SLIDING *
****

WEDGE ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS14-STATIC/SEISMIC DRY

STABILITY ANALYSIS OF ROCK SLOPE WITH WEDGE FAILURE/OVER TOPPLING
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS14.DAT
OUTPUT FILE NAME ->OSASW.DAT
****
SLOPE NO. 1 CASE NO. 1
****

PLANE	1	2	3	4
SAI(DEGREE)	41.0	62.0	.0	48.0
ALPHA(DEGREE)	170.0	70.0	.0	120.0

H = 55.000 M
GAMA = 2.300 T/CU.M
C1 = 30.000 T/SQ.M
C2 = 30.000 T/SQ.M
PHAI1 = 35.000 DEG.
PHAI2 = 35.000 DEG.
U1 = .000 T/SQ.M
U2 = .000 T/SQ.M
EQ.ACCN = .000
EQM = .000
RWL = .000 M
* SLOPE DOES NOT OVERHANG *
*THERE IS CONTACT ON BOTH PLANES 1 AND 2 *
DYNAMIC SETTLEMENT = .0000 M
CRITICAL ACCLERATION = .9900
FACTOR OF SAFETY = 7.2690
* HENCE THE SLOPE IS STABLE IN SLIDING *
****
SLOPE NO. 1 CASE NO. 2
****

PLANE	1	2	3	4
SAI(DEGREE)	41.0	62.0	.0	48.0
ALPHA(DEGREE)	170.0	70.0	.0	120.0

H = 55.000 M
GAMA = 2.300 T/CU.M
C1 = 30.000 T/SQ.M
C2 = 30.000 T/SQ.M

PHAI1 = 35.000 DEG.
PHAI2 = 35.000 DEG.
U1 = .000 T/SQ.M
U2 = .000 T/SQ.M
EQ.ACCN = .300
EQM = 7.000
RWL = .000 M
* SLOPE DOES NOT OVERHANG *
*THERE IS CONTACT ON BOTH PLANES 1 AND 2 *
DYNAMIC SETTLEMENT = .0000 M
CRITICAL ACCLERATION = .9900
FACTOR OF SAFETY = 4.7909
* HENCE THE SLOPE IS STABLE IN SLIDING *
****

WEDGE ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS8-STATIC/SEISMIC SATURATED

STABILITY ANALYSIS OF ROCK SLOPE WITH WEDGE FAILURE/OVER TOPPLING
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS8.DAT
OUTPUT FILE NAME ->OSASW.DAT
****
SLOPE NO. 1 CASE NO. 1
****

PLANE	1	2	3	4
SAI(DEGREE)	40.0	30.0	.0	41.0
ALPHA(DEGREE)	90.0	220.0	.0	150.0

H = 40.000 M
GAMA = 2.400 T/CU.M
C1 = 15.000 T/SQ.M
C2 = 15.000 T/SQ.M
PHAI1 = 23.000 DEG.
PHAI2 = 23.000 DEG.
U1 = 5.742 T/SQ.M
U2 = 5.742 T/SQ.M
EQ.ACCN = .000
EQM = .000
RWL = 5.000 M
* SLOPE DOES NOT OVERHANG *
*THERE IS CONTACT ON BOTH PLANES 1 AND 2 *
DYNAMIC SETTLEMENT = .0000 M
CRITICAL ACCLERATION = .8300
FACTOR OF SAFETY = 4.3260
* HENCE THE SLOPE IS STABLE IN SLIDING *
****
SLOPE NO. 1 CASE NO. 2
****

PLANE	1	2	3	4
SAI(DEGREE)	40.0	30.0	.0	41.0

ALPHA(DEGREE) 90.0 220.0 .0 150.0
H = 40.000 M
GAMA = 2.400 T/CU.M
C1 = 15.000 T/SQ.M
C2 = 15.000 T/SQ.M
PHAI1 = 23.000 DEG.
PHAI2 = 23.000 DEG.
U1 = 5.742 T/SQ.M
U2 = 5.742 T/SQ.M
EQ.ACCN = .300
EQM = 7.000
RWL = 5.000 M
* SLOPE DOES NOT OVERHANG *
*THERE IS CONTACT ON BOTH PLANES 1 AND 2 *
DYNAMIC SETTLEMENT = .0000 M
CRITICAL ACCLERATION = .8300
FACTOR OF SAFETY = 2.0439
* HENCE THE SLOPE IS STABLE IN SLIDING *
****

