FINITE ELEMENT ANALYSIS OF CONCRETE GRAVITY DAM ON STRATIFIED FOUNDATIONS

A DISSERTATION

submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF ENGINEERING
in
WATER RESOURCES DEVELOPMENT

By
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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled **"FINITE ELEMENT ANALYSIS OF CONCRETE GRAVITY DAM ON STRATIFIED FOUNDATIONS"** in partial fulfillment of the requirement for the award of the Degree of Master of Engineering in Water Resources Development (Civil) submitted in the Department of Water Resources Development Training Center of University of Roorkee is an authentic record of my own work carried out during a period from July, 2000 to January, 2001 under the supervision of Dr. B.N. ASTHANA, Emeritus Fellow Water Resources Development Training Center and Dr. N.K. SAMADHIYA, Assistant Professor Department of Civil Engineering, University of Roorkee, Roorkee, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

Dated : 15.1.2001

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

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SYNOPSIS

Concrete Gravity Dam is a solid concrete structure with its cross-section approximately triangular in shape, so proportioned that the external forces exerted on it are resisted by its own weight. The pattern of stress distribution and deformations in the dam foundation system are of great concern for safety and economy in case of a high gravity dam founded on stratified weak rock. Any variation in foundation properties would largely affect the safe design of dam.

In this dissertation, the stresses and deformations have been studied by using 2-D Finite Element Method. The study is divided into 3 parts :

Part 1 – Analysis of a dam section with varying rock modulus of foundation, Poisson's ratio of foundation and foundation extents, considering external loads of water pressure and full uplift pressure.

Part 2 – Analysis of a dam section with external loads of water pressure and modified uplift pressure.

Part 3 - Analysis of the dam section for stresses and deformations with a shear zone at different locations in the foundation with loads and foundation extent as in part-2.

Result of this study which deal with distribution of stresses and deformations have been analyzed and discussed in this dissertation.

The study shows that the foundation elasticity and foundation extent affect the distribution of stresses and deformations in dam foundation system. Poisson's ratio of rock is seen to have little effect on stress distribution and deformations. Tensile stresses are found concentrated around the heel and compressive stresses are the maximum around the toe of the dam. Away from the dam, the stresses and deformations reduce in the foundation.

It has been seen that with a shear zone in foundation, the stresses and deformations increase to the maximum when the shear zone is under the toe of the dam section.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1

INTRODUCTION

Concrete gravity dam is one of the various types of dam which is still the favourite of the designer's choice due to its good record of safety. In designing the concrete gravity dam, the foundation problems are more complex, particularly for high dam. That is why the rock properties and geological features of dam foundation have major role in determining either the stress distribution or deformation in the dam body due to imposed load.

Gruner reported in the ninth congress on large dams (1967) that four hundred important failures of dams of all types have occurred out of over 150,000 dams, 33% of these failures were due to foundation effects. The role of foundation in a gravity dam has been appreciated in overall success of a water resources scheme. The importance of uplift has only been realized towards the end of the 19th century, and grouting procedure has come into being within the last 60 years. Foundation drainage is of still more recent origin. Despite the progress, present techniques of dam design still have many assumptions, approximations and unknown variables.

While designing a gravity dam, the foremost job is how to evaluate the dam foundation system. To study any problem regarding dam foundation system these days, Finite Element Analysis, a power mathematical tool is being used frequently. This method needs a definite solution space with boundary conditions which are being chosen arbitrarily based on some assumptions.

1.1 Objectives of Study

The objectives of the present study is to analyze :

- Stresses, and
- Deformations in dam foundation system due to applied loads.

The study is divided into 3 (three) parts :

Part 1 – Analysis of a dam section with varying rock modulus of foundation, Poisson's ratio of foundation and foundation extents, considering external loads of water pressure and full uplift pressure.

Part 2 – Analysis of a dam section with external loads of water pressure and modified water pressure.

Part 3 - Analysis of a dam section for stresses and deformations with a shear zone at different locations in the foundation with loads and foundation extents as in part-2.

1.2 Methodology

Stresses and deformations in the dam foundation section under different conditions have been worked out by using 2-Dimensional Finite Element Method.

1.3 Brief outline of the Study

A brief outline of the mathematical model leading to the use of computer program which is used in the present study has been given in Chapter - 2. The limitation of the model are also discussed in this chapter.

In Chapter - 3, the results of all cases studied have been analyzed for a 100 m high concrete gravity dam with vertical upstream face and downstream slope of 0.8 H to 1.0 V.

Conclusions of the study have been given in Chapter – 4 along with suggestions for further study.

MATHEMATICAL MODEL, SOLUTION SCHEME AND INPUT DATA

Gravity dams are most commonly designed by method of gravity analysis to ensure the dam stability against:

- Overturning
- Sliding and
- Floatation

without any consideration of the foundation properties, hence it is not capable to predict the actual stresses in dam foundation sufficiently. There was a method which was adopted in such cases as Trial Load method (USBR), but now with the availability of computer programming, it is possible to analyze the dam foundation system by using Finite Element Analysis which is very versatile and some of the advantages of this method are:

- Good accuracy and reliability of the stress and displacement results when used idealized mathematical model properly
- The ability to modify loading conditions and material properties and quickly determining the effect of the changed conditions.
- The ability to vary material properties including non-linear plasticity and temperature effect across a section or in different areas of the model.
- The ability to analyze quickly the effects of a change in shape.
- Modeling of cracked section or an opening joint in the section.
- Analyze non-homogenous, non-elastic foundation concluding weak zones, clay or gauge seams, and discontinuities and also evaluate the effects of these on stress distribution.
- Accommodate curvilinear stress distribution across the thickness of the dam.

For the above reasons, FEM analysis has been adopted in this study to find the effect of foundation on the stresses and deformations in the dam body.

2.1 Finite Element Analysis

The finite element method based on discretization concept, is a generalized analysis approach employed to find variation of deformation and stresses etc. of any structure when determination of such distribution fields become difficult, even some times impossible by using conventional method.

The finite element method utilizes the idea that a continuous body may be considered an assemblage of distinct elements connected at their corner. This computerized method has become a widely used and accepted means of stress analysis in the last decade. The literature of the part few years contains numerous examples of specialized uses of the finite element method. The reason for the ready acceptance and tremendous amount of use of this method is that it made possible the approximate solution of many problems which engineers had been neglecting, over designing, or grossly approximating. The inclusion of the complex geometrical and physical property variations prior to adaptation of the finite element method and the modern high speed digital computer was simply beyond the realm of reality. The finite element method permits a very close approximation of the actual geometry and extensive variations of material properties simply and inexpensively. Because of the ability of the method to analyze special situations, this is the area in which the most application has been made.

The basic concept of finite element method visualizes entire structure on assemblage of individual finite number of small regions or finite elements. The structural idealization is only possible with the use of appropriately shaped two or three dimensional structure elements dividing the original continuum into segments of appropriate shape and size together with retention of material properties of original system in the individual elements, nodes and boundary conditions. Finite element method involves the exact analysis of such idealized method rather than structural approximation of continuum which renders it as a powerful tool for analyzing system involving arbitrary shapes and material values and boundary conditions (USBR).

2.2 Shape Functions

In the finite element, the displacement is assumed to have unknown values only at the nodal points so that the variation within any element is described in terms of the nodal values by means of shape functions.

$$\delta = \sum_{i=1}^{n} N_i \, \delta_i \qquad \text{.... (2.1)}$$

in which Ni depends on the local coordinates and are collectively known as shape function.

In this study, 4 (four) nodes iso-parametric elements have been used. A typical two-dimensional version is illustrated in Figure 2.1. For plane stress and plane strain applications, the displacement fields u (ξ, η) and v (ξ, η) throughout the element are defined using two displacement degrees of freedom at each of the 4 nodes, such as:

$$u = \sum_{i=1}^{4} N_i \, u_i$$

$$\text{...... (2.2)}$$

$$v = \sum_{i=1}^{4} N_i \, w_i$$

The cartesian coordinate x (ξ, η) and y (ξ, η) at any point (ξ, η) within the element are defined by the expressions:

$$x = \sum_{i=1}^{4} N_i \, x_i$$

$$\text{..... (2.3)}$$

$$y = \sum_{i=1}^{4} N_i \, y_i$$

For nodal numbering of 4 (four) nodes iso-parametric elements shown in figure 2.1, all the four shape functions are given as:

$$N_1 = \frac{1}{4}(1-\xi)(1-\eta)$$

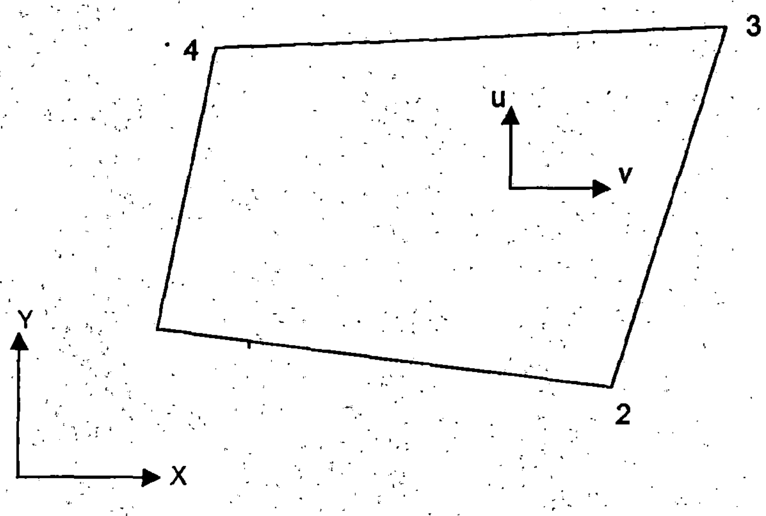
$$N_2 = \frac{1}{4}(1+\xi)(1-\eta)$$

$$\text{... (2.4)}$$

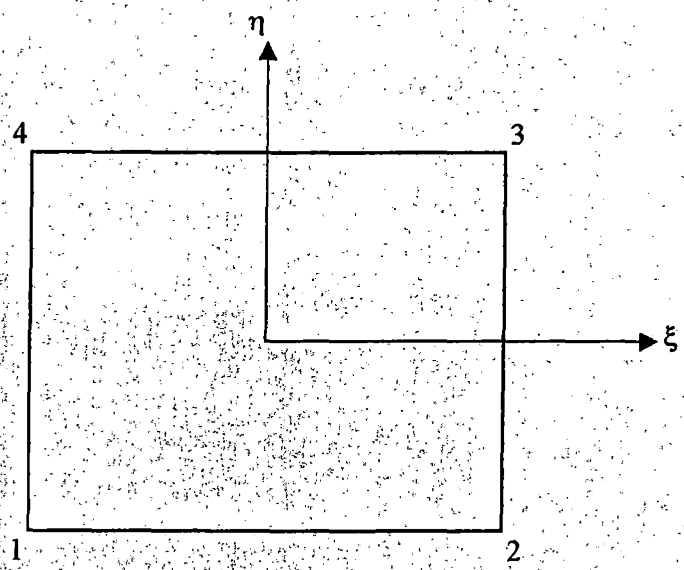
$$N_3 = \frac{1}{4}(1+\xi)(1+\eta)$$

$$N_4 = \frac{1}{4}(1-\xi)(1+\eta)$$

where, ξ and η are natural coordinates.



a. Cartesian coordinate system



b. Natural coordinate system

Figure 2.1 Coordinate System of 4 nodes 2-D FEM

2.3 Strain-Displacement Relationship

For the plane stress and plane strain situations, the strain and displacement relationship at any point within the element may be written as :

$$\{\varepsilon\} = \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \begin{Bmatrix} \partial u/\partial x \\ \partial v/\partial y \\ \dfrac{\partial u}{\partial y} + \dfrac{\partial v}{\partial x} \end{Bmatrix} = \begin{bmatrix} \partial/\partial x & 0 \\ 0 & \partial/\partial y \\ \partial/\partial y & \partial/\partial x \end{bmatrix} \begin{Bmatrix} u \\ v \end{Bmatrix} \quad \text{... (2.5)}$$

Substitution of displacement from eq. 2.2 gives :

$$\{\varepsilon\} = \sum_{i=1}^{n} \begin{bmatrix} \dfrac{\partial N_i}{\partial x} & 0 \\ 0 & \dfrac{\partial N_i}{\partial y} \\ \dfrac{\partial Ni}{\partial y} & \dfrac{\partial N_i}{\partial x} \end{bmatrix} \begin{Bmatrix} u_i \\ v_i \end{Bmatrix} = \sum_{i}^{n} [B_i]\{\partial i\} \quad \text{....... (2.6)}$$

where,

$$\{B_i\} = \begin{bmatrix} \dfrac{\partial Ni}{\partial x} & 0 \\ 0 & \dfrac{\partial Ni}{\partial y} \\ \dfrac{\partial Ni}{\partial y} & \dfrac{\partial Ni}{\partial x} \end{bmatrix} \quad \text{....... (2.7)}$$

where n is the total number of nodes in the element.

2.4 Stress-Strain Relationship

The stress-strain relationship for an elastic material in the absence of the initial stresses and strains, may be written as :

$$\{\sigma\} = [D]\{\varepsilon\} \quad \ldots (2.8)$$

where [D] is the elasticity matrix.

For the plane-stress situations and assuming isotropic materials :

$$[D] = \frac{E}{1-\upsilon}\begin{bmatrix} 1 & \upsilon & 0 \\ \upsilon & 1 & 0 \\ 0 & 0 & \frac{1-\upsilon}{2} \end{bmatrix} \quad \ldots (2.9)$$

And for the plane strain :

$$[D] = \frac{E}{(1+\upsilon)(1-\upsilon)}\begin{bmatrix} 1-\upsilon & \upsilon & 0 \\ \upsilon & 1-\upsilon & 0 \\ 0 & 0 & (1-2\upsilon)/2 \end{bmatrix} \quad \ldots (2.10)$$

2.5 Cartesian Shape Function Derivatives

The strain matrix $[B_i]$ in equation 2.7 depends on the derivatives of shape function N_i with respect to global coordinates. They are determined as follows :

$$\begin{Bmatrix} \frac{\partial Ni}{\partial \xi} \\ \frac{\partial Ni}{\partial \eta} \end{Bmatrix} = \begin{bmatrix} \frac{\partial x}{\partial \xi} & \frac{\partial y}{\partial \xi} \\ \frac{\partial x}{\partial \eta} & \frac{\partial y}{\partial \eta} \end{bmatrix} \begin{Bmatrix} \frac{\partial Ni}{\partial x} \\ \frac{\partial Ni}{\partial y} \end{Bmatrix} = [J] \begin{Bmatrix} \frac{\partial Ni}{\partial x} \\ \frac{\partial Ni}{\partial y} \end{Bmatrix} \quad \ldots\ldots (2.11)$$

where the square matrix [J] is called Jacobian matrix.

From eq. 2.11, the global derivatives can be found out by inverting [J]. Substituting equation 2.3 in the Jacobian matrix for x and y,

$$[J] = \begin{bmatrix} \frac{\partial N1}{\partial \xi} & \frac{\partial N2}{\partial \xi} & \frac{\partial N3}{\partial \xi} & \frac{\partial N4}{\partial \xi} \\ \frac{\partial Ni}{\partial \eta} & \frac{\partial N2}{\partial \eta} & \frac{\partial N3}{\partial \eta} & \frac{\partial N4}{\partial \eta} \end{bmatrix} \begin{bmatrix} x1 & y1 \\ x2 & y2 \\ x3 & y3 \\ x4 & y4 \end{bmatrix} \qquad \ldots\ldots (2.12)$$

2.6 Element Stiffness Matrix

Having evaluated the strain-displacement matrix [B] and the elasticity matrix $[K^e]$ is evaluated as :"

$$[K^e] = \int [B]^T [D][B]\, dV \qquad \ldots\ldots (2.13)$$

Numerical Gauss-Legendre integration technique is used for integration over an area of the element.

2.7 Assemblage of Stiffness Matrices and Load Vectors

The individual element stiffness and loads vectors which computed separately for all the elements are added directly to the global matrix [K] and the load vector {F}, in positions appropriate to the node numbers of the element. Thus for an assembled structure, number of simultaneous equations which equal to the total number of degrees of freedom are obtained by its equilibrium condition of the form :

$$\{F\} = [K]\{\delta\} \qquad \ldots\ldots (2.14)$$

where $\{\delta\}$ is the displacement vector.

Necessary boundary conditions are applied and the resulting simultaneous equations are solved for the primary unknowns of nodal displacements.

2.8 Secondary Unknown

The secondary unknowns such as strain and stress at either gaussian points or at nodal points of each element are computed respectively from the equations 2.6 and 2.8.

The major principles stress σ_{p1} and the minor principal stress σ_{p2} are determined by the equations :

$$\sigma_{p1} = \frac{1}{2}(\sigma_x + \sigma_y) + \sqrt{\left(\frac{\sigma x + \sigma y}{2}\right)^2 + \tau_{xy}^2} \quad \text{.... (2.15)}$$

$$\sigma_{p1} = \frac{1}{2}(\sigma_x + \sigma_y) - \sqrt{\left(\frac{\sigma x + \sigma y}{2}\right)^2 + \tau_{xy}^2} \quad \text{.... (2.16)}$$

where σ_x and σ_y are the horizontal and vertical normal stress respectively and τ_{xy} is the shear stress on both the planes x and y.

2.9 Solution Scheme

2.9.1 2-D case studies

In reality, all high dams together with their foundations where if transverse joints are provided, it is 2-D otherwise is 3-D. When the structure or loading is such that plane stress or strain conditions may not be assumed, the 3-dimensional finite element method may be used. As the cost of three dimensional analysis is likely to be, typically, in the range of 5-10 times that of a two-dimensional approximation (and often much larger) the designer has to consider whether errors introduced by such an assumption are acceptable and on the safe side. Because of the reasons above, 2-D analysis is capable also either of analyzing the majority of problems associated with variations in the geometry of sections of the dam or of solving for stress economically even when great detail is necessary to attain sufficient accuracy. In this study, the structure is divided into elements of an arbitrary. The vertices of these shapes form nodal points. The deflections at the nodal points due to various stresses applied to each element are a function of the element geometry and material properties. The coefficient matrix relating this deflection of the element to the load applied is the individual element stiffness matrix. These stiffness are combined with the stiffness of all the other elements to form a global stiffness matrix. The load existing at each node are determined. The deflections of each node in two directions are unknown. The same number of equations relating stiffness coefficients times unknown deflections to existing loads (right hand members) have been generated. The very large coefficient matrix is banded and symmetric. Advantage of this fact is taken into account in the storage of this matrix. The equations are solved by Gauss elimination.

2.9.2 Discretization of elements

In this study, 4 noded iso-parametric element have been used. The typical two dimensional version is shown in Fig. 1.b. The numbering of elements has been done from top to bottom moving from upstream to downstream.

Figures 2.3 to 2.6 show the finite element mesh which is developed for analysis. In figure 2.3, the dam body consists of 88 elements, when the foundation system is being 368 elements. This discretization is used for analyzing part-1 and part-2 studies. Figures 2.4 and 2.6 are used to analyze part-3 study in which the dam body consists of 88 elements and foundation system has 290 elements. In Figure 2.5, the dam body consists of 99 elements and foundation system has 290 elements. In figures 2.4 to 2.6, the foundation elements have been shaped depending on the inclination and the location of the shear zone.

2.9.3 Dam Section

In this analysis, a 100 m high dam has been taken with vertical upstream face and down stream slope of 0.8 H : 1.0 V. The down stream slope taken is almost same as the slopes of the existing gravity dam sections above medium height. Detail of dam section of some dams are given in table 2.1. The top width of the dam is taken as 8 m. The base width of the dam is 80 m. In case of part-1 case studies, the drainage is considered choked and the uplift pressure equal to head of water is assumed working on the dam base, while in part-2 and part-3 studies, the drainage gallery is assumed at 10 m away from the vertical upstream face of the dam. Thus the modified uplift is considered in this two studies. No fillets have been provided at the heel or toe as they have local effect on stress distribution.

2.9.4 Material characteristic of Dam and foundation

In this case, the system has two distinctly different sub-system of dam and foundation, ignoring presence of interface between dam and foundation at dam base. Hence, dam and foundation have been considered totally integrated as a monolithic structure though it is not true. The effect of different elasticity of the foundation rock have been studied, since the elasticity of the rock foundation affects the stresses and displacements in the dam and the foundation.

The characteristic of dam material which are taken in this study are:

i) Elasticity (E) = 2×10^6 T/m^2

ii) Poisson's ratio (v) = 0.2

iii) Density (μ) = 2.4 T/m^3

In case of the characteristics of foundation Material, for most of the concrete gravity dam sites, the properties of rock material may be comparable to that of dam material. However, depending upon the type of rock available at various site, the properties of the foundations are found to vary substantially. Actual field data of rock properties of several dams has been studied to define the range of values. Relevant data of some of the important dams are given in Table 2.2. In this analysis, the following values of foundation rock have been considered.

i) The Poisson's ratio is taken as 0.2 and 0. 3 in all cases for the foundation rock whose modulus of elasticity ranges from 0.2 to 0.8 of concrete.

ii) Dead weight of the foundation rock has been excluded as the rock mass already exists before construction of any dam, so the density is taken as zero.

iii) The density of water is taken as 1 t/m3.

2.9.5 Loads

The loads usually acting on a gravity dam are as follows :

- Self weight of the dam
- Water pressure
- Uplift pressure
- Silt pressure
- Wave pressure
- Wind load
- Ice pressure (in cold climate only)
- Seismic loads (if located in an earthquake prone region)

All the loads are not considered acting on the dam simultaneously. IS-6512 specifies a combination of loads to be considered for the design of gravity dam. Seismic loads will be acting only occasionally and that too for a short duration on the dam and so it is considered extreme loading combination.

Table 2.1 Profile of some Existing Dams

S. No.	Name of Dam	Height (m)	Up stream slope	Down steam slope
1	Detroit Dam (USA)	92	vertical for top 1/3rd and 1/10th for rest	0.75 : 1
2	Fontana Dam (USA)	134	vertical with fillets at bottom	0.76 : 1
3	Grand Coulee Dam (USA)	167	upper half vertical bottom half 1 : 6.66	0.8 : 1
4	Bhakra Dam (India)	226	vertical for top 110 m and 1 : 2.9 for heel slope	0.8 : 1
5	Shasta Dam (USA)	137	vertical with fillets	0.8 : 1
6	Karjan Dam (India)	100	vertical for 2/3rd and 1:2 for rest	0.8 : 1
7	Narmada Dam (India)	155	vertical for 3/5th and rest 1:4	0.75 : 1

Tabel 2.2 Elastic Constants of Foundation Rock of some dams

S. No.	Name of Dam	Type of Rock	Elastic constant	
			Elasticity in t/m2 x 10^6	Poisson's Ratio υ
1	Bhakra Dam (India)	Sand stone with clay bands	0.28 to 2.4	0.1 to 0.3
2	Yellow Tail (USA)	Lime stone	2.00 to 2.6	0.15 to 0.25
3	Ichari Dam (India)	Granite Lime stone Schist	0.5	0.2
4	Narmada Dam (India)	Granite Lime stone Schist	3.3 to 4.3	0.2
5	Hirakud Dam (India)	Quartize, sheared phylite, granite gneiss, senecite schist	1.14 to 2.3	0.18 to 0.22

In this study, analysis have been done for the following normal loads are:

- self weight
- water pressure
- uplift pressure

which act simultaneously. Here again, for simplification, it is assumed that there is no tail water in downstream.

If the seismic forces are taken as equivalent static forces, the distribution of loads will not be realistic. Therefore, seismic forces can best be accounted for by a dynamic analysis of the dam. This has not been done in this study. Hence the seismic forces have not been considered in the analysis.

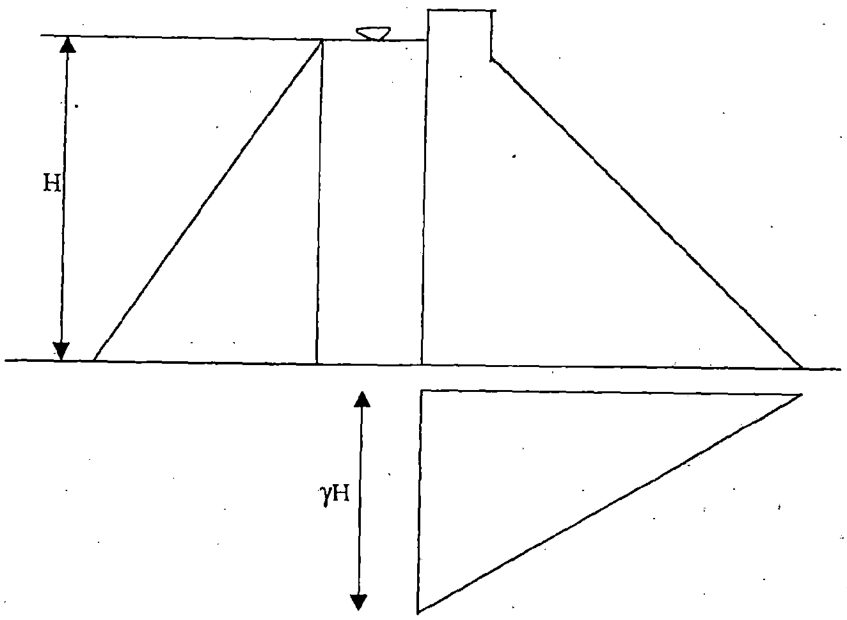
Water level has been taken up to 5 m below the top of the dam. The full and modified uplift pressure are equal to the water head at heel (see figure 2.2). The downward water load on the extended foundation upstream has not been taken by considering the foundation being submersible.

2.9.6 Initial stresses and thermal stresses

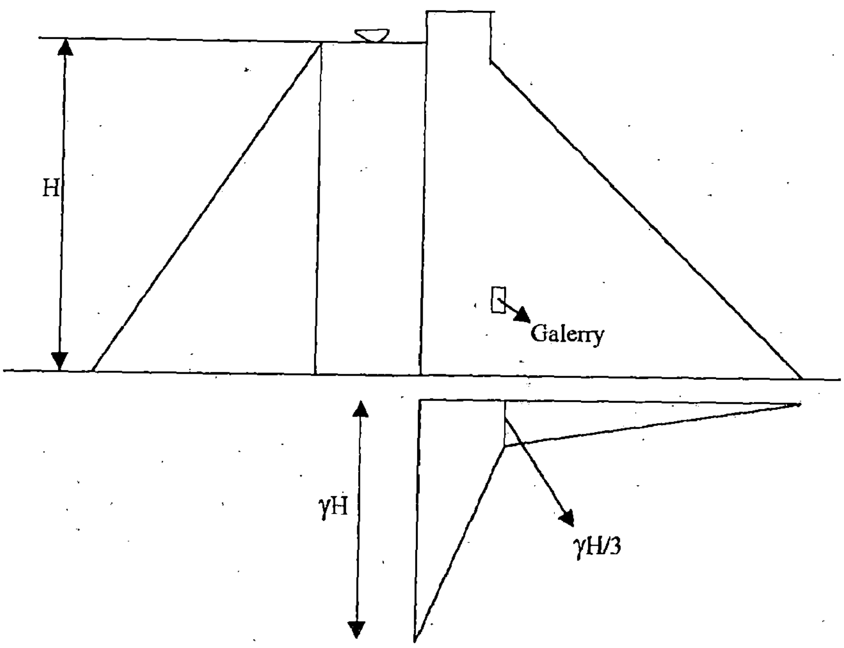
In analysis, initial stresses of the foundation rock have not been considered assuming that the rock underneath the dam base and in whole extent of foundation has been stresses due to own load of in bed and abutment overburden since long. In this study, the dead weight of the foundation has not been taken, so initial stresses can also be neglected safely.

2.9.7 Idealization of Boundary Condition

One of the important idealization in analyzing by this method is how to decide the boundary condition. Since only a finite zone can be include adequate extents in the mesh in the vertical and lateral directions so the approximate boundary conditions can be defined. In this study, by assuming a rigid rock boundary is available below the base of foundation system, hence it has assumed the displacement to be zero. In the lateral distance from the edge of the dam with respect to cases studied, by assuming the foundation material beside in both up stream and down stream direction are less, so the displacements are free for one type of boundary condition and for another type of boundary condition, the horizontal displacement is kept zero and vertical displacement is



a. Full Uplift Pressure



b. Modified Uplift Pressure

Figure 2.2 Uplift Pressure

kept free by assuming that any rigid rock boundary is available beside the upstream and down stream side of foundation.

2.9.8 Cases Analyzed

In this study, the cases to be analyzed are divided into 3 parts :

- part-1, analysis of a dam section with varying rock modulus of foundation, Poisson's ratio of foundation and foundation extents, considering external loads of water pressure and full uplift pressure with different boundary conditions.
- part-2, analysis of the dam section with foundation extent equal to height of dam and foundation elasticity of 0.4 times of concrete elasticity (weak foundation) considering external loads of water pressure and modified uplift pressures with a boundary condition.
- part-3, analysis of the dam section for stresses and deformations with an inclined shear zone at different locations in the foundation considering the loads, foundation extent same as in part-2.

The cases analyzed by 2D-FEM are listed in table 2.3.

2.10 Input

The important part of analyzing the system through finite element method is the preparation of input data. First is the generation of mesh (discretisation) on the surface of the system. The mesh generation can be done manually before feeding to the computer. The mesh adopted for different parts of the study are shown in Figure 2.3, 2.4, 2.5 and 2.6. The feeding of input data is explained below. The Standard FEM program is used for this study.

2.10.1 Card 1 – Title

In this data card, the case which is being studied is mentioned clearly, so that while interpreting the results, it would be always easier to identify output of different cases.

2.10.2 Card 2 – Control Data (on line)

In this data card, we input the data as follows:

a. Problem : Stress and deformation

TABLE 2.3 Table of Cases Analysed

PART NO.	BOUNDARY CONDITION	VARIABLE FOUNDATION MATERIAL	VARIABLE FOUNDATION EXTENT U/S	VARIABLE FOUNDATION EXTENT D/S	VARIABLE FOUNDATION EXTENT BOTTOM	EXTERNAL PRESSURE	REMARK
1	A. U/S Free D/S Free Base Fixed	EF = 0.2 ED EF = 0.3 ED EF = 0.4 ED EF = 0.5 ED EF = 0.6 ED EF = 0.8 ED	1.0 H 1.0 H 1.0 H 1.5 H 1.5 H 1.5 H 2.0 H 2.0 H 2.0 H	1.0 H 1.0 H 1.0 H 1.5 H 1.5 H 1.5 H 2.0 H 2.0 H 2.0 H	1.0 H 2.0 H 3.0 H 1.0 H 2.0 H 3.0 H 1.0 H 2.0 H 3.0 H	1 Water Pressure 2 Full Uplift Pressure	Homogeneous Foundation u = 0.3
	B. U/S Roller D/S Roller Base Fixed	-ditto-	-ditto-	-ditto-	-ditto-	-ditto-	-ditto-
	C. U/S Roller D/S Roller Base Fixed	-ditto-	1.0 H	1.0 H	1.0 H	-ditto-	Homogeneous Foundation u = 0.2
2	U/S Roller D/S Roller Base Fixed	EF = 0.4 ED	1.0 H 1.0 H 1.0 H 2.0 H	1.0 H 1.0 H 1.0 H 2.0 H	1.0 H 2.0 H 3.0 H 1.0 H	1 Water Pressure 2 Modified Uplift Pressure	Homogeneous Foundation u = 0.3
3	U/S Roller D/S Roller Base Fixed	EF = 0.4 ED E_{SZ} = 0.01 ED	2.0 H	2.0 H	1.0 H	1 Water Pressure 2 Modified Uplift Pressure	Shear Zone at: - U/S - Centre - D/S

b. Total no. of nodes	: 418 for part-1 and part-2 cases studies 440 for part-3 case studies
c. No. of nodes or which coordinate to be read	: 418 for part-1 and part-2 cases studies 440 for part-3 case studies
d. Total no. of elements	: 368 for part-1 and part-2 cases studies 388 for part-3a and part-3c cases studies 389 or part-3b case studies
e. No. of nodes per element	: 4
f. Problem type	: Plane strain
g. No. of material	2 for part-1 and part-2 cases studies 3 for part-3 case studies
h. No. of properties per material	: 4
i. No. of Gauss point in each direction (here the stresses are being calculated at 4 points in a single element)	: 2
j. No. of restrained nodes (Here, only base of foundation to be fixed in both direction)	: 29 for part-1a and 2 cases studies 49 for part –1b case studies : 31 for part-3 case studies
k. No. of loading cases	: 1

2.10.3 Card 3 - Connectivity Data

Connectivity is written in anti clockwise way and followed by material type, for example:

Element No.	Connectivity nodes	Material No.
1	1 2 13 12	1

2.10.4 Card 4 – Nodal Coordinates Data

Here, all the coordinates as mentioned in card-2 are written.

2.10.5 Card 5 – Fixity Data

Here, we put all the node numbers of restrained nodes as mentioned in card-2 and followed by the prescribed displacement in x and y direction.

For example,

Node No.	Fixity in x-direction	Fixity in y-direction	Prescribed displacement in x-direction	Prescribed direction in y-direction
11	1	1	0.	0.

2.10.6 Card 6 – Material Properties Data

Here, the node numbers followed by 4 properties as mentioned in card-2 are written. These are :

- Young Modulus
- Poisson's ratio
- Density at x-direction
- Density at y-direction

In part-1 and 2 cases studies, 2 material properties that is for dam and foundation are taken, while in part-3, 3 material properties that is dam, foundation and shear zone are taken. The material properties adopted are as below:

Type of material	Modulus elasticity	Poisson ratio	Density in x-direction	Density in y-direction
Concrete	2 x 10^6 t/m^2	0.2	2.4 t/m^3	0
Foundation	varying from0.4 up to 1.6x10^6 t/m^2	0.2 and 0.3	0	0
Shear zone	2 x 10^4 t/m^2	0.3	0	0

2.10.7 Card 7 – Load Data

Here, the numbers of nodes of point loads if any are written and it is followed by:

- indicator for body force (0 = No, 1 = yes)
- indicator for pressure load (0 = No, 1 = yes)
- numbers of nodes with temperature values.

In all cases studied, there is no point load is assumed to act on dam section, hence it is written as zero. For body force, the indicator '1' is given and for temperature values, indicator '0' is given because the temperature effect in all cases is ignored.

2.10.8 Card 8 – Pressure Load Data

Here, in the first line are written the numbers of pressure loads which is applied on dam section. In all cases there are 18 points for part-1, 2, 3a and 3c studies while part-3b studies has 19 pressure points which consist of water head and uplift pressure. In the next line, the type of pressure followed by node numbers of the pressure side in anti-clockwise direction are written with the weight age of pressure of the side in x and y direction.

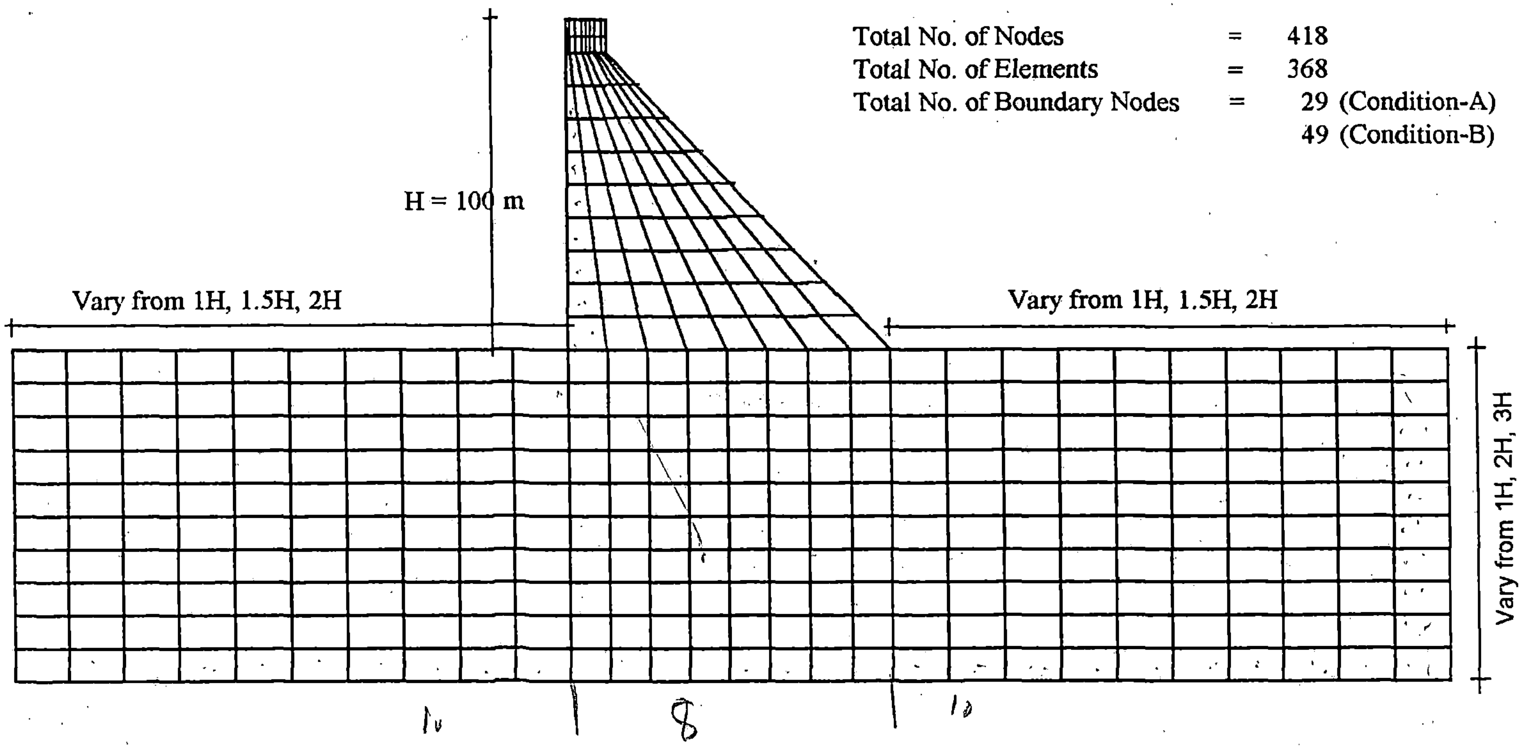


Figure 2.3 FEM Mesh Generation of Part-1 and 2 Study

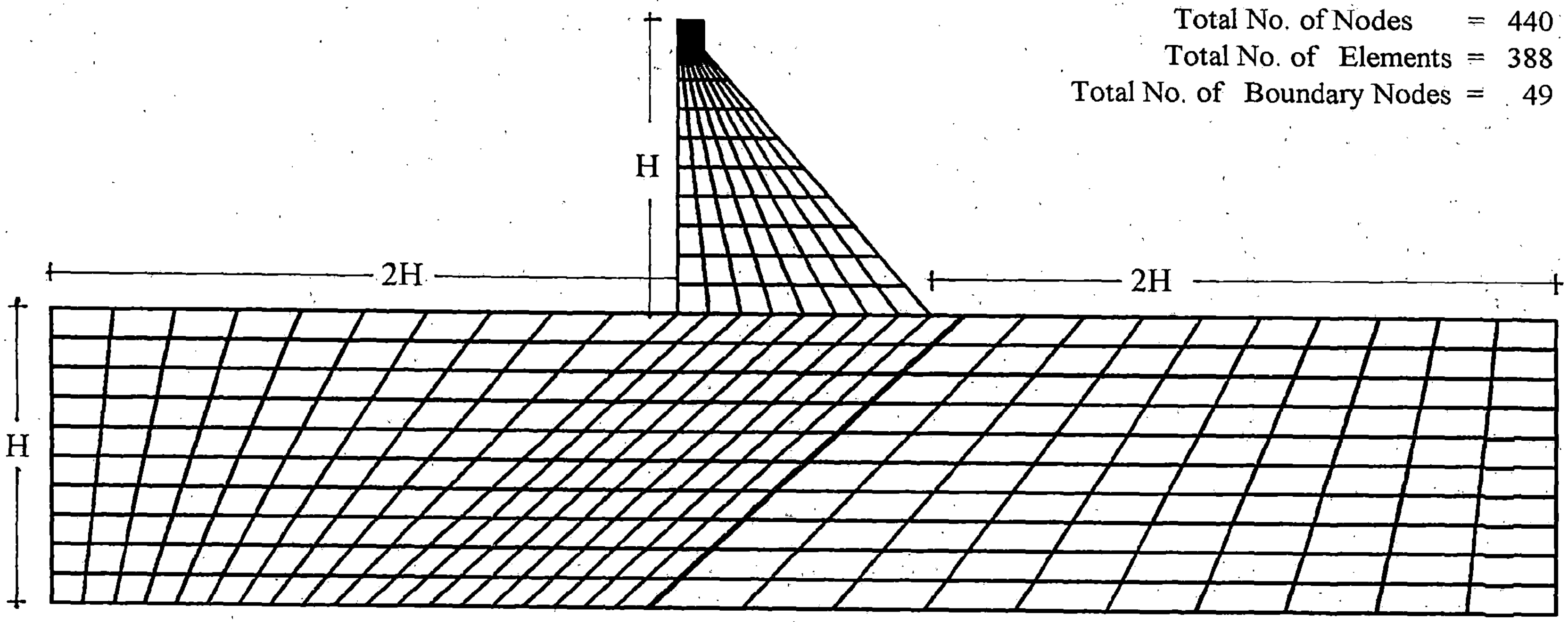


Figure 2.4 FEM Mesh Generation of Part-3 Study (d/s Shear Zone)

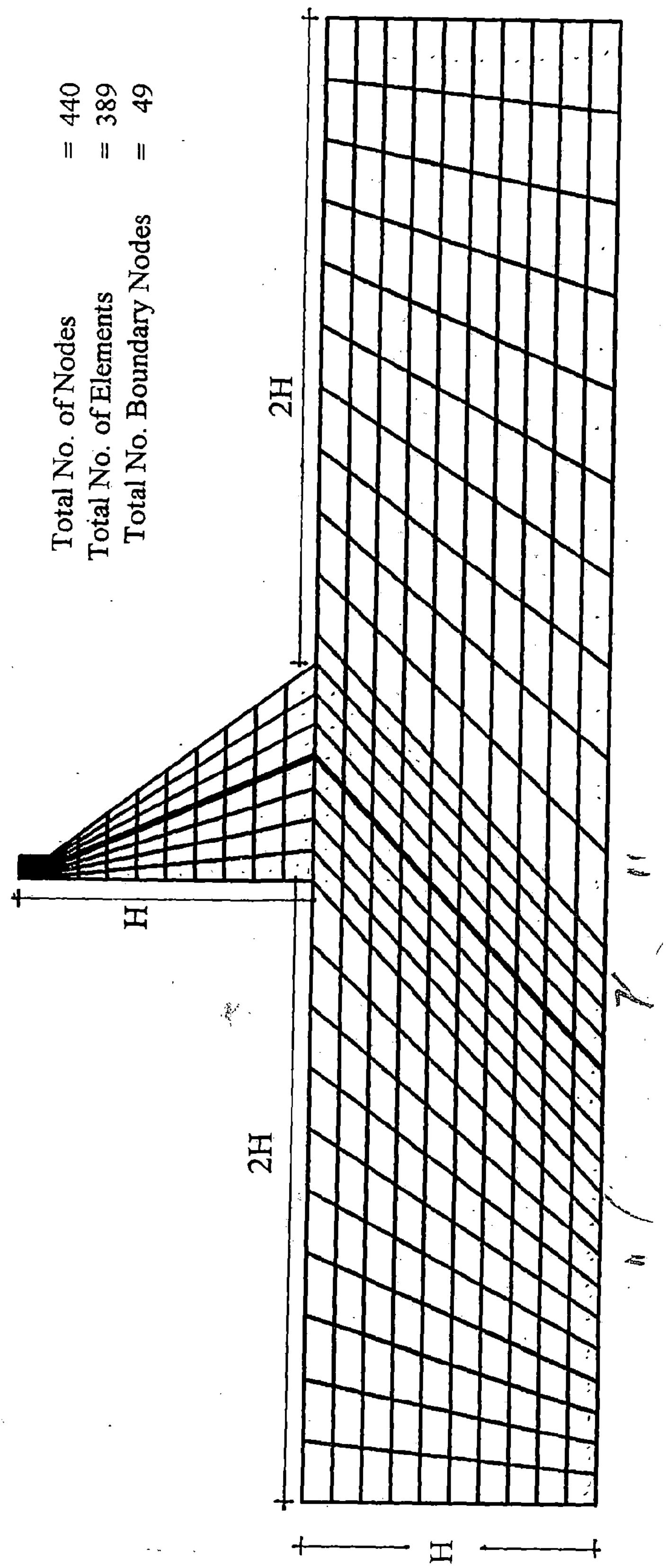


Figure 2.5 FEM Mesh Generation of Part-3 Study (centre Shear Zone)

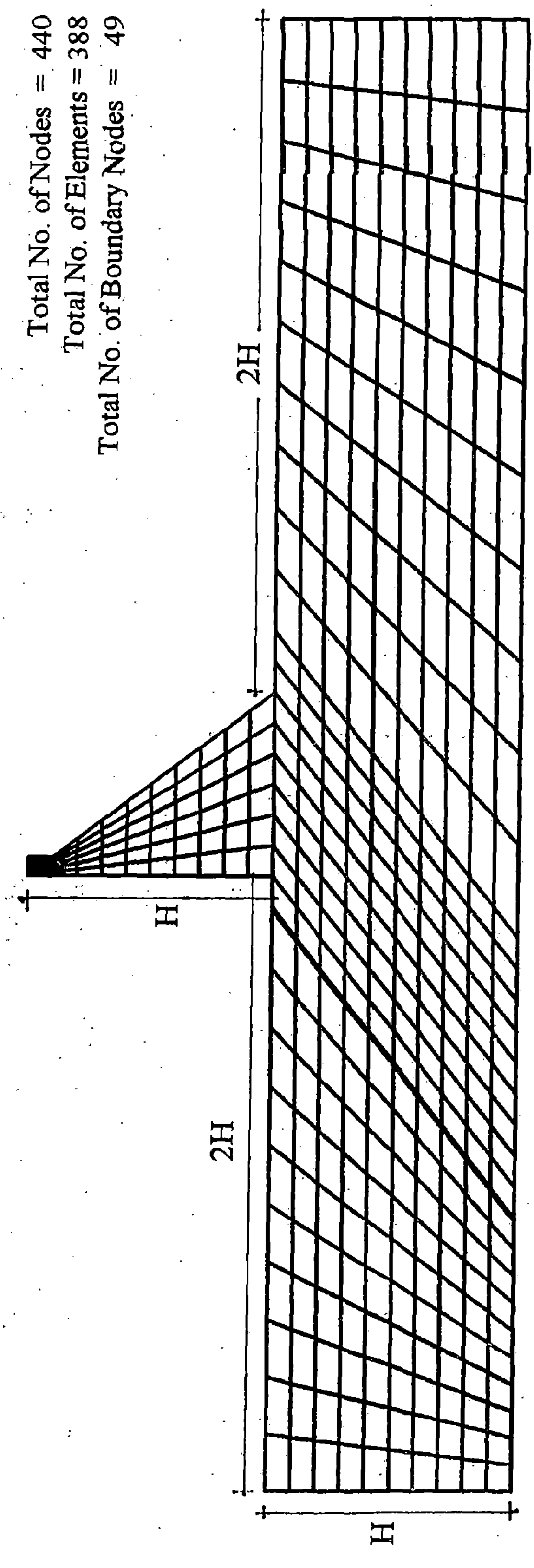


Figure 2.6 FEM Mesh Generation of Part-3 Study (u/s Shear Zone)

RESULTS AND ANALYSIS

3.1 Presentation of Results

Finite element program is used for calculating the stresses (σ_x, σ_y, τ_{xy}), principal stresses ($\sigma1$, $\sigma3$) and strain (ε_x, ε_y, γ_{xy}) at 4 (four) Gaussian points of each element of the discretized dam and foundation system. It also estimates the horizontal and vertical displacements (u, v) of nodal points.