WEDGE ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS10-STATIC/SEISMIC SATURATED

STABILITY ANALYSIS OF ROCK SLOPE WITH WEDGE FAILURE/OVER TOPPLING
****
UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS10.DAT
OUTPUT FILE NAME ->OSASW.DAT
****
SLOPE NO. 1 CASE NO. 1
****

PLANE	1	2	3	4
SAI(DEGREE)	51.0	41.0	.0	60.0
ALPHA(DEGREE)	239.0	150.0	.0	189.0

H = 33.000 M
GAMA = 2.400 T/CU.M
C1 = 15.000 T/SQ.M
C2 = 15.000 T/SQ.M
PHAI1 = 23.000 DEG.
PHAI2 = 23.000 DEG.
U1 = 4.560 T/SQ.M
U2 = 4.560 T/SQ.M
EQ.ACCN = .000
EQM = .000
RWL = 5.000 M
* SLOPE DOES NOT OVERHANG *
*THERE IS CONTACT ON BOTH PLANES 1 AND 2 *
DYNAMIC SETTLEMENT = .0000 M
CRITICAL ACCLERATION = .9200
FACTOR OF SAFETY = 2.7475
* HENCE THE SLOPE IS STABLE IN SLIDING *

****

SLOPE NO. 1 CASE NO. 2

****

PLANE 1 2 3 4
SAI(DEGREE) 51.0 41.0 .0 60.0
ALPHA(DEGREE) 239.0 150.0 .0 189.0
H = 33.000 M
GAMA = 2.400 T/CU.M
C1 = 15.000 T/SQ.M
C2 = 15.000 T/SQ.M
PHAI1 = 23.000 DEG.
PHAI2 = 23.000 DEG.
U1 = 4.560 T/SQ.M
U2 = 4.560 T/SQ.M
EQ.ACCN = .300
EQM = 7.000
RWL = 5.000 M
* SLOPE DOES NOT OVERHANG *
*THERE IS CONTACT ON BOTH PLANES 1 AND 2 *
DYNAMIC SETTLEMENT = .0000 M
CRITICAL ACCLERATION = .9200
FACTOR OF SAFETY = 1.7900
* HENCE THE SLOPE IS STABLE IN SLIDING *

****

WEDGE ANALYSIS OF RIGHT BANK RESERVOIR SLOPE-RBS14-STATIC/SEISMIC SATURATED

STABILITY ANALYSIS OF ROCK SLOPE WITH WEDGE FAILURE/OVER TOPPLING

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS14.DAT
OUTPUT FILE NAME ->OSASW.DAT

****

SLOPE NO. 1 CASE NO. 1

****

PLANE 1 2 3 4
SAI(DEGREE) 41.0 62.0 .0 48.0
ALPHA(DEGREE) 170.0 70.0 .0 120.0
H = 55.000 M
GAMA = 2.400 T/CU.M
C1 = 15.000 T/SQ.M
C2 = 15.000 T/SQ.M
PHAI1 = 23.000 DEG.
PHAI2 = 23.000 DEG.
U1 = 8.264 T/SQ.M
U2 = 8.264 T/SQ.M
EQ.ACCN = .000
EQM = .000
RWL = 5.000 M
* SLOPE DOES NOT OVERHANG *

THERE IS CONTACT ON PLANE 1 ONLY
DYNAMIC SETTLEMENT = .0000 M
CRITICAL ACCLERATION = .4100
FACTOR OF SAFETY = 1.7291
* HENCE THE SLOPE IS STABLE IN SLIDING *
****
SLOPE NO. 1 CASE NO. 2
****
PLANE 1 2 3 4
SAI(DEGREE) 41.0 62.0 .0 48.0
ALPHA(DEGREE) 170.0 70.0 .0 120.0
H = 55.000 M
GAMA = 2.400 T/CU.M
C1 = 15.000 T/SQ.M
C2 = 15.000 T/SQ.M
PHAI1 = 23.000 DEG.
PHAI2 = 23.000 DEG.
U1 = 8.264 T/SQ.M
U2 = 8.264 T/SQ.M
EQ.ACCN = .300
EQM = 7.000
RWL = 5.000 M
* SLOPE DOES NOT OVERHANG *
THERE IS CONTACT ON PLANE 1 ONLY
DYNAMIC SETTLEMENT = .0000 M
CRITICAL ACCLERATION = .4100
FACTOR OF SAFETY = 1.1262
* HENCE THE SLOPE IS STABLE IN SLIDING *
****

APPENDIX -XIV

SAMPLE INPUT FILES
FOR EXECUTION OF PROGRAM WAVE

SAMPLE INPUT FILE FOR EXECUTION OF PROGRAM – WAVE
THIS PROGRAM IS CAMPUTES THE HEIGHT OF WAVE GENERATED IN A RESERVOIR DUE TO LANDSLIDE (FIG.8.3)

```
NAME OF PROGRAM              -> WAVE.FOR
UNITS USED                   -> TONNE-METER-DEGREE
```

```
GIVE INPUT DATA IN THE FOLLOWING SEQUENCE ->
NCASE (= NUMBER OF PROBLEMS)
TITLE OF PROBLEM IN ONE LINE (<80 CHARACTERS)
FS, PHI, W, H, AI, S RWL, G, GAMAW, RD
THE ABOVE TWO LINES ARE  REPEATED NCASE TIMES.
```

```
ENTER      0  FOR TERMINATION
           1  FOR FURTHER HELP
           2  FOR EXECUTION
AV          = COEFFICIENT OF VERTICAL EARTQUAKE ACCELERATION
AH          = COEFFICIENT OF HORIZONTAL EARTQUAKE ACCELERATION
AI          = DIP OF PLANE OR INTERSECTION OF JOINT PLANES
            = AVERAGE DIP OF CIRCULAR WEDGE
FS          = STATIC RESIDUAL FACTOR OF SAFETY OF THE SLOPE
              DURING LANDSLIDE. (C = 0.0. & PHI = PHIR / 2)
G           = ACCELERATION DUE TO GRAVITY
GAMAW       = UNIT WEIGHT OF WATER
H           = HEIGHT OF SLOPE
PHI         = ANGLE OF SLIDING FRICTION (= PHIR / 2)
RWL         = MEAN DEPTH OF RESERVOIR
RD          = DISTANCE OF LANDSLIDE FROM DAM
S           = DISTANCE OF MOVEMENT OF LANDSLIDE
```

```
ENTER       0 FOR TERMINATION

            2 FOR EXECUTION
```

APPENDIX -XV

OUTPUT FILES OF PROGRAM WAVE

WAVE HEIGHT IN RESERVOIR DUE TO LAND SLIDE AT RBS14 (RIGHT BANK)

HEIGHT OF WAVE DUE TO LAND SLIDE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS14.dat
OUTPUT FILE NAME ->OWAVE.dat

****

CASE = 1
RESIDUAL FACTOR OF SAFTY = .0282
RESIDUAL ANGLE OF FRICTION = 15.0000
WEIGHT OF WEDGE (TOTAL) = .500E+04
HEIGHT OF SLOPE = 55.0000
DIP OF LAND SLIDE = 84.0000
DISTANCE OF SLOPE MOVEMENT = 35.0000
HEIGHT OF WATER ABOVE TOE = 25.0000
ACCELERATION DUE TO GRAVITY = 9.8100
UNIT WEIGHT OF WATER = 1.0000
MAXIMUM WAVE HEIGHT DUE TO LAND SLIDE= .7760
HEIGHT OF WAVE = .1940
AT DISTANCE FROM LAND SLIDE = 400.0000
MAXIMUM VELOCITY OF LAND SLIDE = 25.7625
KINETIC ENERGY OF LAND SLIDE = .4330

****

WAVE HEIGHT IN RESERVOIR DUE TO LAND SLIDE AT RBS15 (RIGHT BANK)

HEIGHT OF WAVE DUE TO LAND SLIDE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS15.DAT
OUTPUT FILE NAME ->OWAVE.DAT

****

CASE = 1
RESIDUAL FACTOR OF SAFTY = .0000
RESIDUAL ANGLE OF FRICTION = 15.0000
WEIGHT OF WEDGE (TOTAL) = .520E+04
HEIGHT OF SLOPE = 70.0000
DIP OF LAND SLIDE = 90.0000
DISTANCE OF SLOPE MOVEMENT = 40.0000
HEIGHT OF WATER ABOVE TOE = 20.0000
ACCELERATION DUE TO GRAVITY = 9.8100
UNIT WEIGHT OF WATER = 1.0000
MAXIMUM WAVE HEIGHT DUE TO LAND SLIDE= 1.3550
HEIGHT OF WAVE = .1807
AT DISTANCE FROM LAND SLIDE = 600.0000
MAXIMUM VELOCITY OF LAND SLIDE = 28.0143
KINETIC ENERGY OF LAND SLIDE = 1.3000