By using data listed in Chapter – 2 under the parts input, displacements and stresses were computed for the various cases studied.

The results of all cases studied have been divided under following 3 parts :

- Part 1

  Under this part, the effect of foundation elasticity, Poisson's ratio of foundation and foundation extent with 2 (two) types of boundary conditions in dam-foundation system is studied by using external loads of water pressure and full uplift pressure.

- Part 2

  Under this part, some of foundation extents with one value of rigidity of foundation elasticity have been studied with external loads of water pressure and modified uplift (drainage gallery is present at 10 m from upstream face of dam) with one type of boundary condition. Here, the effect of deeper and wider foundation extent is studied in greater detail.

- Part 3

  Under this part, one of the foundation extent with one rigidity of foundation elasticity is studied with one type of boundary condition where shear zone is located in the foundation. Here, shear zone is located at different places that is at upstream, center and downstream of dam respectively.

For each of the above cases, the values of σ_x, σ_y, τ_{xy}, σ_{p1}, σ_{p2}, horizontal and vertical displacements have been chosen for the purpose of comparative analysis.

3.2 Discussions on the Results of Part – 1 Study

In this part, cases studied used 6 values of foundation elasticity viz. :

a. Ef = 0.2 Ed
b. Ef = 0.3 Ed
c. Ef = 0.4 Ed
d. Ef = 0.5 Ed
e. Ef = 0.6 Ed
f. Ef = 0.8 Ed

Each case of foundation elasticity has been analyzed for the following 9 combinations of foundation extent:

- 1H u/s, 1H d/s and 1H bottom
- 1H u/s, 1H d/s and 2H bottom
- 1H u/s, 1H d/s and 3H bottom
- 1.5H u/s, 1.5H d/s and 1H bottom
- 1.5H u/s, 1.5H d/s and 2H bottom
- 1.5H u/s, 1.5H d/s and 3H bottom
- 2H u/s, 2H d/s and 1H bottom
- 2H u/s, 2H d/s and 2H bottom
- 2H u/s, 2H d/s and 3H bottom, where H is the height of dam section.

Each combination of foundation elasticity and foundation extent has been analyzed for 2 types of boundary conditions, one of fixed bottom, and free at lateral foundation extents, and the other of fixed bottom and roller at lateral foundation extents. The effect of Poisson's ratio of foundation rock has also been studied with foundation extent of 1H u/s, 1H d/s and 1H bottom.

The results of the analysis of all these cases are shown in Tables 3.1 to 3.29 and Figures 3.1 to 3.28. These tables and figures indicate the deflections and stresses at several critical points in the dam body. Deflections have been tabulated for the top (crest), heel and toe, while stresses for heel and toe of the dam section are tabulated. In displacements value from these tables, the positive sign expresses for the right or upward direction and negative sign expresses for the left or downward direction. In stresses value from these tables, the positive sign means in tensile condition and the negative sign means in compressive condition. Boundary condition of fixed at bottom and free at lateral sides is called condition-A and another with sides as roller is denoted as condition-B.

3.2.1 Displacement

Displacement in dam occurs due to gravity load, water pressure, foundation and abutment deformations and the temperature effects. This last effect is due to partly the temperature gradients set up due to the heat of hydration of cement and its gradual dissipation and partly due to seasonal and diurnal climatic changes and exposure to the sum, but this effect is not considered in these study.

Tables 3.1 and 3.2, and Figures 3.1 and 3.2 indicate the horizontal and vertical displacement at crest, heel and toe for all cases of this part of study for boundary condition-A. From Table 3.1, it can be seen that the deflections tend to decrease with increase in modulus value of foundation. From Table 3.2, the effect of foundation extent is more clear. At crest and toe, there is no change in direction of both horizontal and vertical displacements with deeper foundations in any case of lateral foundation extent. But, at heel, as foundation extent is taken deeper in any lateral foundation extent, the horizontal displacement changes the direction from negative to positive. Here, negative indicates the movement to the left and positive to the right direction.

Logically, horizontal displacement is caused by applied water pressure which pushes the dam from left to right direction. The uplift pressure which acts upward on base of dam overturns the dam to clockwise direction. Here, the gravity load of dam has to balance the uplift pressure effect to keep the dam in stability condition. The results show that the displacement of heel reduce with the increase in modulus value of foundation rock.

The effect of foundation extent, at any value of rock modulus, is seen to reduce the horizontal displacement with the increase in lateral extent of foundation. As deeper extent of foundation at any lateral foundation is seen to increase the horizontal displacement.

In vertical direction, the effect of foundation extent at any foundation elasticity shows that as the foundation extent becomes deeper at any lateral foundation extent, the displacement tends to decrease at crest and heel, but increases at toe. But at any depth of foundation extent, the increase in lateral foundation extent decreases the displacement at crest, heel and toe. Figures 3.1 and 3.2 show the trend of change in displacement both in horizontal and vertical direction at crest, heel and toe. The change in displacement is steeper in the range of foundation elasticity from 0.2 to 0.6. than the range from 0.6-0.8 of foundation elasticity. The displacements in general are asymptotic in the range of Ef/Ed = 0.8.

Tables 3.3 and 3.4, and Figures 3.3 and 3.4 show the displacement at crest, heel and toe with boundary condition-B. From Table 3.3, it can be seen that as rigid the foundation elasticity in any foundation extent, the horizontal and vertical displacement at crest, heel and toe tend to decrease. From Table 3.4, the effect of depth of foundation extent on displacement at crest is not seen to be significant, while at heel and toe, the decrease in horizontal displacement can be seen. In this case, horizontal displacement at crest and toe are in the right direction, but heel moves to left direction. The vertical displacement at crest and heel tends to decrease (Table 3.4) as the foundation depth increase in any lateral foundation extent, while at toe it tends to increase. And as the lateral foundation extent increases in any depth of foundation, the displacement tends to decrease at the crest, heel and toe. The vertical displacement at crest and heel are in the upward direction and toe in the downward direction. From Figures 3.3 and 3.4, the trend of displacements at crest, heel and toe can be clearly seen. The rate of increase in displacement at foundation elasticity from 0.2 to 0.6 is steeper than from 0.6 to 0.8 of foundation elasticity.

From the statements above, it can be noted that the change in displacement in horizontal direction is not too large if it is compared with vertical direction. Logically, due to the roller at the end of lateral foundation extent, horizontal displacement is zero and at it is free to have vertical displacement. Thus the results show that the horizontal displacement is not as big as vertical displacement.

The results in this case are found similar to that of boundary condition-A described above. The trend of variation of displacements at crest, heel and toe with the change in foundation extent and value of rock modulus is similar and the values of displacements are practically same as obtained in case of boundary condition-A. In case of boundary condition-B, the variation in the values of displacement with increase in depth of foundation has been found less than that in case-A. The comparison between the results with two boundary conditions can be seen in Table 3.5 to 3.8 and Figures 3.5 to 3.6. From Tables 3.5 and 3.6, it can be noted that in case of dam with foundation extent more than 1H, the difference in the displacements between conditions-A and B tend to be smaller especially at crest and toe as the rock modulus increases. At heel, it can be seen that at any foundation elasticity, and at any lateral extent, the horizontal displacement in condition-A tends to change direction with increase in depth while in condition-B the direction remains same. The clear difference also can be seen in horizontal displacement at heel and toe with change in lateral extent from 1H u/s, 1H d/s and 2H u/s, 2H d/s with increase in the foundation extent in the two conditions, as the increase in condition B is less. From Figure 3.5, it can clearly be seen that as the foundation elasticity increases, the difference in horizontal displacement between conditions-A and B reduce at crest, heel and toe.

In vertical displacement, the difference is negligible in the two boundary conditions. Tables 3.7 and 3.8, and Figure 3.6 show the comparison between the two conditions against vertical displacement.

Table 3.9, Figures 3.7 and 3.8 show the horizontal and vertical displacements at crest, heel and toe with Poisson's ratio of foundation rock as 0.2. This result indicate that the displacements are similar to part-1B study, where displacements tend to decrease with the increase in foundation elasticity. Figures 3.7 and 3.8 clearly show this trend.

Tables 3.10 and 3.11, and Figures 3.9 and 3.10 show the comparison between part-1B study and part-1C study for horizontal and vertical displacement at crest, heel and toe with the change in Poisson's ratio from 0.3 to 0.2. The results show only marginal change in the values of displacement. The displacements are found slightly more in case of Poisson's ratio equal to 0.2.

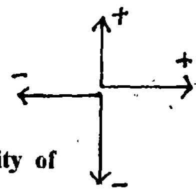
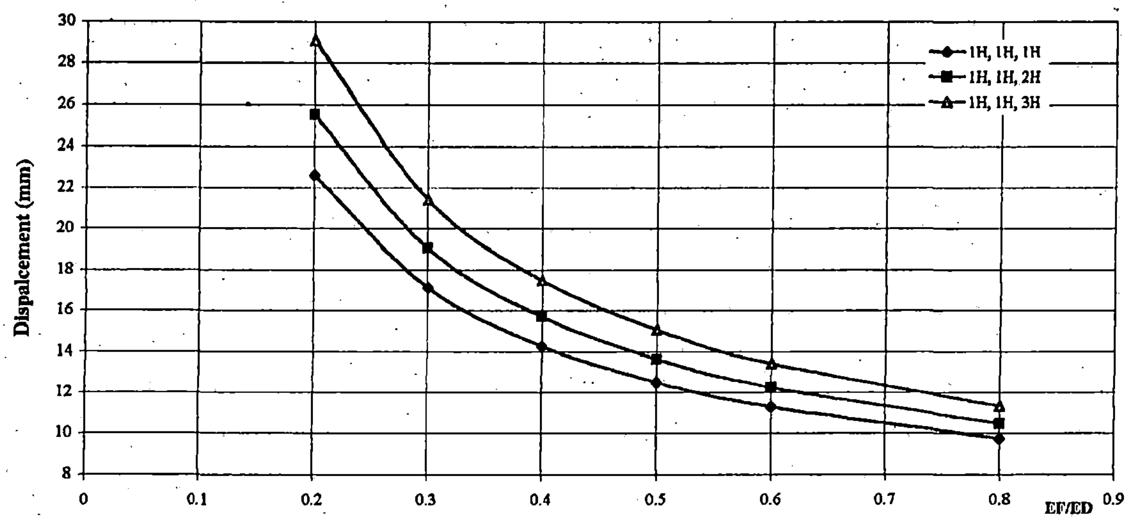


Table 3.1 Displacement at Crest, Heel and Toe with different Rigidity of Foundation in any Foundation Extent of Part-1A Study

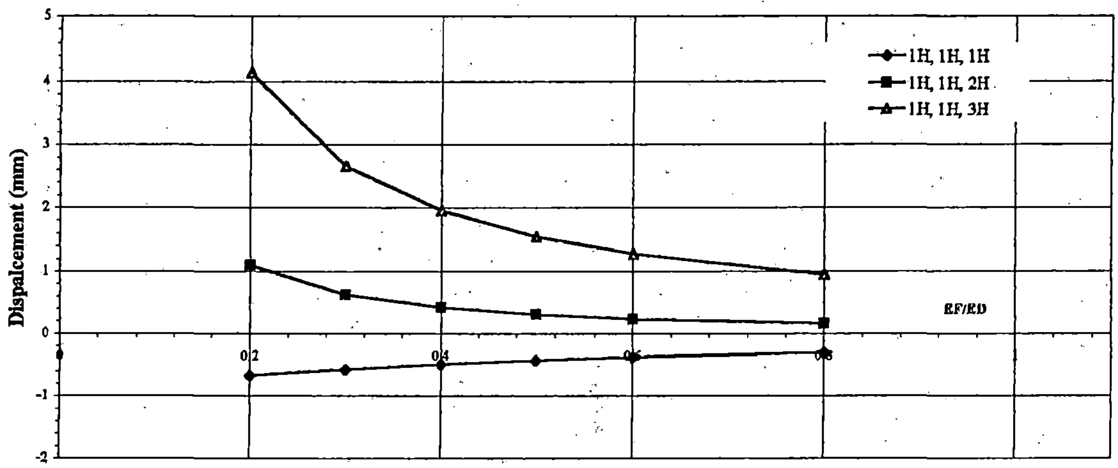
Case No.	Foundation Extent		EF/ED	Horizontal (mm)			Vertical (mm)		
				Crest	Heel	Toe	Crest	Heel	Toe
1	U/S	1H	0.2	22.66	-0.67	1.45	3.53	4.60	-6.28
	D/S	1H	0.3	17.14	-0.58	1.02	2.31	3.22	-3.98
	Bottom	1H	0.4	14.26	-0.49	0.77	1.69	2.49	-2.89
			0.5	12.50	-0.43	0.62	1.31	2.03	-2.25
			0.6	11.29	-0.38	0.51	1.05	1.72	-1.84
			0.8	9.75	-0.30	0.37	0.72	1.32	-1.34
2	U/S	1H	0.2	25.53	1.10	3.10	2.57	3.58	-8.17
	D/S	1H	0.3	19.06	0.62	2.12	1.67	2.53	-5.26
	Bottom	2H	0.4	15.71	0.42	1.60	1.21	1.96	-3.85
			0.5	13.66	0.31	1.28	0.92	1.61	-3.03
			0.6	12.25	0.24	1.07	0.73	1.36	-2.49
			0.8	10.47	0.16	0.79	0.48	1.05	-1.83
3	U/S	1H	0.2	29.12	4.14	6.06	1.64	2.59	-9.63
	D/S	1H	0.3	21.44	2.66	4.09	1.05	1.85	-6.25
	Bottom	3H	0.4	17.49	1.96	3.09	0.74	1.45	-4.60
			0.5	15.07	1.54	2.47	0.55	1.19	-3.63
			0.6	13.43	1.27	2.06	0.41	1.01	-3.00
			0.8	11.34	0.94	1.54	0.24	0.78	-2.22
4	U/S	1.5H	0.2	22.14	-0.76	1.30	3.40	4.43	-6.08
	D/S	1.5H	0.3	16.80	-0.63	0.91	2.23	3.10	-3.86
	Bottom	1H	0.4	14.02	-0.53	0.69	1.63	2.39	-2.80
			0.5	12.31	-0.45	0.55	1.26	1.95	-2.18
			0.6	11.13	-0.40	0.46	1.01	1.65	-1.79
			0.8	9.63	-0.32	0.33	0.69	1.26	-1.30
5	U/S	1.5H	0.2	23.65	-0.03	1.90	2.47	3.45	-7.70
	D/S	1.5H	0.3	17.80	-0.13	1.31	1.60	2.44	-4.95
	Bottom	2H	0.4	14.78	-0.14	1.00	1.16	1.89	-3.62
			0.5	12.91	-0.14	0.80	0.88	1.55	-2.85
			0.6	11.64	-0.13	0.66	0.69	1.31	-2.34
			0.8	9.46	-0.10	0.43	0.37	0.91	-1.52
6	U/S	1.5H	0.2	24.78	1.18	3.03	1.51	2.44	-8.69
	D/S	1.5H	0.3	18.55	0.70	2.06	0.96	1.75	-5.63
	Bottom	3H	0.4	15.33	0.48	1.56	0.67	1.37	-4.14
			0.5	13.35	0.37	1.25	0.49	1.13	-3.26
			0.6	11.99	0.30	1.04	0.37	0.96	-2.69
			0.8	10.27	0.21	0.77	0.21	0.74	-1.99
7	U/S	2H	0.2	21.77	-0.78	1.25	3.28	4.27	-5.92
	D/S	2H	0.3	16.56	-0.64	0.88	2.15	2.98	-3.76
	Bottom	1H	0.4	13.85	-0.53	0.67	1.57	2.30	-2.73
			0.5	12.17	-0.45	0.53	1.21	1.88	-2.13
			0.6	11.02	-0.40	0.44	0.97	1.59	-1.74
			0.8	9.55	-0.32	0.32	0.66	1.21	-1.27
8	U/S	2H	0.2	23.00	-0.32	1.58	2.40	3.36	-7.47
	D/S	2H	0.3	17.38	-0.31	1.10	1.56	2.37	-4.81
	Bottom	2H	0.4	14.46	-0.28	0.83	1.13	1.84	-3.52
			0.5	12.66	-0.25	0.66	0.86	1.51	-2.77
			0.6	11.43	-0.22	0.55	0.67	1.28	-2.27
			0.8	9.86	-0.18	0.40	0.44	0.98	-1.67
9	U/S	2H	0.2	23.37	0.27	2.08	1.49	2.40	-8.32
	D/S	2H	0.3	17.62	0.10	1.43	0.95	1.72	-5.38
	Bottom	3H	0.4	14.63	0.04	1.08	0.67	1.35	-3.95
			0.5	12.79	0.01	0.87	0.49	1.11	-3.12
			0.6	11.54	0.00	0.72	0.36	0.95	-2.57
			0.8	9.93	-0.01	0.53	0.20	0.73	-1.90

Table 3.2 Displacement at Crest, Heel and Toe with different Foundation Extent in any Rigidity of Foundation of Part-1A Study

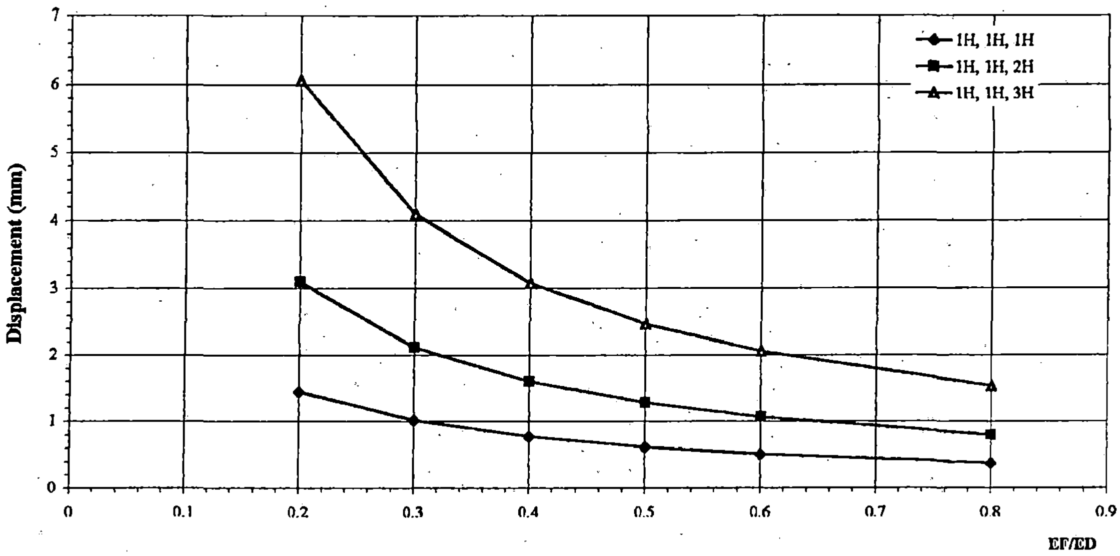
Case No.	EF/ED	Foundation Extent			Horizontal (mm)			Vertical (mm)		
		U/S	D/S	Bottom	Crest	Heel	Toe	Crest	Heel	Toe
1	0.2	1.0H	1.0H	1.0H	22.66	-0.67	1.45	3.53	4.60	-6.28
		1.0H	1.0H	2.0H	25.53	1.10	3.10	2.57	3.58	-8.17
		1.0H	1.0H	3.0H	29.12	4.14	6.06	1.64	2.59	-9.63
		~~1.5H~~	~~1.5H~~	~~1.0H~~	22.14	-0.76	1.30	3.40	4.43	-6.08
		1.5H	1.5H	2.0H	23.65	-0.03	1.90	2.47	3.45	-7.70
		1.5H	1.5H	3.0H	24.78	1.18	3.03	1.51	2.44	-8.69
		2.0H	2.0H	1.0H	21.77	-0.78	1.25	3.28	4.27	-5.92
		2.0H	2.0H	2.0H	23.00	-0.32	1.58	2.40	3.36	-7.47
		2.0H	2.0H	3.0H	23.37	0.27	2.08	1.49	2.40	-8.32
2	0.3	1.0H	1.0H	1.0H	17.14	-0.58	1.02	2.31	3.22	-3.98
		1.0H	1.0H	2.0H	19.06	0.62	2.12	1.67	2.53	-5.26
		1.0H	1.0H	3.0H	21.44	2.66	4.09	1.05	1.85	-6.25
		1.5H	1.5H	1.0H	16.80	-0.63	0.91	2.23	3.10	-3.86
		1.5H	1.5H	2.0H	17.80	-0.13	1.31	1.60	2.44	-4.95
		1.5H	1.5H	3.0H	18.55	0.70	2.06	0.96	1.75	-5.63
		2.0H	2.0H	1.0H	16.56	-0.64	0.88	2.15	2.98	-3.76
		2.0H	2.0H	2.0H	17.38	-0.31	1.10	1.56	2.37	-4.81
		2.0H	2.0H	3.0H	17.62	0.10	1.43	0.95	1.72	-5.38
3	0.4	1.0H	1.0H	1.0H	14.26	-0.49	0.77	1.69	2.49	-2.89
		1.0H	1.0H	2.0H	15.71	0.42	1.60	1.21	1.96	-3.85
		1.0H	1.0H	3.0H	17.49	1.96	3.09	0.74	1.45	-4.60
		1.5H	1.5H	1.0H	14.02	-0.53	0.69	1.63	2.39	-2.80
		1.5H	1.5H	2.0H	14.78	-0.14	1.00	1.16	1.89	-3.62
		1.5H	1.5H	3.0H	15.33	0.48	1.56	0.67	1.37	-4.14
		2.0H	2.0H	1.0H	13.85	-0.53	0.67	1.57	2.30	-2.73
		2.0H	2.0H	2.0H	14.46	-0.28	0.83	1.13	1.84	-3.52
		2.0H	2.0H	3.0H	14.63	0.04	1.08	0.67	1.35	-3.95
4	0.5	1.0H	1.0H	1.0H	12.50	-0.43	0.62	1.31	2.03	-2.25
		1.0H	1.0H	2.0H	13.66	0.31	1.28	0.92	1.61	-3.03
		1.0H	1.0H	3.0H	15.07	1.54	2.47	0.55	1.19	-3.63
		1.5H	1.5H	1.0H	12.31	-0.45	0.55	1.26	1.95	-2.18
		1.5H	1.5H	2.0H	12.91	-0.14	0.80	0.88	1.55	-2.85
		1.5H	1.5H	3.0H	13.35	0.37	1.25	0.49	1.13	-3.26
		2.0H	2.0H	1.0H	12.17	-0.45	0.53	1.21	1.88	-2.13
		2.0H	2.0H	2.0H	12.66	-0.25	0.66	0.86	1.51	-2.77
		2.0H	2.0H	3.0H	12.79	0.01	0.87	0.49	1.11	-3.12
5	0.6	1.0H	1.0H	1.0H	11.29	-0.38	0.51	1.05	1.72	-1.84
		1.0H	1.0H	2.0H	12.25	0.24	1.07	0.73	1.36	-2.49
		1.0H	1.0H	3.0H	13.43	1.27	2.06	0.41	1.01	-3.00
		1.5H	1.5H	1.0H	11.13	-0.40	0.46	1.01	1.65	-1.79
		1.5H	1.5H	2.0H	11.64	-0.13	0.66	0.69	1.31	-2.34
		1.5H	1.5H	3.0H	11.99	0.30	1.04	0.37	0.96	-2.69
		2.0H	2.0H	1.0H	11.02	-0.40	0.44	0.97	1.59	-1.74
		2.0H	2.0H	2.0H	11.43	-0.22	0.55	0.67	1.28	-2.27
		2.0H	2.0H	3.0H	11.54	0.00	0.72	0.36	0.95	-2.57
6	0.8	1.0H	1.0H	1.0H	9.75	-0.30	0.37	0.72	1.32	-1.34
		1.0H	1.0H	2.0H	10.47	0.16	0.79	0.48	1.05	-1.83
		1.0H	1.0H	3.0H	11.34	0.94	1.54	0.24	0.78	-2.22
		1.5H	1.5H	1.0H	9.63	-0.32	0.33	0.69	1.26	-1.30
		1.5H	1.5H	2.0H	9.46	-0.10	0.43	0.37	0.91	-1.52
		1.5H	1.5H	3.0H	10.27	0.21	0.77	0.21	0.74	-1.99
		2.0H	2.0H	1.0H	9.55	-0.32	0.32	0.66	1.21	-1.27
		2.0H	2.0H	2.0H	9.86	-0.18	0.40	0.44	0.98	-1.67
		2.0H	2.0H	3.0H	9.93	-0.01	0.53	0.20	0.73	-1.90



a. Crest

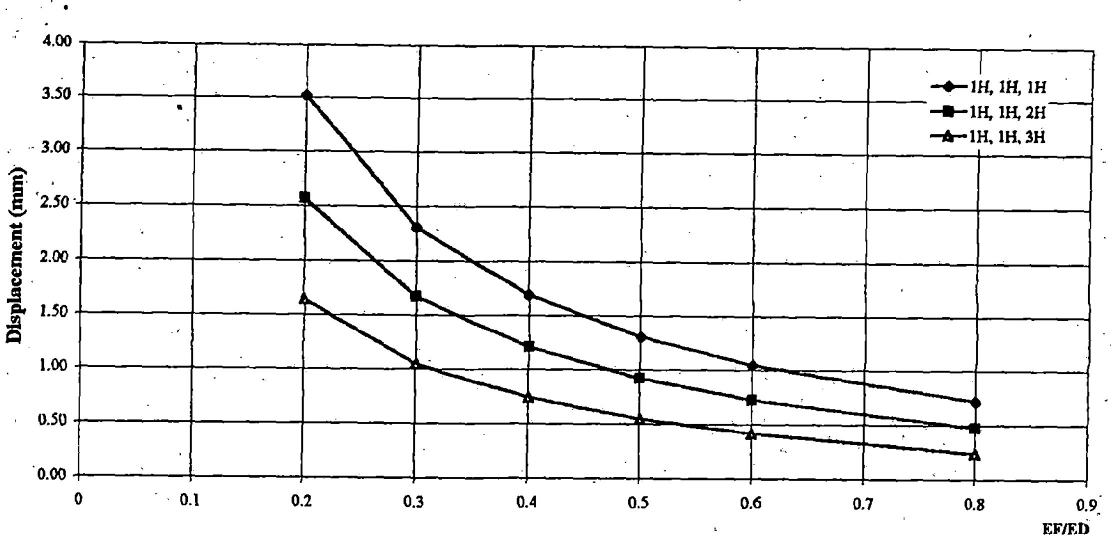


b. Heel

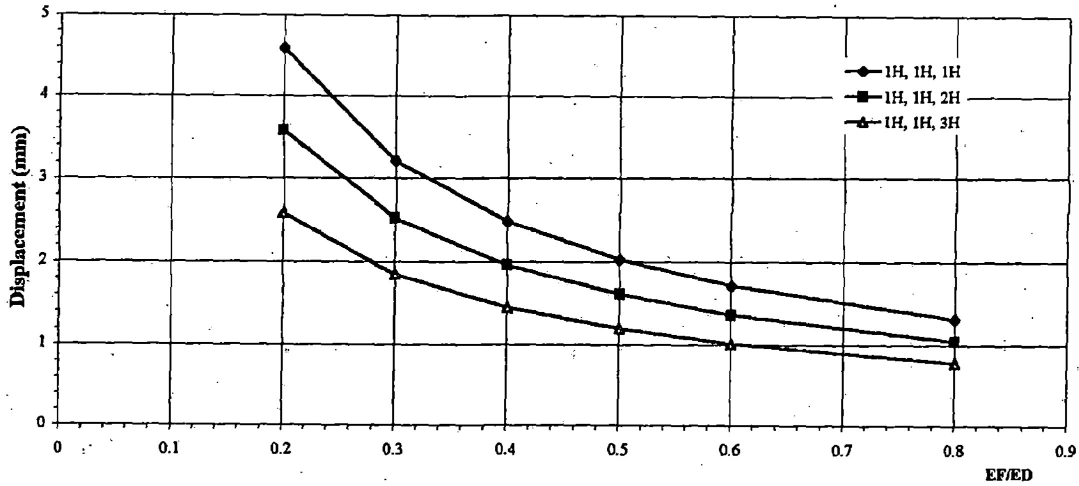


c. Toe

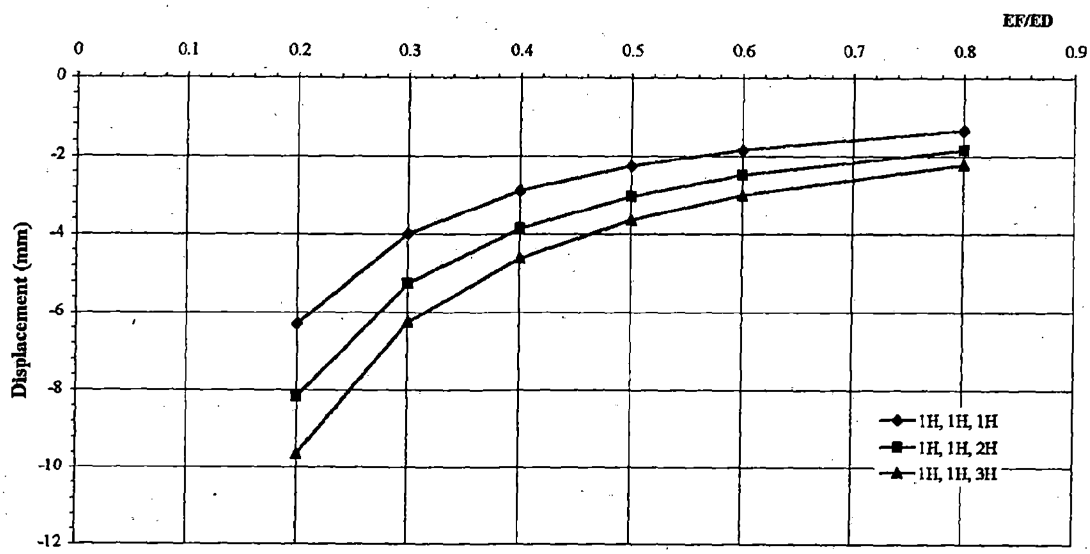
Figure 3.1 Horizontal displacement of Part-1A Study



a. Crest



b. Heel



c. Toe

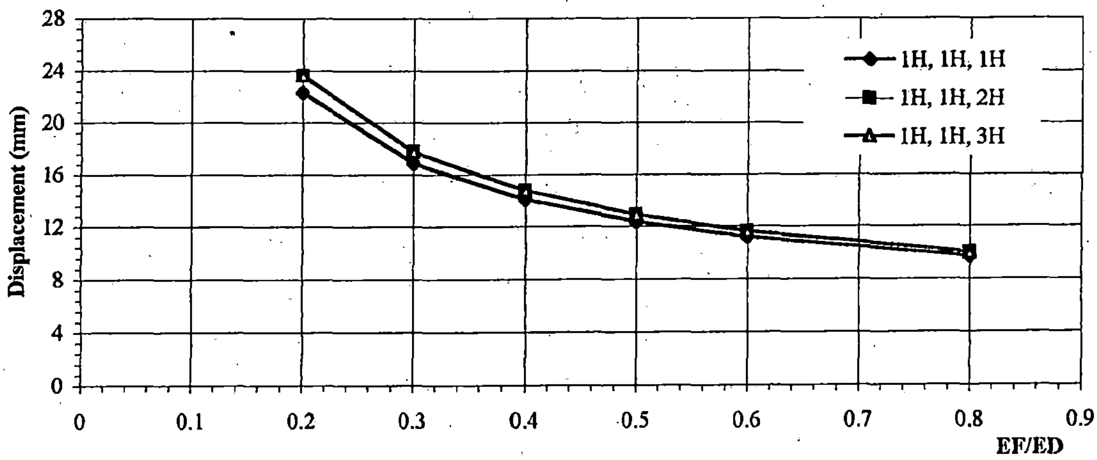
Figure 3.2 Vertical displacement of Part-1A study

Table 3.3 Displacement at Crest, Heel and Toe with different Rigidity of Foundation in any Foundation Extent of Part-1B Study

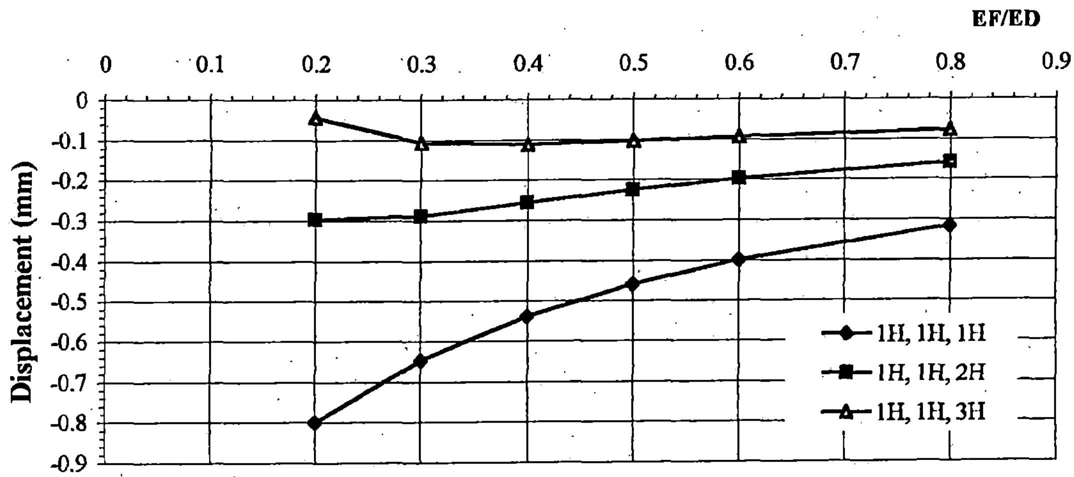
Case No.	Foundation Extent	EF/ED	Horizontal (mm)			Vertical (mm)		
			Crest	Heel	Toe	Crest	Heel	Toe
1	U/S 1H	0.2	22.32	-0.80	1.19	3.57	4.63	-6.17
	D/S 1H	0.3	16.91	-0.65	0.83	2.35	3.24	-3.91
	Bottom 1H	0.4	14.09	-0.54	0.63	1.71	2.50	-2.83
		0.5	12.36	-0.46	0.50	1.33	2.04	-2.21
		0.6	11.18	-0.40	0.41	1.06	1.73	-1.80
		0.8	9.66	-0.32	0.29	0.73	1.32	-1.31
2	U/S 1H	0.2	23.62	-0.30	1.54	2.84	3.83	-7.61
	D/S 1H	0.3	17.77	-0.29	1.07	1.85	2.69	-4.89
	Bottom 2H	0.4	14.75	-0.26	0.80	1.34	2.09	-3.57
		0.5	12.89	-0.22	0.64	1.03	1.71	-2.80
		0.6	11.61	-0.20	0.53	0.82	1.45	-2.30
		0.8	9.99	-0.16	0.38	0.54	1.11	-1.69
3	U/S 1H	0.2	23.65	-0.04	1.72	1.87	2.80	-8.50
	D/S 1H	0.3	17.79	-0.11	1.18	1.21	1.99	-5.49
	Bottom 3H	0.4	14.75	-0.11	0.90	0.86	1.55	-4.03
		0.5	12.88	-0.10	0.72	0.64	1.28	-3.18
		0.6	11.61	-0.09	0.59	0.49	1.09	-2.62
		0.8	9.98	-0.08	0.44	0.30	0.84	-1.93
4	U/S 1.5H	0.2	22.06	-0.79	1.22	3.43	4.45	-6.05
	D/S 1.5H	0.3	16.74	-0.64	0.85	2.25	3.11	-3.84
	Bottom 1H	0.4	13.98	-0.54	0.65	1.64	2.40	-2.79
		0.5	12.27	-0.46	0.51	1.27	1.96	-2.17
		0.6	11.10	-0.40	0.42	1.02	1.66	-1.78
		0.8	9.61	-0.32	0.31	0.70	1.27	-1.29
5	U/S 1.5H	0.2	23.07	-0.41	1.42	2.65	3.62	-7.44
	D/S 1.5H	0.3	17.41	-0.37	0.98	1.72	2.55	-4.78
	Bottom 2H	0.4	14.49	-0.32	0.74	1.25	1.98	-3.49
		0.5	12.68	-0.27	0.59	0.96	1.62	-2.74
		0.6	11.44	-0.24	0.48	0.75	1.37	-2.25
		0.8	9.86	-0.19	0.35	0.50	1.05	-1.66
6	U/S 1.5H	0.2	23.08	-0.17	1.58	1.88	2.79	-8.12
	D/S 1.5H	0.3	17.42	-0.19	1.09	1.21	1.99	-5.24
	Bottom 3H	0.4	14.48	-0.17	0.83	0.86	1.55	-3.85
		0.5	12.67	-0.15	0.66	0.64	1.27	-3.03
		0.6	11.43	-0.13	0.55	0.49	1.08	-2.50
		0.8	9.85	-0.11	0.40	0.30	0.83	-1.84
7	U/S 2H	0.2	21.74	-0.79	1.22	3.29	4.28	-5.91
	D/S 2H	0.3	16.54	-0.64	0.85	2.16	2.99	-3.75
	Bottom 1H	0.4	13.83	-0.53	0.65	1.57	2.31	-2.72
		0.5	11.01	-0.40	0.42	0.97	1.59	-1.74
		0.6	11.01	-0.40	0.42	0.97	1.59	-1.74
		0.8	9.54	-0.32	0.31	0.66	1.22	-1.27
8	U/S 2H	0.2	22.77	-0.44	1.39	2.49	3.44	-7.35
	D/S 2H	0.3	17.23	-0.39	0.96	1.62	2.42	-4.73
	Bottom 2H	0.4	14.35	-0.33	0.73	1.17	1.88	-3.46
		0.5	12.57	-0.28	0.58	0.90	1.54	-2.72
		0.6	11.36	-0.25	0.48	0.70	1.31	-2.23
		0.8	9.80	-0.20	0.35	0.46	1.00	-1.64
9	U/S 2H	0.2	22.69	-0.25	1.48	1.77	2.67	-7.97
	D/S 2H	0.3	17.17	-0.24	1.03	1.14	1.90	-5.15
	Bottom 3H	0.4	14.29	-0.21	0.78	0.81	1.48	-3.78
		0.5	12.52	-0.18	0.62	0.60	1.22	-2.98
		0.6	11.31	-0.16	0.51	0.46	1.04	-2.45
		0.8	9.76	-0.13	0.38	0.27	0.80	-1.81

Table 3.4 Displacement at Crest, Heel and Toe with different Foundation Extent in any Rigidity of Foundation of Part-1B Study

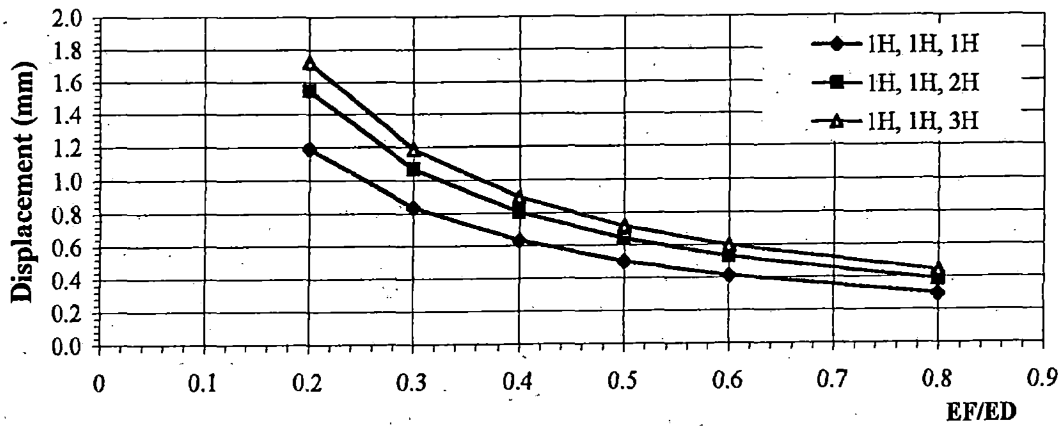
Case No.	EF/ED	Foundation Extent			Horizontal (mm)			Vertical (mm)		
		U/S	D/S	Bottom	Crest	Heel	Toe	Crest	Heel	Toe
1	0.2	1.0H	1.0H	1.0H	22.32	-0.80	1.19	3.57	4.63	-6.17
		1.0H	1.0H	2.0H	23.62	-0.30	1.54	2.84	3.83	-7.61
		1.0H	1.0H	3.0H	23.65	-0.04	1.72	1.87	2.80	-8.50
		1.5H	1.5H	1.0H	22.06	-0.79	1.22	3.43	4.45	-6.05
		1.5H	1.5H	2.0H	23.07	-0.41	1.42	2.65	3.62	-7.44
		1.5H	1.5H	3.0H	23.08	-0.17	1.58	1.88	2.79	-8.12
		2.0H	2.0H	1.0H	21.74	-0.79	1.22	3.29	4.28	-5.91
		2.0H	2.0H	2.0H	22.77	-0.44	1.39	2.49	3.44	-7.35
		2.0H	2.0H	3.0H	22.69	-0.25	1.48	1.77	2.67	-7.97
2	0.3	1.0H	1.0H	1.0H	16.91	-0.65	0.83	2.35	3.24	-3.91
		1.0H	1.0H	2.0H	17.77	-0.29	1.07	1.85	2.69	-4.89
		1.0H	1.0H	3.0H	17.79	-0.11	1.18	1.21	1.99	-5.49
		1.5H	1.5H	1.0H	16.74	-0.64	0.85	2.25	3.11	-3.84
		1.5H	1.5H	2.0H	17.41	-0.37	0.98	1.72	2.55	-4.78
		1.5H	1.5H	3.0H	17.42	-0.19	1.09	1.21	1.99	-5.24
		2.0H	2.0H	1.0H	16.54	-0.64	0.85	2.16	2.99	-3.75
		2.0H	2.0H	2.0H	17.23	-0.39	0.96	1.62	2.42	-4.73
		2.0H	2.0H	3.0H	17.17	-0.24	1.03	1.14	1.90	-5.15
3	0.4	1.0H	1.0H	1.0H	14.09	-0.54	0.63	1.71	2.50	-2.83
		1.0H	1.0H	2.0H	14.75	-0.26	0.80	1.34	2.09	-3.57
		1.0H	1.0H	3.0H	14.75	-0.11	0.90	0.86	1.55	-4.03
		1.5H	1.5H	1.0H	13.98	-0.54	0.65	1.64	2.40	-2.79
		1.5H	1.5H	2.0H	14.49	-0.32	0.74	1.25	1.98	-3.49
		1.5H	1.5H	3.0H	14.48	-0.17	0.83	0.86	1.55	-3.85
		2.0H	2.0H	1.0H	13.83	-0.53	0.65	1.57	2.31	-2.72
		2.0H	2.0H	2.0H	14.35	-0.33	0.73	1.17	1.88	-3.46
		2.0H	2.0H	3.0H	14.29	-0.21	0.78	0.81	1.48	-3.78
4	0.5	1.0H	1.0H	1.0H	12.36	-0.46	0.50	1.33	2.04	-2.21
		1.0H	1.0H	2.0H	12.89	-0.22	0.64	1.03	1.71	-2.80
		1.0H	1.0H	3.0H	12.88	-0.10	0.72	0.64	1.28	-3.18
		1.5H	1.5H	1.0H	12.27	-0.46	0.51	1.27	1.96	-2.17
		1.5H	1.5H	2.0H	12.68	-0.27	0.59	0.96	1.62	-2.74
		1.5H	1.5H	3.0H	12.67	-0.15	0.66	0.64	1.27	-3.03
		2.0H	2.0H	1.0H	11.01	-0.40	0.42	0.97	1.59	-1.74
		2.0H	2.0H	2.0H	12.57	-0.28	0.58	0.90	1.54	-2.72
		2.0H	2.0H	3.0H	12.52	-0.18	0.62	0.60	1.22	-2.98
5	0.6	1.0H	1.0H	1.0H	11.18	-0.40	0.41	1.06	1.73	-1.80
		1.0H	1.0H	2.0H	11.61	-0.20	0.53	0.82	1.45	-2.30
		1.0H	1.0H	3.0H	11.61	-0.09	0.59	0.49	1.09	-2.62
		1.5H	1.5H	1.0H	11.10	-0.40	0.42	1.02	1.66	-1.78
		1.5H	1.5H	2.0H	11.44	-0.24	0.48	0.75	1.37	-2.25
		1.5H	1.5H	3.0H	11.43	-0.13	0.55	0.49	1.08	-2.50
		2.0H	2.0H	1.0H	11.01	-0.40	0.42	0.97	1.59	-1.74
		2.0H	2.0H	2.0H	11.36	-0.25	0.48	0.70	1.31	-2.23
		2.0H	2.0H	3.0H	11.31	-0.16	0.51	0.46	1.04	-2.45
6	0.8	1.0H	1.0H	1.0H	9.66	-0.32	0.29	0.73	1.32	-1.31
		1.0H	1.0H	2.0H	9.99	-0.16	0.38	0.54	1.11	-1.69
		1.0H	1.0H	3.0H	9.98	-0.08	0.44	0.30	0.84	-1.93
		1.5H	1.5H	1.0H	9.61	-0.32	0.31	0.70	1.27	-1.29
		1.5H	1.5H	2.0H	9.86	-0.19	0.35	0.50	1.05	-1.66
		1.5H	1.5H	3.0H	9.85	-0.11	0.40	0.30	0.83	-1.84
		2.0H	2.0H	1.0H	9.54	-0.32	0.31	0.66	1.22	-1.27
		2.0H	2.0H	2.0H	9.80	-0.20	0.35	0.46	1.00	-1.64
		2.0H	2.0H	3.0H	9.76	-0.13	0.38	0.27	0.80	-1.81