****

WAVE HEIGHT IN RESERVOIR DUE TO LAND SLIDE AT RBS16 (RIGHT BANK)

HEIGHT OF WAVE DUE TO LAND SLIDE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS16.DAT
OUTPUT FILE NAME ->OWAVE.DAT

****

CASE = 1
RESIDUAL FACTOR OF SAFTY = .1862
RESIDUAL ANGLE OF FRICTION = 16.0000
WEIGHT OF WEDGE (TOTAL) = .500E+04
HEIGHT OF SLOPE = 80.0000
DIP OF LAND SLIDE = 57.0000
DISTANCE OF SLOPE MOVEMENT = 45.0000
HEIGHT OF WATER ABOVE TOE = 20.0000
ACCELERATION DUE TO GRAVITY = 9.8100
UNIT WEIGHT OF WATER = 1.0000
MAXIMUM WAVE HEIGHT DUE TO LAND SLIDE= 1.0924
HEIGHT OF WAVE = .1748
AT DISTANCE FROM LAND SLIDE = 500.0000
MAXIMUM VELOCITY OF LAND SLIDE = 24.5475
KINETIC ENERGY OF LAND SLIDE = .9598

****

WAVE HEIGHT IN RESERVOIR DUE TO LAND SLIDE AT RBS17 (RIGHT BANK)

HEIGHT OF WAVE DUE TO LAND SLIDE

****

UNITS USED -> TONNE - METER - DEGREE
INPUT FILE NAME ->IRBS17.DAT
OUTPUT FILE NAME ->OWAVE.DAT

****

CASE = 1
RESIDUAL FACTOR OF SAFTY = .1723
RESIDUAL ANGLE OF FRICTION = 16.0000
WEIGHT OF WEDGE (TOTAL) = .500E+05
HEIGHT OF SLOPE = 80.0000
DIP OF LAND SLIDE = 59.0000
DISTANCE OF SLOPE MOVEMENT = 50.0000
HEIGHT OF WATER ABOVE TOE = 25.0000
ACCELERATION DUE TO GRAVITY = 9.8100
UNIT WEIGHT OF WATER = 1.0000
MAXIMUM WAVE HEIGHT DUE TO LAND SLIDE= 4.1162
HEIGHT OF WAVE = 1.3721
AT DISTANCE FROM LAND SLIDE = 300.0000
MAXIMUM VELOCITY OF LAND SLIDE = 26.3819
KINETIC ENERGY OF LAND SLIDE = 4.5407

****

WAVE HEIGHT IN RESERVOIR DUE TO LAND SLIDE AT LBS5 (LEFT BANK)

HEIGHT OF WAVE DUE TO LAND SLIDE

```
***************************************************************************
UNITS USED          -> TONNE - METER - DEGREE
INPUT FILE NAME      ->ILBS5.DAT
OUTPUT FILE NAME     ->OWAVE.DAT
***************************************************************************
CASE = 1
RESIDUAL FACTOR OF SAFTY            =     .0923
RESIDUAL ANGLE OF FRICTION          =   15.0000
WEIGHT OF WEDGE (TOTAL)             =  .520E+04
HEIGHT OF SLOPE                     =   80.0000
DIP OF LAND SLIDE                   =   71.0000
DISTANCE OF SLOPE MOVEMENT          =   50.0000
HEIGHT OF WATER ABOVE TOE           =   25.0000
ACCELERATION DUE TO GRAVITY         =    9.8100
UNIT WEIGHT OF WATER                =    1.0000
MAXIMUM WAVE HEIGHT DUE TO LAND SLIDE=     .9447
HEIGHT OF WAVE                      =     .0630
AT DISTANCE FROM LAND SLIDE         = 1500.0000
MAXIMUM VELOCITY OF LAND SLIDE      =   29.0168
KINETIC ENERGY OF LAND SLIDE        =     .5713
***************************************************************************
```