a. Crest

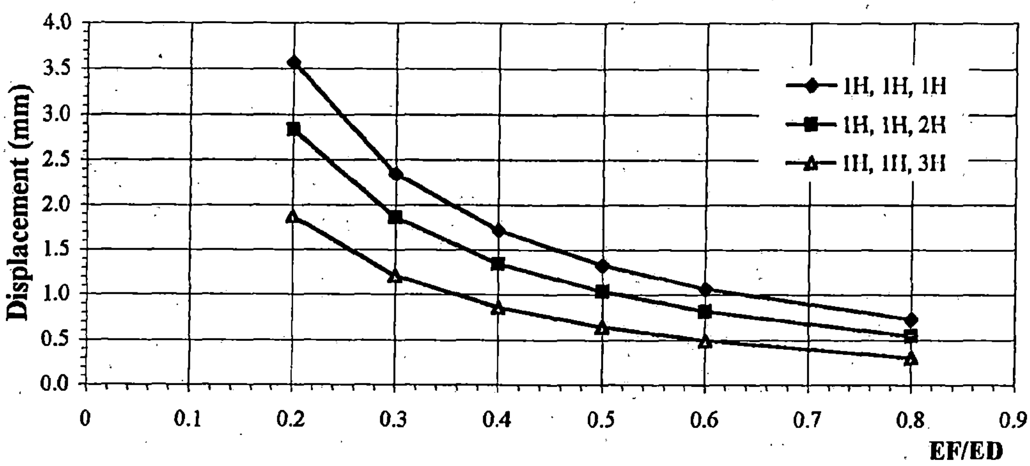


b. Heel

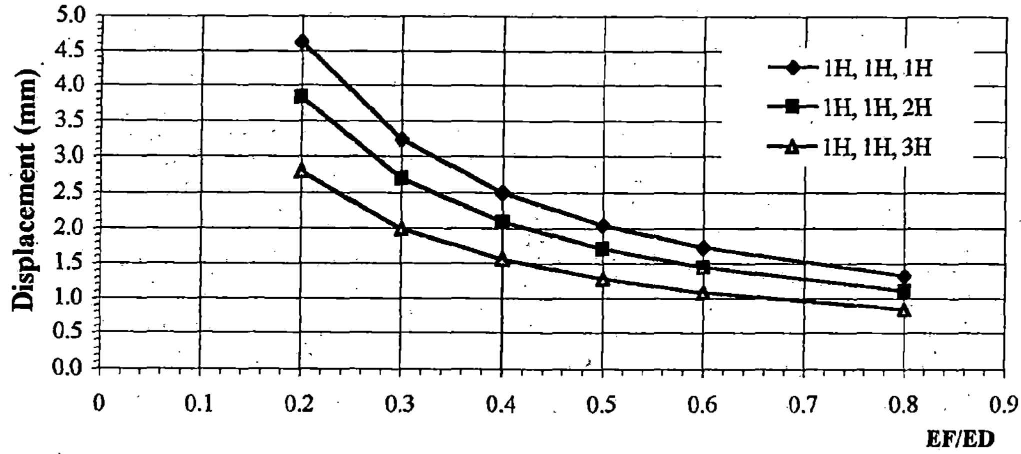


c. Toe

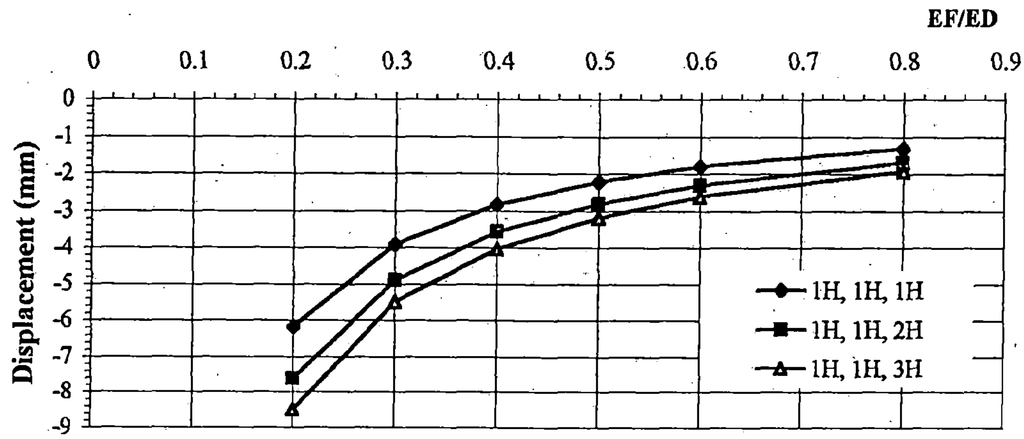
Fig. 3.3 Horizontal displacement of Part-1B study



a. Crest



b. Heel



c. Toe

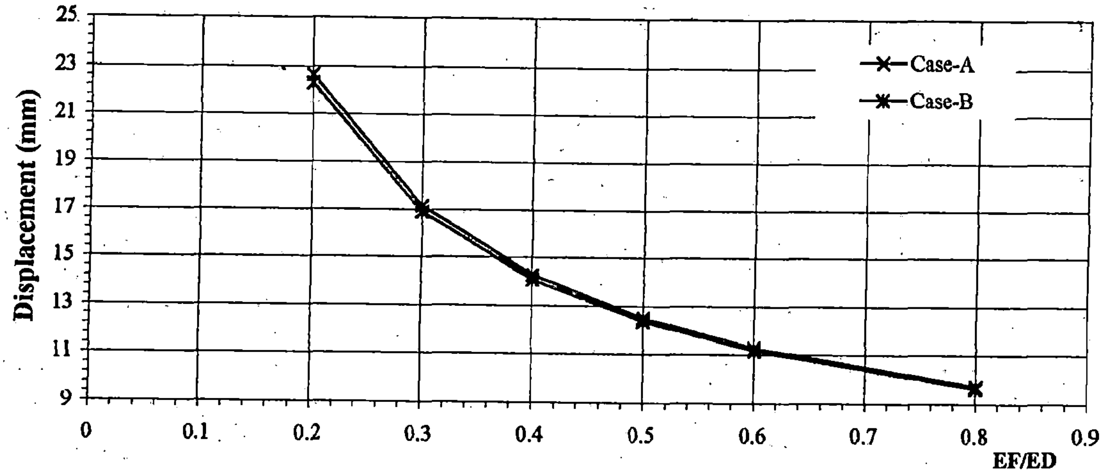
Fig. 3.4 Vertical displacement of Part-1B study

Table 3.5 Comparison between Part-1A and Part-1B Study of Horizontal Displacement with different Rigidity of Foundation in any Foundation Extent

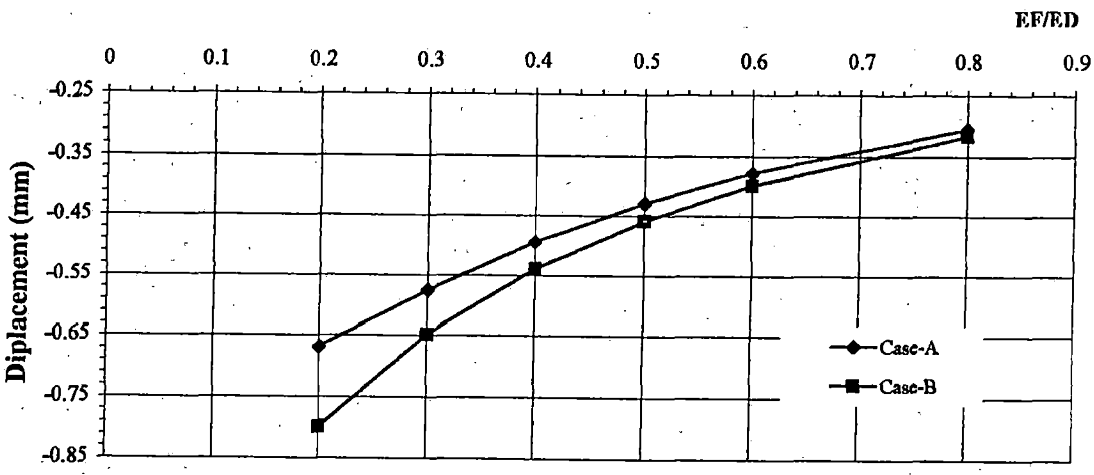
Case No.	Foundation Extent		EF/ED	Horizontal (mm)					
				Crest		Heel		Toe	
				Case-A	Case-B	Case-A	Case-B	Case-A	Case-B
	U/S	1H	0.2	22.66	22.32	-0.67	-0.80	1.45	1.19
	D/S	1H	0.3	17.14	16.91	-0.58	-0.65	1.02	0.83
	Bottom	1H	0.4	14.26	14.09	-0.49	-0.54	0.77	0.63
			0.5	12.50	12.36	-0.43	-0.46	0.62	0.50
			0.6	11.29	11.18	-0.38	-0.40	0.51	0.41
			0.8	9.75	9.66	-0.30	-0.32	0.37	0.29
	U/S	1H	0.2	25.53	23.62	1.10	-0.30	3.10	1.54
	D/S	1H	0.3	19.06	17.77	0.62	-0.29	2.12	1.07
	Bottom	2H	0.4	15.71	14.75	0.42	-0.26	1.60	0.80
			0.5	13.66	12.89	0.31	-0.22	1.28	0.64
			0.6	12.25	11.61	0.24	-0.20	1.07	0.53
			0.8	10.47	9.99	0.16	-0.16	0.79	0.38
	U/S	1H	0.2	29.12	23.65	4.14	-0.04	6.06	1.72
	D/S	1H	0.3	21.44	17.79	2.66	-0.11	4.09	1.18
	Bottom	3H	0.4	17.49	14.75	1.96	-0.11	3.09	0.90
			0.5	15.07	12.88	1.54	-0.10	2.47	0.72
			0.6	13.43	11.61	1.27	-0.09	2.06	0.59
			0.8	11.34	9.98	0.94	-0.08	1.54	0.44
	U/S	1.5H	0.2	22.14	22.06	-0.76	-0.79	1.30	1.22
	D/S	1.5H	0.3	16.80	16.74	-0.63	-0.64	0.91	0.85
	Bottom	1H	0.4	14.02	13.98	-0.53	-0.54	0.69	0.65
			0.5	12.31	12.27	-0.45	-0.46	0.55	0.51
			0.6	11.13	11.10	-0.40	-0.40	0.46	0.42
			0.8	9.63	9.61	-0.32	-0.32	0.33	0.31
	U/S	1.5H	0.2	23.65	23.07	-0.03	-0.41	1.90	1.42
	D/S	1.5H	0.3	17.80	17.41	-0.13	-0.37	1.31	0.98
	Bottom	2H	0.4	14.78	14.49	-0.14	-0.32	1.00	0.74
			0.5	12.91	12.68	-0.14	-0.27	0.80	0.59
			0.6	11.64	11.44	-0.13	-0.24	0.66	0.48
			0.8	9.46	9.86	-0.10	-0.19	0.43	0.35
	U/S	1.5H	0.2	24.78	23.08	1.18	-0.17	3.03	1.58
	D/S	1.5H	0.3	18.55	17.42	0.70	-0.19	2.06	1.09
	Bottom	3H	0.4	15.33	14.48	0.48	-0.17	1.56	0.83
			0.5	13.35	12.67	0.37	-0.15	1.25	0.66
			0.6	11.99	11.43	0.30	-0.13	1.04	0.55
			0.8	10.27	9.85	0.21	-0.11	0.77	2.68
	U/S	2H	0.2	21.77	21.74	-0.78	-0.79	1.25	1.22
	D/S	2H	0.3	16.56	16.54	-0.64	-0.64	0.88	0.85
	Bottom	1H	0.4	13.85	13.83	-0.53	-0.53	0.67	0.65
			0.5	12.17	11.01	-0.45	-0.40	0.53	0.42
			0.6	11.02	11.01	-0.40	-0.40	0.44	0.42
			0.8	9.55	9.54	-0.32	-0.32	0.32	0.31
	U/S	2H	0.2	23.00	22.77	-0.32	-0.44	1.58	1.39
	D/S	2H	0.3	17.38	17.23	-0.31	-0.39	1.10	0.96
	Bottom	2H	0.4	14.46	14.35	-0.28	-0.33	0.83	0.73
			0.5	12.66	12.57	-0.25	-0.28	0.66	0.58
			0.6	11.43	11.36	-0.22	-0.25	0.55	0.48
			0.8	9.86	9.80	-0.18	-0.20	0.40	0.35
	U/S	2H	0.2	23.37	22.69	0.27	-0.25	2.08	1.48
	D/S	2H	0.3	17.62	17.17	0.10	-0.24	1.43	1.03
	Bottom	3H	0.4	14.63	14.29	0.04	-0.21	1.08	0.78
			0.5	12.79	12.52	0.01	-0.18	0.87	0.62
			0.6	11.54	11.31	0.00	-0.16	0.72	0.51
			0.8	9.93	9.76	-0.01	-0.13	0.53	0.38

Table 3.6 Comparison between Part -1A and Part -1B Study of Horizontal Displacement with different Foundation Extent in any Rigidity of Foundation

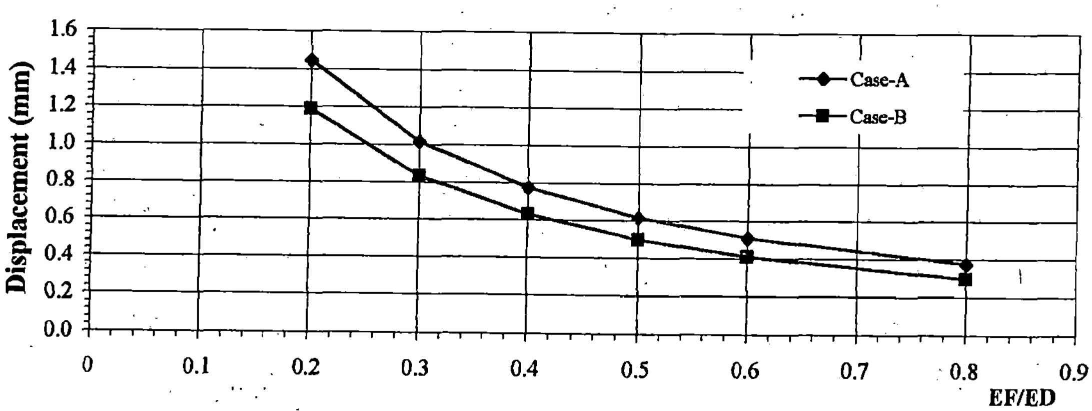
Case No.	EF/ED	Foundation Extent			Horizontal (mm)					
					Crest		Heel		Toe	
		U/S	D/S	Bottom	Case-A	Case-B	Case-A	Case-B	Case-A	Case-B
1	0.2	1.0H	1.0H	1.0H	22.66	22.32	-0.67	-0.80	1.45	1.19
		1.0H	1.0H	2.0H	25.53	23.62	1.10	-0.30	3.10	1.54
		1.0H	1.0H	3.0H	29.12	23.65	4.14	-0.04	6.06	1.72
		1.5H	1.5H	1.0H	22.14	22.06	-0.76	-0.79	1.30	1.22
		1.5H	1.5H	2.0H	23.65	23.07	-0.03	-0.41	1.90	1.42
		1.5H	1.5H	3.0H	24.78	23.08	1.18	-0.17	3.03	1.58
		2.0H	2.0H	1.0H	21.77	21.74	-0.78	-0.79	1.25	1.22
		2.0H	2.0H	2.0H	23.00	22.77	-0.32	-0.44	1.58	1.39
		2.0H	2.0H	3.0H	23.37	22.69	0.27	-0.25	2.08	1.48
2	0.3	1.0H	1.0H	1.0H	17.14	16.91	-0.58	-0.65	1.02	0.83
		1.0H	1.0H	2.0H	19.06	17.77	0.62	-0.29	2.12	1.07
		1.0H	1.0H	3.0H	21.44	17.79	2.66	-0.11	4.09	1.18
		1.5H	1.5H	1.0H	16.80	16.74	-0.63	-0.64	0.91	0.85
		1.5H	1.5H	2.0H	17.80	17.41	-0.13	-0.37	1.31	0.98
		1.5H	1.5H	3.0H	18.55	17.42	0.70	-0.19	2.06	1.09
		2.0H	2.0H	1.0H	16.56	16.54	-0.64	-0.64	0.88	0.85
		2.0H	2.0H	2.0H	17.38	17.23	-0.31	-0.39	1.10	0.96
		2.0H	2.0H	3.0H	17.62	17.17	0.10	-0.24	1.43	1.03
3	0.4	1.0H	1.0H	1.0H	14.26	14.09	-0.49	-0.54	0.77	0.63
		1.0H	1.0H	2.0H	15.71	14.75	0.42	-0.26	1.60	0.80
		1.0H	1.0H	3.0H	17.49	14.75	1.96	-0.11	3.09	0.90
		1.5H	1.5H	1.0H	14.02	13.98	-0.53	-0.54	0.69	0.65
		1.5H	1.5H	2.0H	14.78	14.49	-0.14	-0.32	1.00	0.74
		1.5H	1.5H	3.0H	15.33	14.48	0.48	-0.17	1.56	0.83
		2.0H	2.0H	1.0H	13.85	13.83	-0.53	-0.53	0.67	0.65
		2.0H	2.0H	2.0H	14.46	14.35	-0.28	-0.33	0.83	0.73
		2.0H	2.0H	3.0H	14.63	14.29	0.04	-0.21	1.08	0.78
4	0.5	1.0H	1.0H	1.0H	12.50	12.36	-0.43	-0.46	0.62	0.50
		1.0H	1.0H	2.0H	13.66	12.89	0.31	-0.22	1.28	0.64
		1.0H	1.0H	3.0H	15.07	12.88	1.54	-0.10	2.47	0.72
		1.5H	1.5H	1.0H	12.31	12.27	-0.45	-0.46	0.55	0.51
		1.5H	1.5H	2.0H	12.91	12.68	-0.14	-0.27	0.80	0.59
		1.5H	1.5H	3.0H	13.35	12.67	0.37	-0.15	1.25	0.66
		2.0H	2.0H	1.0H	12.17	11.01	-0.45	-0.40	0.53	0.42
		2.0H	2.0H	2.0H	12.66	12.57	-0.25	-0.28	0.66	0.58
		2.0H	2.0H	3.0H	12.79	12.52	0.01	-0.18	0.87	0.62
5	0.6	1.0H	1.0H	1.0H	11.29	11.18	-0.38	-0.40	0.51	0.41
		1.0H	1.0H	2.0H	12.25	11.61	0.24	-0.20	1.07	0.53
		1.0H	1.0H	3.0H	13.43	11.61	1.27	-0.09	2.06	0.59
		1.5H	1.5H	1.0H	11.13	11.10	-0.40	-0.40	0.46	0.42
		1.5H	1.5H	2.0H	11.64	11.44	-0.13	-0.24	0.66	0.48
		1.5H	1.5H	3.0H	11.99	11.43	0.30	-0.13	1.04	0.55
		2.0H	2.0H	1.0H	11.02	11.01	-0.40	-0.40	0.44	0.42
		2.0H	2.0H	2.0H	11.43	11.36	-0.22	-0.25	0.55	0.48
		2.0H	2.0H	3.0H	11.54	11.31	0.00	-0.16	0.72	0.51
6	0.8	1.0H	1.0H	1.0H	9.75	9.66	-0.30	-0.32	0.37	0.29
		1.0H	1.0H	2.0H	10.47	9.99	0.16	-0.16	0.79	0.38
		1.0H	1.0H	3.0H	11.34	9.98	0.94	-0.08	1.54	0.44
		1.5H	1.5H	1.0H	9.63	9.61	-0.32	-0.32	0.33	0.31
		1.5H	1.5H	2.0H	9.46	9.86	-0.10	-0.19	0.43	0.35
		1.5H	1.5H	3.0H	10.27	9.85	0.21	-0.11	0.77	2.68
		2.0H	2.0H	1.0H	9.55	9.54	-0.32	-0.32	0.32	0.31
		2.0H	2.0H	2.0H	9.86	9.80	-0.18	-0.20	0.40	0.35
		2.0H	2.0H	3.0H	9.93	9.76	-0.01	-0.13	0.53	0.38



a. Crest



b. Heel



c. Toe

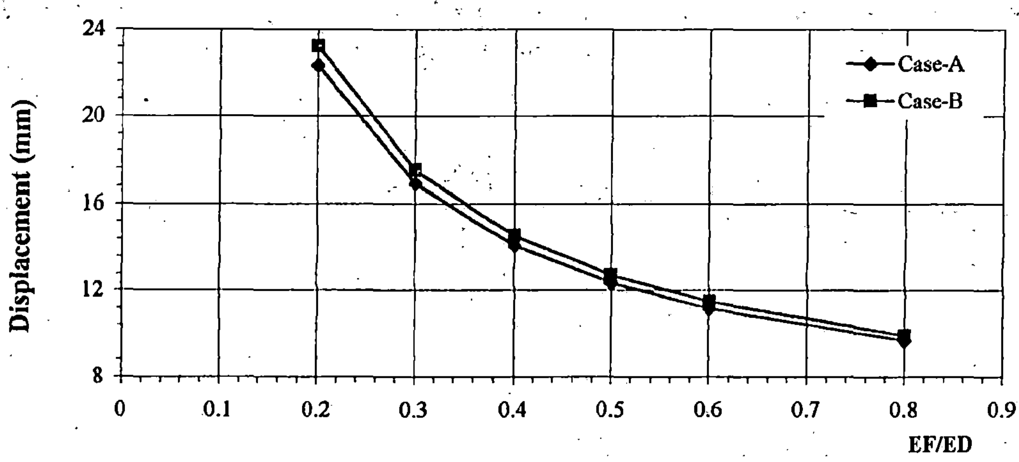
Figure 3.5 **Comparison of Horizontal Displacement between Part-1A and 1B Study with Foundation Extent 1H u/s, 1H d/s, 1H bottom**

Table 3.7 Comparison between Part-1A and Part-1B Study of Vertical Displacement with different Rigidity of Foundation in any Foundation Extent

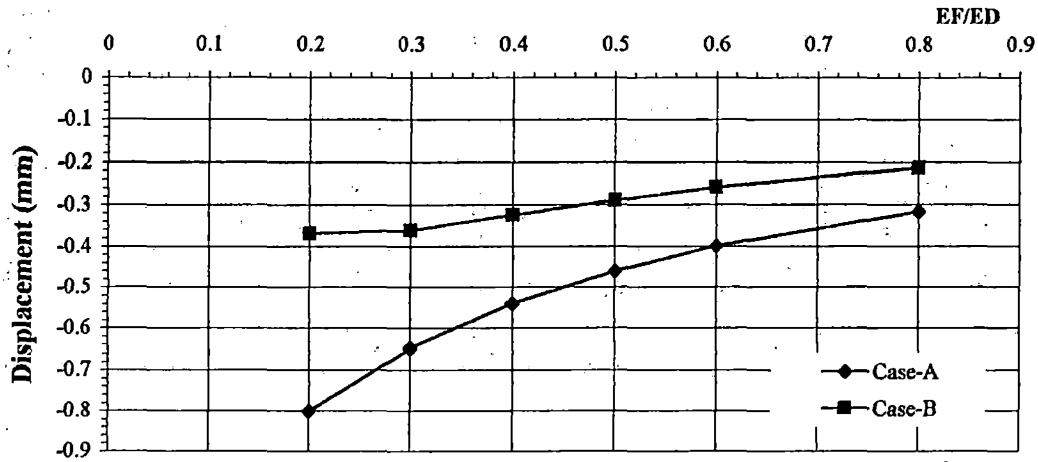
Case No.	Foundation Extent		EF/ED	Vertical (mm)					
				Crest		Heel		Toe	
				Case-A	Case-B	Case-A	Case-B	Case-A	Case-B
1	U/S	1H	0.2	3.53	3.57	4.60	4.63	-6.28	-6.17
	D/S	1H	0.3	2.31	2.35	3.22	3.24	-3.98	-3.91
	Bottom	1H	0.4	1.69	1.71	2.49	2.50	-2.89	-2.83
			0.5	1.31	1.33	2.03	2.04	-2.25	-2.21
			0.6	1.05	1.06	1.72	1.73	-1.84	-1.80
			0.8	0.72	0.73	1.32	1.32	-1.34	-1.31
2	U/S	1H	0.2	2.57	2.84	3.58	3.83	-8.17	-7.61
	D/S	1H	0.3	1.67	1.85	2.53	2.69	-5.26	-4.89
	Bottom	2H	0.4	1.21	1.34	1.96	2.09	-3.85	-3.57
			0.5	0.92	1.03	1.61	1.71	-3.03	-2.80
			0.6	0.73	0.82	1.36	1.45	-2.49	-2.30
			0.8	0.48	0.54	1.05	1.11	-1.83	-1.69
3	U/S	1H	0.2	1.64	1.87	2.59	2.80	-9.63	-8.50
	D/S	1H	0.3	1.05	1.21	1.85	1.99	-6.25	-5.49
	Bottom	3H	0.4	0.74	0.86	1.45	1.55	-4.60	-4.03
			0.5	0.55	0.64	1.19	1.28	-3.63	-3.18
			0.6	0.41	0.49	1.01	1.09	-3.00	-2.62
			0.8	0.24	0.30	0.78	0.84	-2.22	-1.93
4	U/S	1.5H	0.2	3.40	3.43	4.43	4.45	-6.08	-6.05
	D/S	1.5H	0.3	2.23	2.25	3.10	3.11	-3.86	-3.84
	Bottom	1H	0.4	1.63	1.64	2.39	2.40	-2.80	-2.79
			0.5	1.26	1.27	1.95	1.96	-2.18	-2.17
			0.6	1.01	1.02	1.65	1.66	-1.79	-1.78
			0.8	0.69	0.70	1.26	1.27	-1.30	-1.29
5	U/S	1.5H	0.2	2.47	2.65	3.45	3.62	-7.70	-7.44
	D/S	1.5H	0.3	1.60	1.72	2.44	2.55	-4.95	-4.78
	Bottom	2H	0.4	1.16	1.25	1.89	1.98	-3.62	-3.49
			0.5	0.88	0.96	1.55	1.62	-2.85	-2.74
			0.6	0.69	0.75	1.31	1.37	-2.34	-2.25
			0.8	0.37	0.50	0.91	1.05	-1.52	-1.66
6	U/S	1.5H	0.2	1.51	1.88	2.44	2.79	-8.69	-8.12
	D/S	1.5H	0.3	0.96	1.21	1.75	1.99	-5.63	-5.24
	Bottom	3H	0.4	0.67	0.86	1.37	1.55	-4.14	-3.85
			0.5	0.49	0.64	1.13	1.27	-3.26	-3.03
			0.6	0.37	0.49	0.96	1.08	-2.69	-2.50
			0.8	0.21	-0.11	0.74	1.17	-1.99	-3.22
7	U/S	2H	0.2	3.28	3.29	4.27	4.28	-5.92	-5.91
	D/S	2H	0.3	2.15	2.16	2.98	2.99	-3.76	-3.75
	Bottom	1H	0.4	1.57	1.57	2.30	2.31	-2.73	-2.72
			0.5	1.21	0.97	1.88	1.59	-2.13	-1.74
			0.6	0.97	0.97	1.59	1.59	-1.74	-1.74
			0.8	0.66	0.66	1.21	1.22	-1.27	-1.27
8	U/S	2H	0.2	2.40	2.49	3.36	3.44	-7.47	-7.35
	D/S	2H	0.3	1.56	1.62	2.37	2.42	-4.81	-4.73
	Bottom	2H	0.4	1.13	1.17	1.84	1.88	-3.52	-3.46
			0.5	0.86	0.90	1.51	1.54	-2.77	-2.72
			0.6	0.67	0.70	1.28	1.31	-2.27	-2.23
			0.8	0.44	0.46	0.98	1.00	-1.67	-1.64
9	U/S	2H	0.2	1.49	1.77	2.40	2.67	-8.32	-7.97
	D/S	2H	0.3	0.95	1.14	1.72	1.90	-5.38	-5.15
	Bottom	3H	0.4	0.67	0.81	1.35	1.48	-3.95	-3.78
			0.5	0.49	0.60	1.11	1.22	-3.12	-2.98
			0.6	0.36	0.46	0.95	1.04	-2.57	-2.45
			0.8	0.20	0.27	0.73	0.80	-1.90	-1.81

Table 3.8 Comparison between Part -1A and Part -1B Study of Vertical Displacement with different Foundation Extent in any Rigidity of Foundation

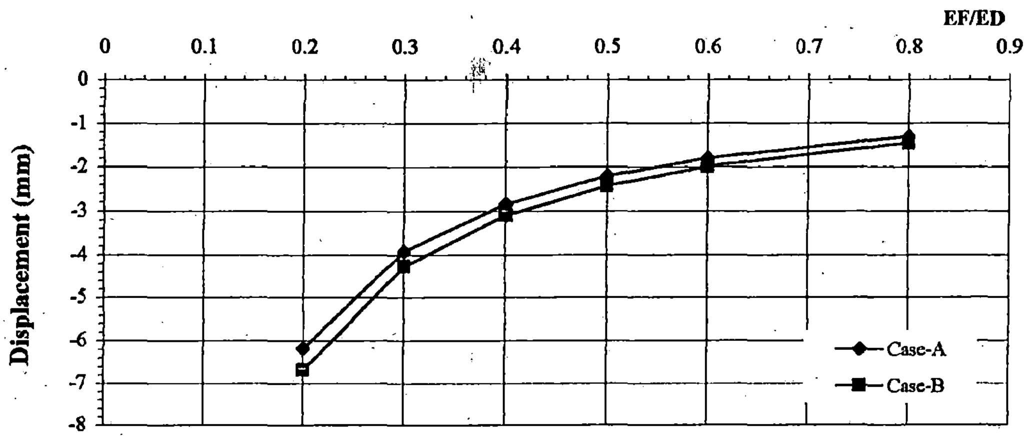
Case No.	EF/ED	Foundation Extent			Vertical (mm)					
					Crest		Heel		Toe	
		U/S	D/S	Bottom	Case-A	Case-B	Case-A	Case-B	Case-A	Case-B
1	0.2	1.0H	1.0H	1.0H	3.53	3.57	4.60	4.63	-6.28	-6.17
		1.0H	1.0H	2.0H	2.57	2.84	3.58	3.83	-8.17	-7.61
		1.0H	1.0H	3.0H	1.64	1.87	2.59	2.80	-9.63	-8.50
		1.5H	1.5H	1.0H	3.40	3.43	4.43	4.45	-6.08	-6.05
		1.5H	1.5H	2.0H	2.47	2.65	3.45	3.62	-7.70	-7.44
		1.5H	1.5H	3.0H	1.51	1.88	2.44	2.79	-8.69	-8.12
		2.0H	2.0H	1.0H	3.28	3.29	4.27	4.28	-5.92	-5.91
		2.0H	2.0H	2.0H	2.40	2.49	3.36	3.44	-7.47	-7.35
		2.0H	2.0H	3.0H	1.49	1.77	2.40	2.67	-8.32	-7.97
2	0.3	1.0H	1.0H	1.0H	2.31	2.35	3.22	3.24	-3.98	-3.91
		1.0H	1.0H	2.0H	1.67	1.85	2.53	2.69	-5.26	-4.89
		1.0H	1.0H	3.0H	1.05	1.21	1.85	1.99	-6.25	-5.49
		1.5H	1.5H	1.0H	2.23	2.25	3.10	3.11	-3.86	-3.84
		1.5H	1.5H	2.0H	1.60	1.72	2.44	2.55	-4.95	-4.78
		1.5H	1.5H	3.0H	0.96	1.21	1.75	1.99	-5.63	-5.24
		2.0H	2.0H	1.0H	2.15	2.16	2.98	2.99	-3.76	-3.75
		2.0H	2.0H	2.0H	1.56	1.62	2.37	2.42	-4.81	-4.73
		2.0H	2.0H	3.0H	0.95	1.14	1.72	1.90	-5.38	-5.15
3	0.4	1.0H	1.0H	1.0H	1.69	1.71	2.49	2.50	-2.89	-2.83
		1.0H	1.0H	2.0H	1.21	1.34	1.96	2.09	-3.85	-3.57
		1.0H	1.0H	3.0H	0.74	0.86	1.45	1.55	-4.60	-4.03
		1.5H	1.5H	1.0H	1.63	1.64	2.39	2.40	-2.80	-2.79
		1.5H	1.5H	2.0H	1.16	1.25	1.89	1.98	-3.62	-3.49
		1.5H	1.5H	3.0H	0.67	0.86	1.37	1.55	-4.14	-3.85
		2.0H	2.0H	1.0H	1.57	1.57	2.30	2.31	-2.73	-2.72
		2.0H	2.0H	2.0H	1.13	1.17	1.84	1.88	-3.52	-3.46
		2.0H	2.0H	3.0H	0.67	0.81	1.35	1.48	-3.95	-3.78
4	0.5	1.0H	1.0H	1.0H	1.31	1.33	2.03	2.04	-2.25	-2.21
		1.0H	1.0H	2.0H	0.92	1.03	1.61	1.71	-3.03	-2.80
		1.0H	1.0H	3.0H	0.55	0.64	1.19	1.28	-3.63	-3.18
		1.5H	1.5H	1.0H	1.26	1.27	1.95	1.96	-2.18	-2.17
		1.5H	1.5H	2.0H	0.88	0.96	1.55	1.62	-2.85	-2.74
		1.5H	1.5H	3.0H	0.49	0.64	1.13	1.27	-3.26	-3.03
		2.0H	2.0H	1.0H	1.21	0.97	1.88	1.59	-2.13	-1.74
		2.0H	2.0H	2.0H	0.86	0.90	1.51	1.54	-2.77	-2.72
		2.0H	2.0H	3.0H	0.49	0.60	1.11	1.22	-3.12	-2.98
5	0.6	1.0H	1.0H	1.0H	1.05	1.06	1.72	1.73	-1.84	-1.80
		1.0H	1.0H	2.0H	0.73	0.82	1.36	1.45	-2.49	-2.30
		1.0H	1.0H	3.0H	0.41	0.49	1.01	1.09	-3.00	-2.62
		1.5H	1.5H	1.0H	1.01	1.02	1.65	1.66	-1.79	-1.78
		1.5H	1.5H	2.0H	0.69	0.75	1.31	1.37	-2.34	-2.25
		1.5H	1.5H	3.0H	0.37	0.49	0.96	1.08	-2.69	-2.50
		2.0H	2.0H	1.0H	0.97	0.97	1.59	1.59	-1.74	-1.74
		2.0H	2.0H	2.0H	0.67	0.70	1.28	1.31	-2.27	-2.23
		2.0H	2.0H	3.0H	0.36	0.46	0.95	1.04	-2.57	-2.45
6	0.8	1.0H	1.0H	1.0H	0.72	0.73	1.32	1.32	-1.34	-1.31
		1.0H	1.0H	2.0H	0.48	0.54	1.05	1.11	-1.83	-1.69
		1.0H	1.0H	3.0H	0.24	0.30	0.78	0.84	-2.22	-1.93
		1.5H	1.5H	1.0H	0.69	0.70	1.26	1.27	-1.30	-1.29
		1.5H	1.5H	2.0H	0.37	0.50	0.91	1.05	-1.52	-1.66
		1.5H	1.5H	3.0H	0.21	-0.11	0.74	1.17	-1.99	-3.22
		2.0H	2.0H	1.0H	0.66	0.66	1.21	1.22	-1.27	-1.27
		2.0H	2.0H	2.0H	0.44	0.46	0.98	1.00	-1.67	-1.64
		2.0H	2.0H	3.0H	0.20	0.27	0.73	0.80	-1.90	-1.81



a. Crest



b. Heel

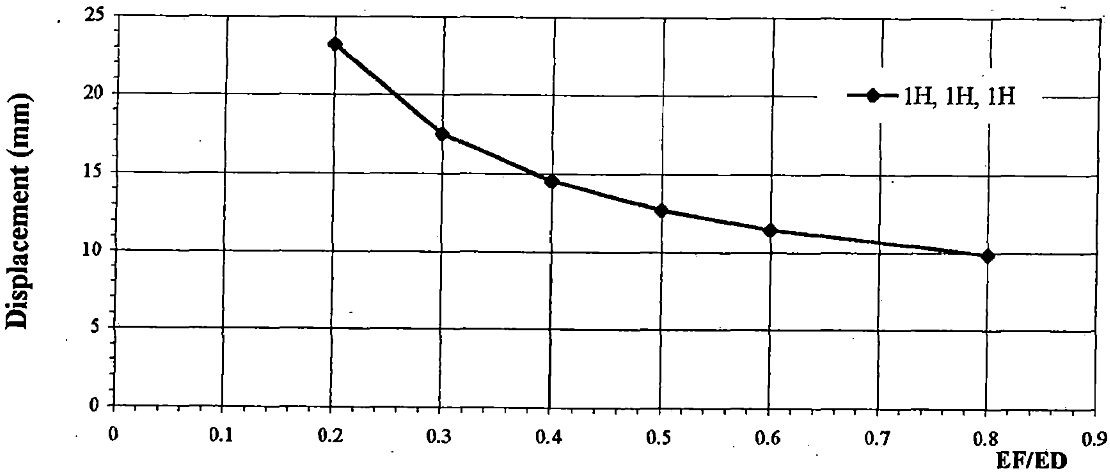


c. Toe

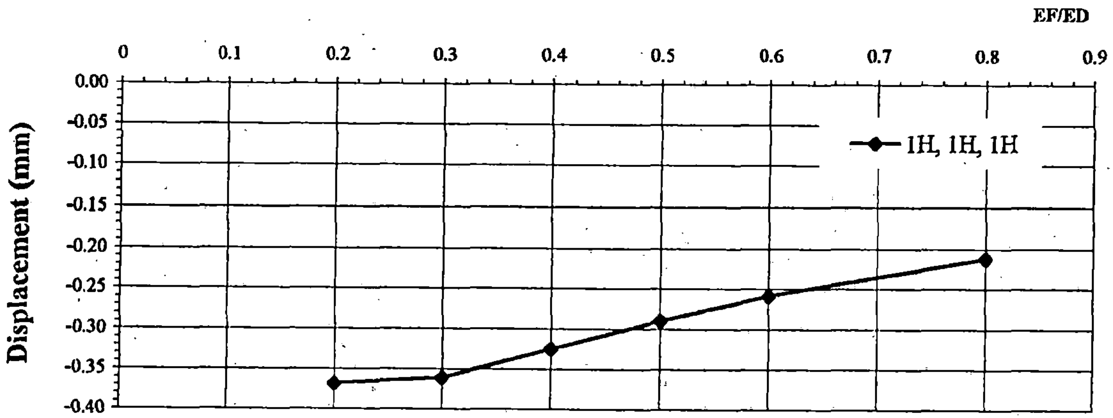
Figure 3.6 Comparison of Vertical Displacement between Part-1A and 1B Study with Foundation Extent 1H u/s, 1H d/s, 1H bottom

Table 3.9 Displacements at crest, heel and toe of Part-1C study (Poisson's ratio 0.2)

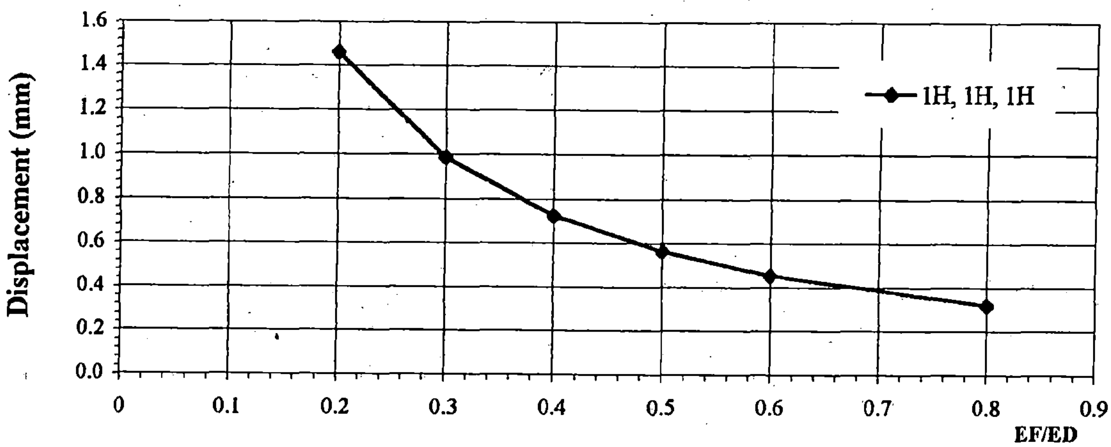
Case No.	Foundation Extent		EF/ED	Horizontal (mm)			Vertical (mm)		
				Crest	Heel	Toe	Crest	Heel	Toe
1	U/S	1 H	0.2	23.21	-0.37	1.46	3.58	4.65	-6.67
	D/S	1 H	0.3	17.50	-0.36	0.98	2.36	3.26	-4.26
	Bottom	1 H	0.4	14.55	-0.32	0.72	1.73	2.53	-3.10
			0.5	12.73	-0.29	0.56	1.34	2.07	-2.43
			0.6	11.49	-0.26	0.45	1.08	1.75	-1.99
			0.8	9.90	-0.21	0.32	0.74	1.34	-1.45



a. Crest

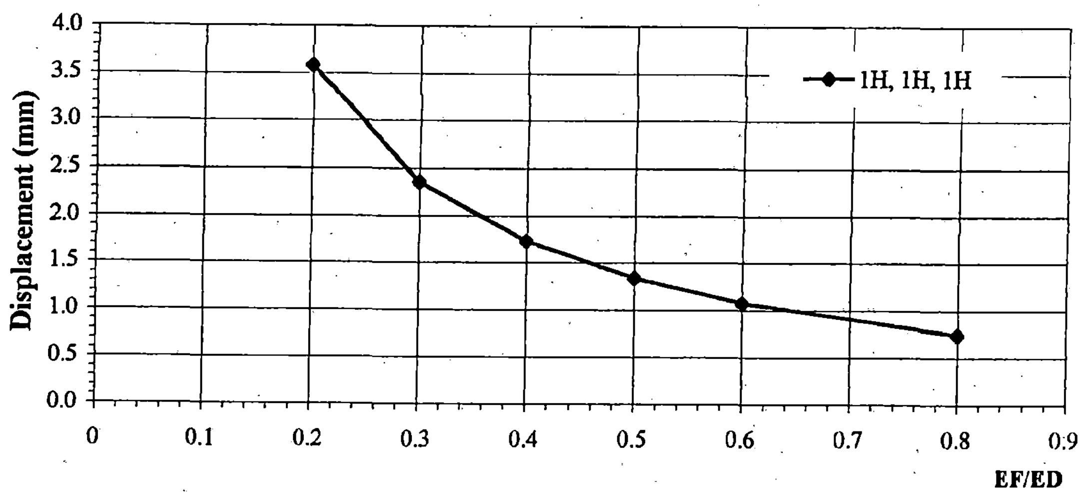


b. Heel

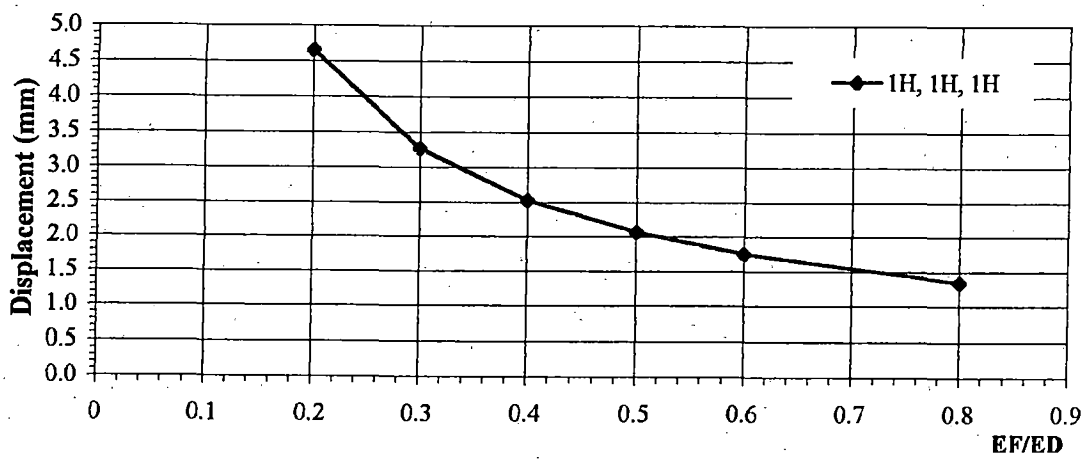


c. Toe

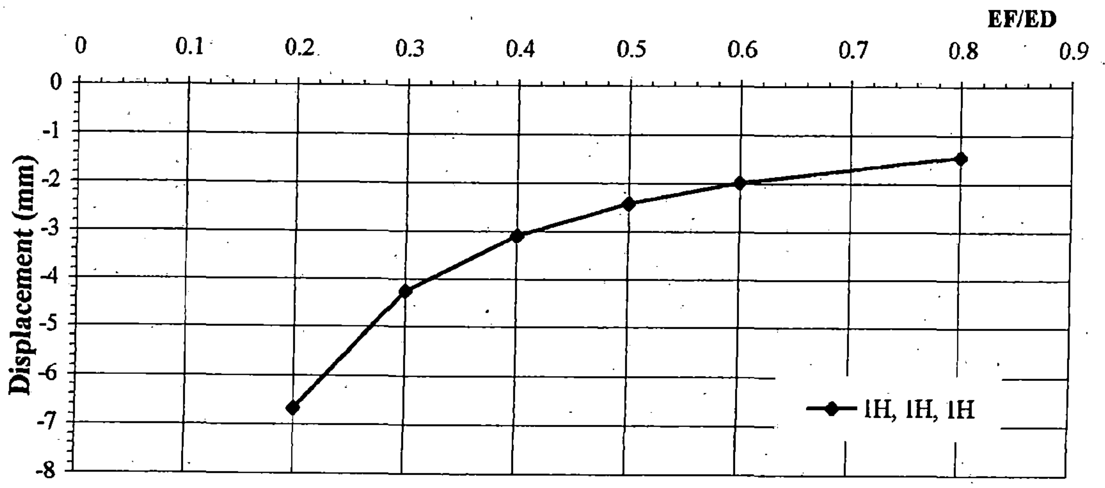
Fig. 3.7 Horizonal Displacement of Part-1C Study



a. Crest



b. Heel



c. Toe

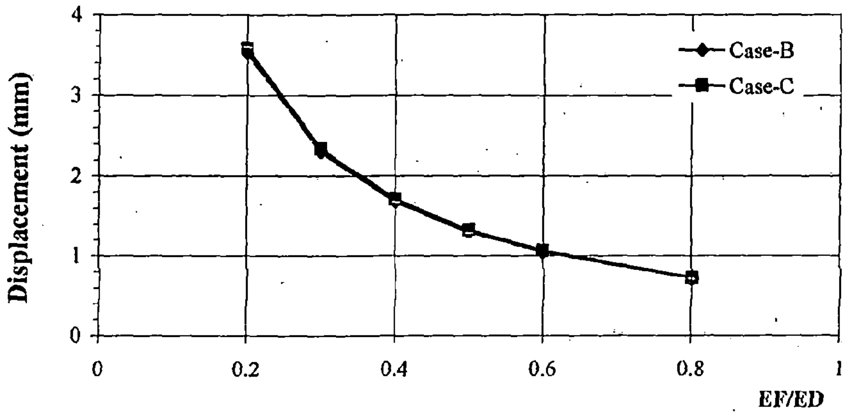
Fig. 3.8 Vertical displacement of Part-1C Study

Table 3.10 Comparison between Part-1B and Part-1C Study of Horizontal Displacement with different Rigidity of Foundation in any Foundation Extent

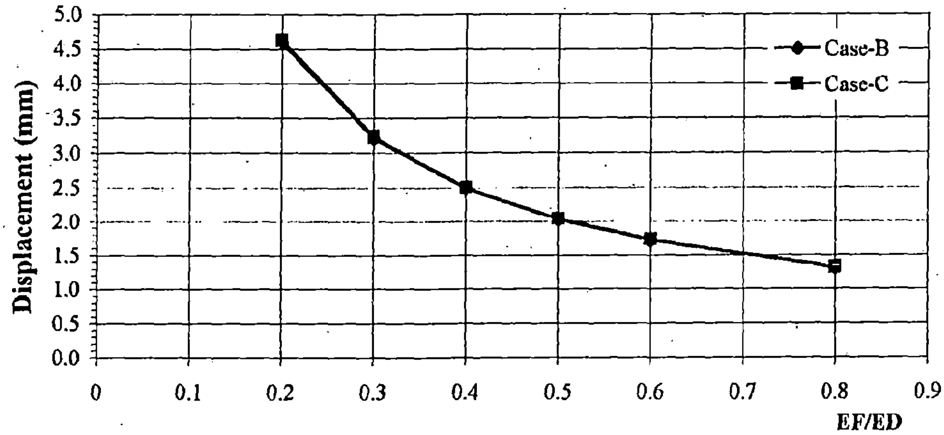
Case No.	Foundation Extent	EF/ED	Horizontal (mm)					
			Crest		Heel		Toe	
			Case-B	Case-C	Case-B	Case-C	Case-B	Case-C
1	U/S 1H	0.2	22.32	23.21	-0.80	-0.37	1.19	1.46
	D/S 1H	0.3	16.91	17.50	-0.65	-0.36	0.83	0.98
	Bottom 1H	0.4	14.09	14.55	-0.54	-0.32	0.63	0.72
		0.5	12.36	12.73	-0.46	-0.29	0.50	0.56
		0.6	11.18	11.49	-0.40	-0.26	0.41	0.45
		0.8	9.66	9.90	-0.32	-0.21	0.29	0.32

Table 3.11 Comparison between Part -1B and Part -1C Study of Vertical Displacement with different Rigidity of Foundation in any Foundation with Extent

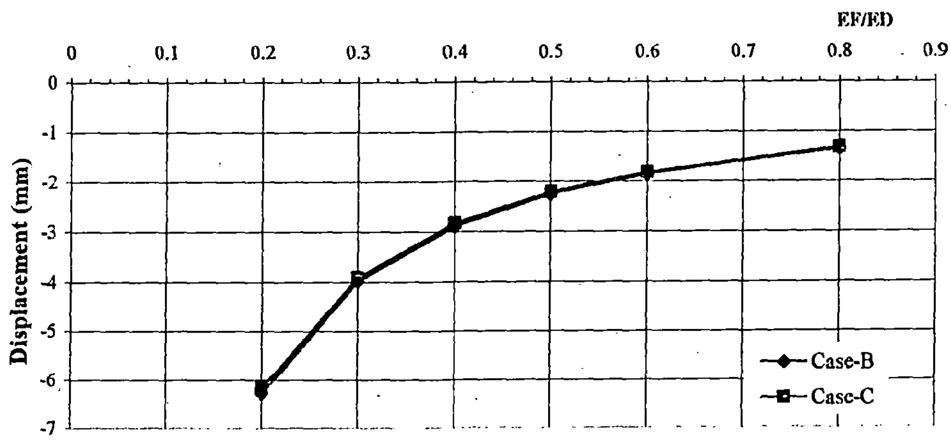
Case No.	Foundation Extent	EF/ED	Vertical (mm)					
			Crest		Heel		Toe	
			Case-B	Case-C	Case-B	Case-C	Case-B	Case-C
1	U/S 1H	0.2	3.57	3.58	4.63	4.65	-6.17	-6.67
	D/S 1H	0.3	2.35	2.36	3.24	3.26	-3.91	-4.26
	Bottom 1H	0.4	1.71	1.73	2.50	2.53	-2.83	-3.10
		0.5	1.33	1.34	2.04	2.07	-2.21	-2.43
		0.6	1.06	1.08	1.73	1.75	-1.80	-1.99
		0.8	0.73	0.74	1.32	1.34	-1.31	-1.45



a. Crest

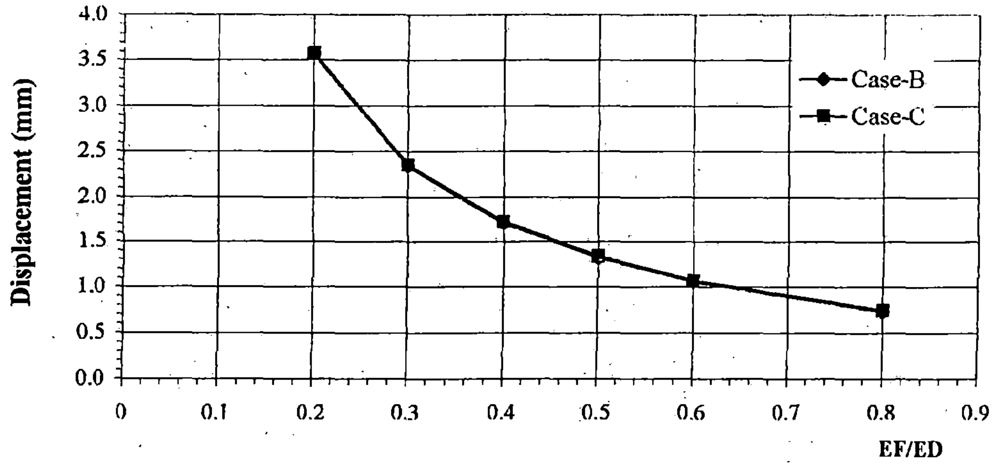


b. Heel

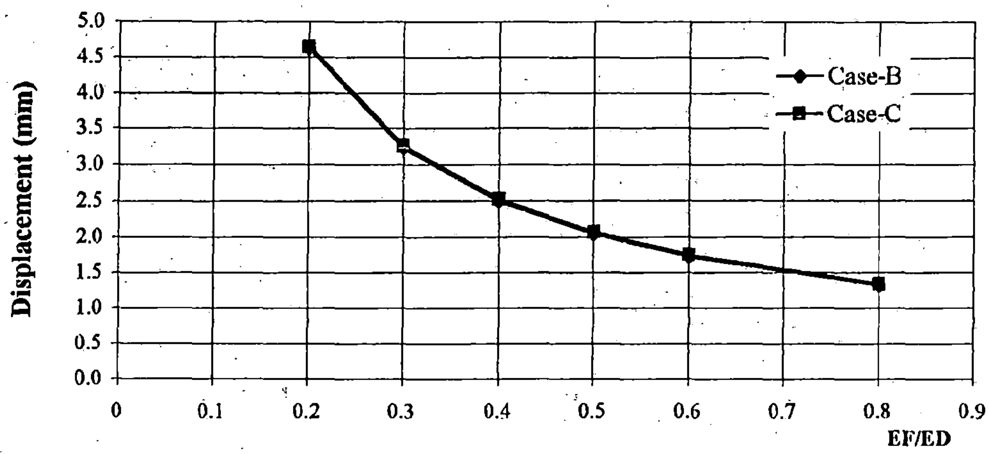


c. Toe

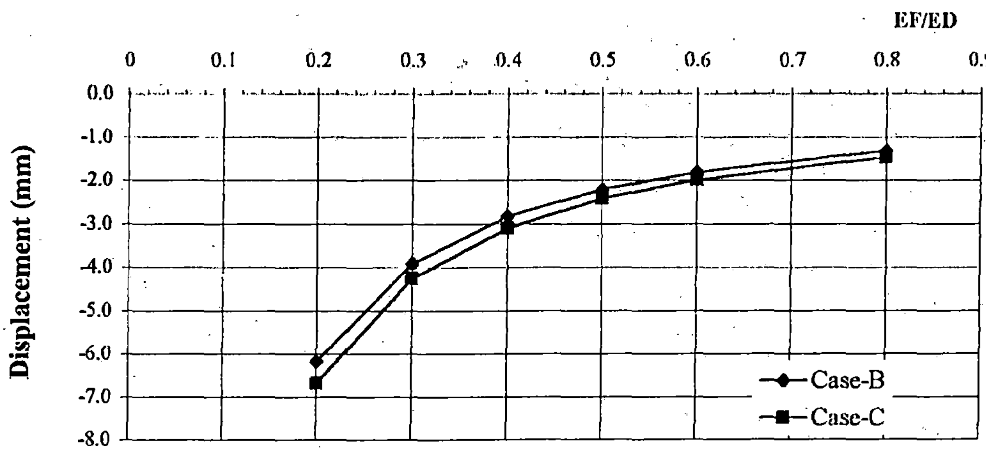
Figure 3.9 Comparison of Horizontal Displacement between Part-1B and 1C Study with Foundation Extent 1H u/s, 1H d/s, 1H bottom



a. Crest



b. Heel



c. Toe

Figure 3.10 Comparison of Vertical Displacement between Part-1B and 1C Study with Foundation Extent 1H u/s, 1H d/s, 1H bottom

3.2.2 Stresses

Stresses in concrete gravity dam are of importance. By knowing the stresses in dam body, the dimension of dam section can be optimized. Concrete as a material of dam is strong enough to resist compressive stress, but not too strong to resist the tensile stress. That is why the allowable tensile stress is taken around 1/10th of allowable compressive stress.

Tables 3.12 and 3.13, and Figures 3.11 and 3.12 indicate the horizontal and vertical stresses at heel and toe with boundary condition-A. From Table 3.12, it is evident that with any foundation extent, the horizontal stress tends to decrease both at heel and toe with increase in rock modulus of foundation. But at heel the decreasing rate is not that steep as at toe (see Figure 3.11). Tensile stress occurs at heel and compressive stress at toe. From these tables in any foundation extent, the vertical stress at heel tends to increase and that at toe tends to decrease with increase in rock modulus (see Figure 3.12). Here, tensile stress also occurs at heel and compressive stress at toe. Table 3.13 indicate the effect of foundation extent at any rock modulus of foundation against horizontal and vertical stresses. From this table, it can be seen that as the depth of the foundation extent at any lateral extent, increase both the horizontal and vertical stresses tend to decrease.

Tables 3.14 and 3.15, and Figures 3.13 and 3.14 show the horizontal and vertical stresses at heel and toe with boundary condition-B. From these results, it can be seen that for each foundation extent and each value of foundation elasticity, the horizontal and vertical stresses at heel and toe are of the same order as in case of boundary condition-A. Tensile stress occurs at heel and compressive stress at toe (Figures 3.13 and 3.14). From Table 3.15, it can be seen that at any foundation elasticity, as depth of the foundation extent at any lateral extent increases the horizontal and vertical stresses at heel and toe tend to decrease. Logically, due to horizontal water pressure acting at the vertical upstream face of dam, a clockwise acts on the dam body which will lift the heel of dam up and press the toe of dam into foundation. So, due to this pressure, tensile stress will occurs at heel and compressive stress at toe. Uplift pressure which act at the base of dam will also lift the dam up especially at heel where it will be maximum. Here, the equilibrium occurs when the gravity load works to resist these external pressures. The gravity load causes stress along the base of dam. The maximum compressive stress works at heel and minimum compressive stress at toe. So, stress at heel will be vary from tension to compression according to the weight-age of each pressures or loads. If at heel, tensile stress of external pressures is bigger than compressive stress due to gravity, so that point will be in tension otherwise compression. At toe, it is clear that compressive stress dominantly works at that point because compressive stress is yielded both by gravity load and water pressure.

Tables 3.16 and 3.17, and Figures 3.15 and 3.18 show the comparison of horizontal and vertical stresses between boundary condition-A and condition-B. From These tables and figures, it can be noted that there is insignificant change in vertical stresses at the heel and toe in the two cases. The variation in horizontal stresses at toe is also negligible. The difference in horizontal stresses at heel reduces as the lateral extent is increased.

Tables 3.18 and 3.19 show the shear and principal stress at heel and toe of condition-A. It can be seen from the tables that as the foundation elasticity increases, shear stress at heel tends to increase slightly and at toe it decreases at any foundation extent. The same trend is depicted with the increase in foundation extent also. The same trend of change in shear stress value has been observed with boundary condition-B (Tables 3.20 and 3.21).

Comparison of shear stress between two boundary conditions can be seen in Tables 3.22 and 3.23 and Figure 3.19. From these tables, the shear stress at condition-A is seen less than that with condition-B. At wider lateral extent, it can be noted that the shear stress at condition-A is nearly same as condition-B. From Figure 3.19, it can also be seen that the shear stress at heel and toe show the same behavior. The difference in shear stress at toe is less than that at heel.

The principal stresses at heel and toe with boundary condition-A can be seen in Tables 3.18 and 3.19. From Table 3.18, it can be seen that at heel, with increase in value of foundation elasticity at any foundation extent, the major principal stress tends to increase but it tends to decrease at toe. At any foundation elasticity, with wider and deeper foundation extent, the principal stress at heel and toe tend to decrease. Minor principal stress at heel is not seen to be affected by value of foundation elasticity but at toe, it has shown decreasing trend with increase in elastic modulus of foundation. Table

3.19 shows the principal stresses with variable foundation extent against different value of foundation elasticity.

In condition-B, the trend in change of values of principal stresses is found similarly to that with condition-A (Tables 3.20 and 3.21).

Comparison of the principal stresses in between boundary condition-A and B can be seen in Tables 3.24 and 3.25. It can be seen that the principal stresses with boundary condition-A are slightly more than those with condition-B at heel, and slightly less at toe. This trend is shown in Figure 3.20 also. This figure also shows the increasing and decreasing trend of major principal stress at heel and toe with change in foundation elasticity.

Table 3.26 and Figures 3.21 to 3.24 show the stresses of part-1C study with changed Poisson's ratio. From These tables and figures, it can be seen that horizontal stress at heel and toe tend to decrease with increase in value of the foundation elasticity. Vertical stress at heel tends to increase while at the toe it tends to decrease with increase in the value of foundation elasticity. Shear stress and major principal stresses in this case tend to increase at heel and decrease at toe. It also can be noted that these increasing and decreasing rate in shear stress and principal stresses are sharper in foundation elasticity range of 0.2 to 0.6 as compared to the foundation elasticity range of 0.6 to 0.8.

Comparison of stresses with two values of Poisson's ratio between part-1B and part-1C of this study can be seen in Tables 3.27 to 3.29 and Figures 3.25 to 3.28. From Table 3.27 and Figure 3.25, it can be seen that at heel, difference in the horizontal stress is somewhat more than that at toe. While in vertical stress, the difference is marginal both at heel and toe with increasing foundation elasticity (see Table 3.27 and Figure 3.26). From Table 3.28 and Figure 3.27, it can also be seen that at heel, the shear stress in case of part-1C is less than that of part-1B but at toe it is more. And the difference is marginal with increase in foundation elasticity. The major principal stresses at heel in part-1C are slightly more than those in part-1B study but at toe these are slightly less (see Table 3.29 and Figure 3.28).

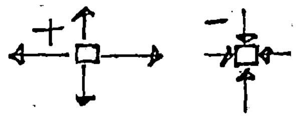
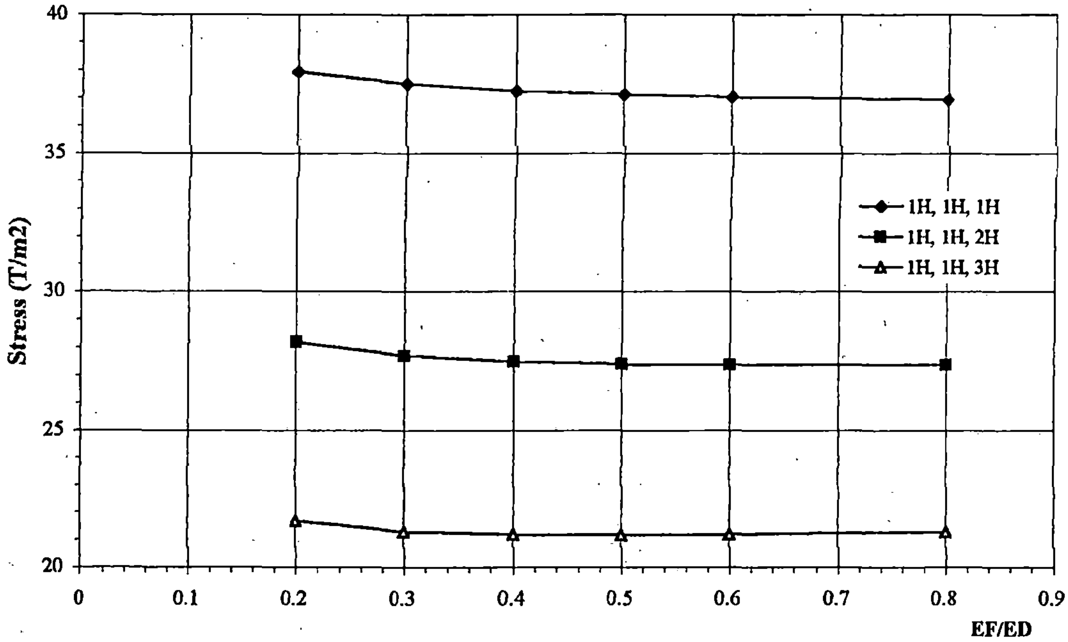


Table 3.12 Horizontal and Vertical Stress at Heel and Toe with different Rigidity of Foundation in any Foundation Extent of Part -1A Study (Ton/m^2)

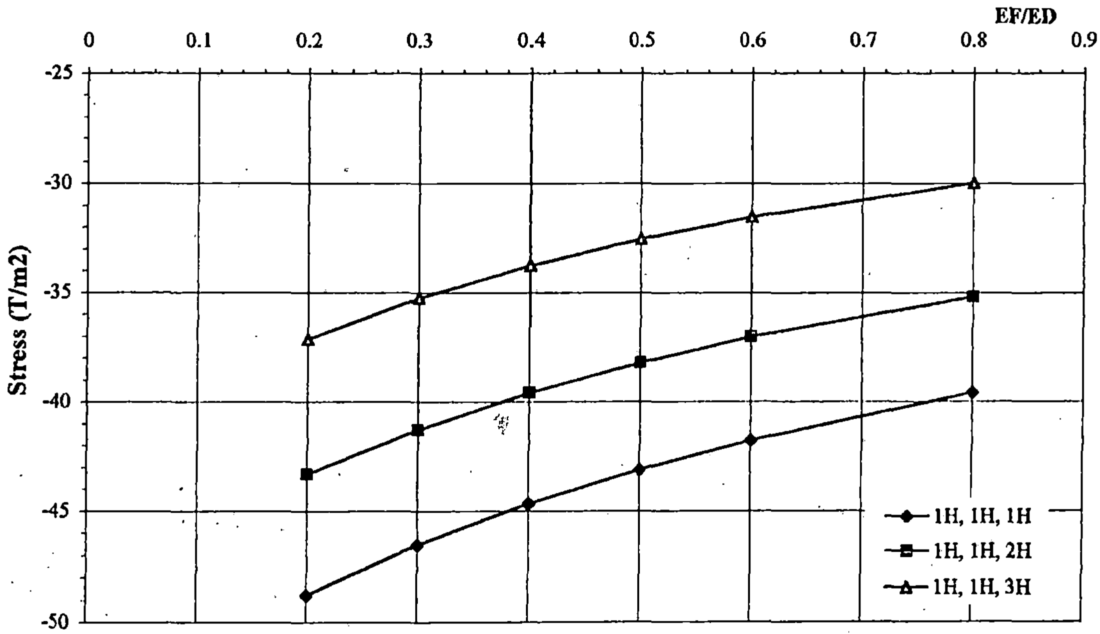
Case No.	Foundation Extent		EF/ED	Horizontal		Vertical	
				Heel	Toe	Heel	Toe
1	U/S	1H	0.2	37.93	-48.79	68.19	-72.05
	D/S	1H	0.3	37.48	-46.55	74.54	-64.86
	Bottom	1H	0.4	37.23	-44.67	78.49	-59.96
			0.5	37.11	-43.10	81.19	-56.39
			0.6	37.02	-41.75	83.09	-53.63
			0.8	36.91	-39.58	85.58	-49.62
2	U/S	1H	0.2	28.19	-43.31	55.71	-67.07
	D/S	1H	0.3	27.69	-41.27	61.05	-61.23
	Bottom	2H	0.4	27.48	-39.59	64.35	-57.25
			0.5	27.40	-38.19	66.58	-54.34
			0.6	27.36	-37.02	68.15	-52.08
			0.8	27.38	-35.18	70.26	-48.81
3	U/S	1H	0.2	21.68	-37.13	48.30	-62.30
	D/S	1H	0.3	21.29	-35.24	52.86	-57.31
	Bottom	3H	0.4	21.18	-33.74	55.64	-53.94
			0.5	21.17	-32.52	57.50	-51.47
			0.6	21.20	-31.52	58.80	-49.56
			0.8	21.29	-29.97	60.53	-46.79
4	U/S	1.5H	0.2	34.07	-46.43	63.39	-67.70
	D/S	1.5H	0.3	33.54	-44.35	69.27	-61.02
	Bottom	1H	0.4	33.28	-42.59	72.92	-56.50
			0.5	33.12	-41.10	75.36	-53.20
			0.6	33.02	-39.82	77.06	-50.65
			0.8	32.91	-37.75	79.28	-46.95
5	U/S	1.5H	0.2	26.53	-43.48	53.36	-64.85
	D/S	1.5H	0.3	26.02	-41.37	58.45	-59.22
	Bottom	2H	0.4	25.82	-39.64	61.60	-55.41
			0.5	25.75	-38.20	63.71	-52.60
			0.6	25.73	-36.99	65.20	-50.44
			0.8	25.78	-34.34	67.83	-46.09
6	U/S	1.5H	0.2	20.59	-38.39	46.88	-61.11
	D/S	1.5H	0.3	20.23	-36.35	51.30	-56.22
	Bottom	3H	0.4	20.15	-34.72	54.00	-52.91
			0.5	20.17	-33.41	55.80	-50.48
			0.6	20.22	-32.33	57.06	-48.61
			0.8	20.35	-30.67	58.73	-45.88
7	U/S	2H	0.2	31.42	-44.25	59.78	-64.23
	D/S	2H	0.3	30.87	-42.26	65.33	-57.95
	Bottom	1H	0.4	30.58	-40.58	68.71	-53.72
			0.5	30.41	-39.15	70.94	-50.63
			0.6	30.30	-37.93	72.50	-48.26
			0.8	30.17	-35.95	74.48	-44.81
8	U/S	2H	0.2	25.13	-42.72	51.44	-62.69
	D/S	2H	0.3	24.63	-40.60	56.34	-57.27
	Bottom	2H	0.4	24.43	-38.85	59.33	-53.59
			0.5	24.36	-37.40	61.32	-50.90
			0.6	24.34	-36.20	62.72	-48.82
			0.8	24.37	-34.30	64.54	-45.79
9	U/S	2H	0.2	19.76	-38.47	45.74	-59.77
	D/S	2H	0.3	19.43	-36.36	50.08	-55.00
	Bottom	3H	0.4	19.36	-34.67	52.67	-51.75
			0.5	19.39	-33.32	54.40	-49.37
			0.6	19.44	-32.20	55.60	-47.54
			0.8	19.58	-30.51	57.19	-44.87

Table 3.13 Horizontal and Vertical Stress at Heel and Toe with different Foundation Extent in any Rigidity of Foundation of Part -1A Study (Ton/m^2)

Case No.	EF/ED	Foundation Extent			Horizontal		Vertical	
		U/S	D/S	Bottom	Heel	Toe	Heel	Toe
1	0.2	1.0H	1.0H	1.0H	37.93	-48.79	68.19	-72.05
		1.0H	1.0H	2.0H	28.19	-43.31	55.71	-67.07
		1.0H	1.0H	3.0H	21.68	-37.13	48.30	-62.30
		1.5H	1.5H	1.0H	34.07	-46.43	63.39	-67.70
		1.5H	1.5H	2.0H	26.53	-43.48	53.36	-64.85
		1.5H	1.5H	3.0H	20.59	-38.39	46.88	-61.11
		2.0H	2.0H	1.0H	31.42	-44.25	59.78	-64.23
		2.0H	2.0H	2.0H	25.13	-42.72	51.44	-62.69
		2.0H	2.0H	3.0H	19.76	-38.47	45.74	-59.77
2	0.3	1.0H	1.0H	1.0H	37.48	-46.55	74.54	-64.86
		1.0H	1.0H	2.0H	27.69	-41.27	61.05	-61.23
		1.0H	1.0H	3.0H	21.29	-35.24	52.86	-57.31
		1.5H	1.5H	1.0H	33.54	-44.35	69.27	-61.02
		1.5H	1.5H	2.0H	26.02	-41.37	58.45	-59.22
		1.5H	1.5H	3.0H	20.23	-36.35	51.30	-56.22
		2.0H	2.0H	1.0H	30.87	-42.26	65.33	-57.95
		2.0H	2.0H	2.0H	24.63	-40.60	56.34	-57.27
		2.0H	2.0H	3.0H	19.43	-36.36	50.08	-55.00
3	0.4	1.0H	1.0H	1.0H	37.23	-44.67	78.49	-59.96
		1.0H	1.0H	2.0H	27.48	-39.59	64.35	-57.25
		1.0H	1.0H	3.0H	21.18	-33.74	55.64	-53.94
		1.5H	1.5H	1.0H	33.28	-42.59	72.92	-56.50
		1.5H	1.5H	2.0H	25.82	-39.64	61.60	-55.41
		1.5H	1.5H	3.0H	20.15	-34.72	54.00	-52.91
		2.0H	2.0H	1.0H	30.58	-40.58	68.71	-53.72
		2.0H	2.0H	2.0H	24.43	-38.85	59.33	-53.59
		2.0H	2.0H	3.0H	19.36	-34.67	52.67	-51.75
4	0.5	1.0H	1.0H	1.0H	37.11	-43.10	81.19	-56.39
		1.0H	1.0H	2.0H	27.40	-38.19	66.58	-54.34
		1.0H	1.0H	3.0H	21.17	-32.52	57.50	-51.47
		1.5H	1.5H	1.0H	33.12	-41.10	75.36	-53.20
		1.5H	1.5H	2.0H	25.75	-38.20	63.71	-52.60
		1.5H	1.5H	3.0H	20.17	-33.41	55.80	-50.48
		2.0H	2.0H	1.0H	30.41	-39.15	70.94	-50.63
		2.0H	2.0H	2.0H	24.36	-37.40	61.32	-50.90
		2.0H	2.0H	3.0H	19.39	-33.32	54.40	-49.37
5	0.6	1.0H	1.0H	1.0H	37.02	-41.75	83.09	-53.63
		1.0H	1.0H	2.0H	27.36	-37.02	68.15	-52.08
		1.0H	1.0H	3.0H	21.20	-31.52	58.80	-49.56
		1.5H	1.5H	1.0H	33.02	-39.82	77.06	-50.65
		1.5H	1.5H	2.0H	25.73	-36.99	65.20	-50.44
		1.5H	1.5H	3.0H	20.22	-32.33	57.06	-48.61
		2.0H	2.0H	1.0H	30.30	-37.93	72.50	-48.26
		2.0H	2.0H	2.0H	24.34	-36.20	62.72	-48.82
		2.0H	2.0H	3.0H	19.44	-32.20	55.60	-47.54
6	0.8	1.0H	1.0H	1.0H	36.91	-39.58	85.58	-49.62
		1.0H	1.0H	2.0H	27.38	-35.18	70.26	-48.81
		1.0H	1.0H	3.0H	21.29	-29.97	60.53	-46.79
		1.5H	1.5H	1.0H	32.91	-37.75	79.28	-46.95
		1.5H	1.5H	2.0H	25.78	-34.34	67.83	-46.09
		1.5H	1.5H	3.0H	20.35	-30.67	58.73	-45.88
		2.0H	2.0H	1.0H	30.17	-35.95	74.48	-44.81
		2.0H	2.0H	2.0H	24.37	-34.30	64.54	-45.79
		2.0H	2.0H	3.0H	19.58	-30.51	57.19	-44.87

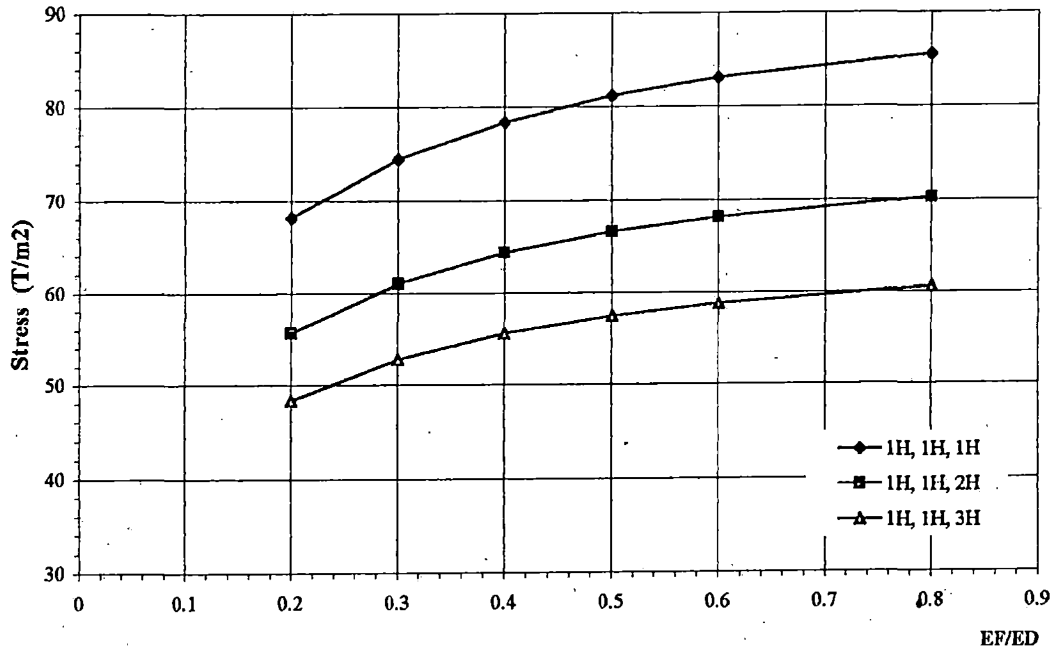


a. Heel

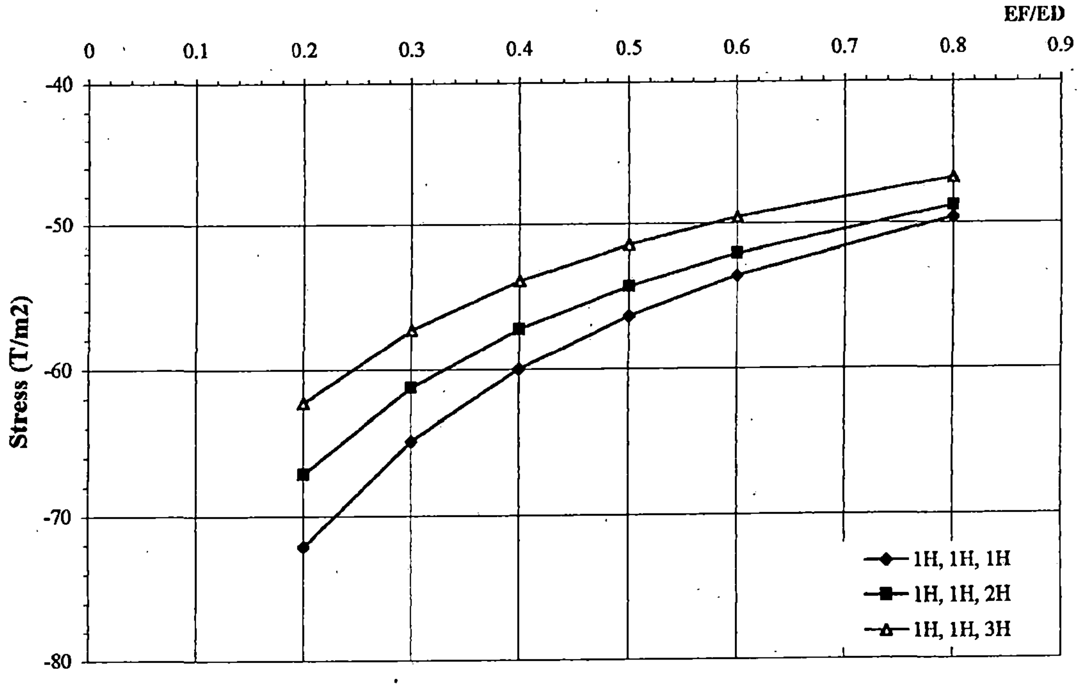


b. Toe

Figure 3.11 Horizontal Stress of Part-1A Study



a. Heel



b. Toe

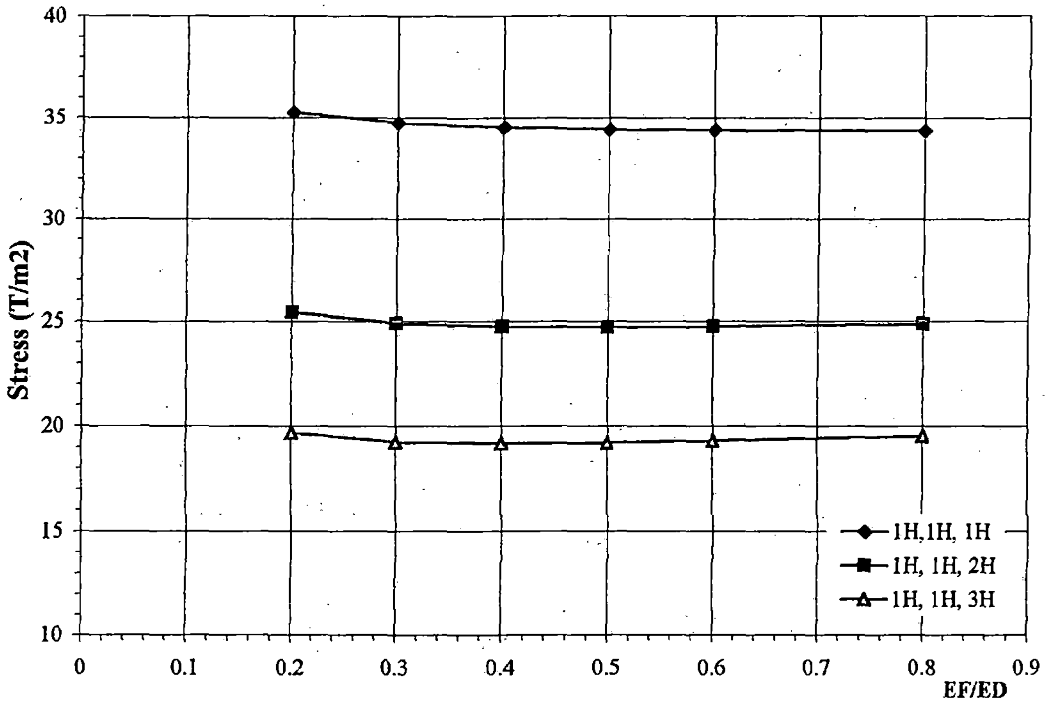
Figure 3.12 Vertical Stress of Part-1A Study

Table 3.14 Horizontal and Vertical Stress at Heel and Toe with different Rigidity of Foundation in any Foundation Extent of Part -1B Study (Ton/m²)

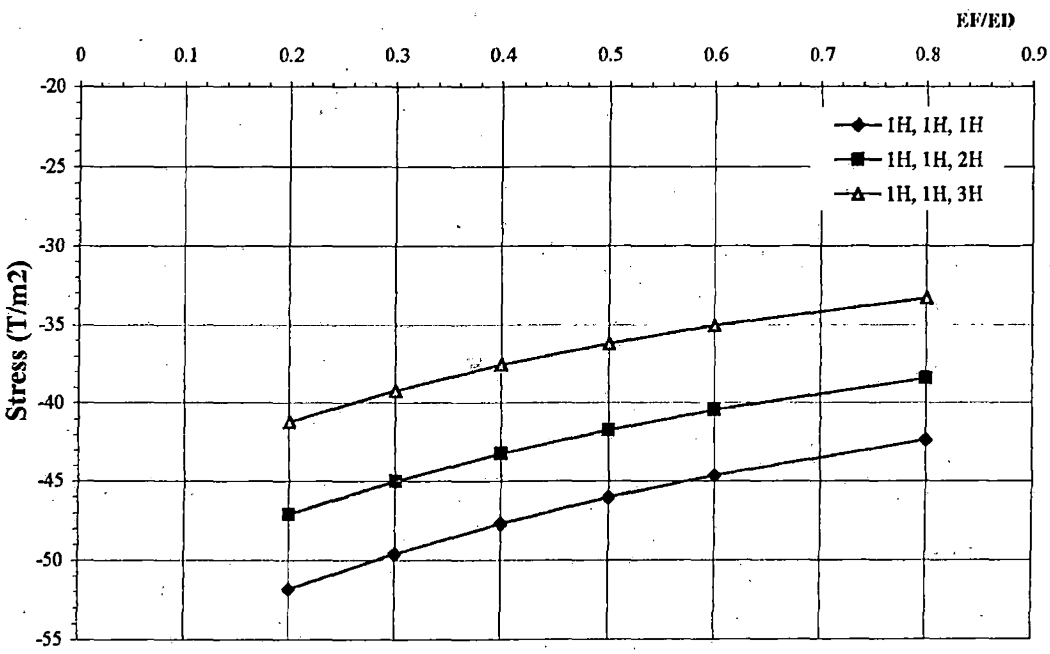
Case No.	Foundation Extent		EF/ED	Horizontal		Vertical	
				Heel	Toe	Heel	Toe
1	U/S	1H	0.2	35.25	-51.82	67.85	-72.62
	D/S	1H	0.3	34.75	-49.60	74.06	-65.47
	Bottom	1H	0.4	34.51	-47.67	77.94	-60.59
			0.5	34.42	-46.03	80.59	-57.01
			0.6	34.38	-44.62	82.49	-54.23
			0.8	34.37	-42.32	84.99	-50.18
2	U/S	1H	0.2	25.42	-47.10	55.39	-67.66
	D/S	1H	0.3	24.89	-45.01	60.56	-61.86
	Bottom	2H	0.4	24.73	-43.22	63.79	-57.90
			0.5	24.71	-41.72	66.00	-54.97
			0.6	24.74	-40.44	67.56	-52.69
			0.8	24.87	-38.41	69.67	-49.37
3	U/S	1H	0.2	19.68	-41.20	48.12	-62.78
	D/S	1H	0.3	19.26	-39.21	52.54	-57.83
	Bottom	3H	0.4	19.19	-37.56	55.26	-54.45
			0.5	19.24	-36.20	57.09	-51.97
			0.6	19.32	-35.07	58.40	-50.04
			0.8	19.52	-33.32	60.14	-47.22
4	U/S	1.5H	0.2	33.11	-47.60	63.31	-67.87
	D/S	1.5H	0.3	32.57	-45.52	69.14	-61.21
	Bottom	1H	0.4	32.31	-43.75	72.77	-56.70
			0.5	32.17	-42.23	75.18	-53.39
			0.6	32.09	-40.92	76.88	-50.84
			0.8	32.01	-38.81	79.09	-47.13
5	U/S	1.5H	0.2	24.49	-45.68	53.13	-65.22
	D/S	1.5H	0.3	24.01	-43.52	58.13	-59.61
	Bottom	2H	0.4	23.87	-41.72	61.25	-55.80
			0.5	23.85	-40.21	63.34	-52.99
			0.6	23.88	-38.93	64.82	-50.80
			0.8	24.00	-36.93	66.79	-47.62
6	U/S	1.5H	0.2	18.92	-40.62	46.72	-61.41
	D/S	1.5H	0.3	18.60	-38.51	51.08	-56.54
	Bottom	3H	0.4	18.57	-36.80	53.75	-53.23
			0.5	18.65	-35.41	55.53	-50.79
			0.6	18.74	-34.25	56.79	-48.89
			0.8	18.95	-32.48	58.46	-46.14
7	U/S	2H	0.2	31.06	-44.70	59.75	-64.28
	D/S	2H	0.3	30.50	-42.71	65.28	-58.02
	Bottom	1H	0.4	30.21	-41.02	68.65	-53.78
			0.5	30.05	-39.58	70.88	-50.70
			0.6	29.95	-38.35	72.43	-48.32
			0.8	29.83	-36.36	74.42	-44.87
8	U/S	2H	0.2	23.81	-44.16	51.32	-62.92
	D/S	2H	0.3	23.33	-41.98	56.15	-57.51
	Bottom	2H	0.4	23.17	-40.18	59.12	-53.83
			0.5	23.14	-38.69	61.10	-51.14
			0.6	23.15	-37.44	62.49	-49.04
			0.8	23.24	-35.47	64.31	-45.99
9	U/S	2H	0.2	18.37	-40.04	45.61	-60.01
	D/S	2H	0.3	18.09	-37.85	49.89	-55.24
	Bottom	3H	0.4	18.08	-36.09	52.46	-51.99
			0.5	18.15	-34.68	54.17	-49.59
			0.6	18.25	-33.52	55.38	-47.75
			0.8	18.45	-31.73	56.98	-45.06

Table 3.15 Horizontal and Vertical Stresses at Heel and Toe with different Foundation Extent in any Rigidity of Foundation of Part -1B Study (Ton/m²)

Case No.	EF/ED	Foundation Extent			Horizontal		Vertical	
		U/S	D/S	Bottom	Heel	Toe	Heel	Toe
1	0.2	1.0H	1.0H	1.0H	35.25	-51.82	67.85	-72.62
		1.0H	1.0H	2.0H	25.42	-47.10	55.39	-67.66
		1.0H	1.0H	3.0H	19.68	-41.20	48.12	-62.78
		1.5H	1.5H	1.0H	33.11	-47.60	63.31	-67.87
		1.5H	1.5H	2.0H	24.49	-45.68	53.13	-65.22
		1.5H	1.5H	3.0H	18.92	-40.62	46.72	-61.41
		2.0H	2.0H	1.0H	31.06	-44.70	59.75	-64.28
		2.0H	2.0H	2.0H	23.81	-44.16	51.32	-62.92
		2.0H	2.0H	3.0H	18.37	-40.04	45.61	-60.01
2	0.3	1.0H	1.0H	1.0H	34.75	-49.60	74.06	-65.47
		1.0H	1.0H	2.0H	24.89	-45.01	60.56	-61.86
		1.0H	1.0H	3.0H	19.26	-39.21	52.54	-57.83
		1.5H	1.5H	1.0H	32.57	-45.52	69.14	-61.21
		1.5H	1.5H	2.0H	24.01	-43.52	58.13	-59.61
		1.5H	1.5H	3.0H	18.60	-38.51	51.08	-56.54
		2.0H	2.0H	1.0H	30.50	-42.71	65.28	-58.02
		2.0H	2.0H	2.0H	23.33	-41.98	56.15	-57.51
		2.0H	2.0H	3.0H	18.09	-37.85	49.89	-55.24
3	0.4	1.0H	1.0H	1.0H	34.51	-47.67	77.94	-60.59
		1.0H	1.0H	2.0H	24.73	-43.22	63.79	-57.90
		1.0H	1.0H	3.0H	19.19	-37.56	55.26	-54.45
		1.5H	1.5H	1.0H	32.31	-43.75	72.77	-56.70
		1.5H	1.5H	2.0H	23.87	-41.72	61.25	-55.80
		1.5H	1.5H	3.0H	18.57	-36.80	53.75	-53.23
		2.0H	2.0H	1.0H	30.21	-41.02	68.65	-53.78
		2.0H	2.0H	2.0H	23.17	-40.18	59.12	-53.83
		2.0H	2.0H	3.0H	18.08	-36.09	52.46	-51.99
4	0.5	1.0H	1.0H	1.0H	34.42	-46.03	80.59	-57.01
		1.0H	1.0H	2.0H	24.71	-41.72	66.00	-54.97
		1.0H	1.0H	3.0H	19.24	-36.20	57.09	-51.97
		1.5H	1.5H	1.0H	32.17	-42.23	75.18	-53.39
		1.5H	1.5H	2.0H	23.85	-40.21	63.34	-52.99
		1.5H	1.5H	3.0H	18.65	-35.41	55.53	-50.79
		2.0H	2.0H	1.0H	30.05	-39.58	70.88	-50.70
		2.0H	2.0H	2.0H	23.14	-38.69	61.10	-51.14
		2.0H	2.0H	3.0H	18.15	-34.68	54.17	-49.59
5	0.6	1.0H	1.0H	1.0H	34.38	-44.62	82.49	-54.23
		1.0H	1.0H	2.0H	24.74	-40.44	67.56	-52.69
		1.0H	1.0H	3.0H	19.32	-35.07	58.40	-50.04
		1.5H	1.5H	1.0H	32.09	-40.92	76.88	-50.84
		1.5H	1.5H	2.0H	23.88	-38.93	64.82	-50.80
		1.5H	1.5H	3.0H	18.74	-34.25	56.79	-48.89
		2.0H	2.0H	1.0H	29.95	-38.35	72.43	-48.32
		2.0H	2.0H	2.0H	23.15	-37.44	62.49	-49.04
		2.0H	2.0H	3.0H	18.25	-33.52	55.38	-47.75
6	0.8	1.0H	1.0H	1.0H	34.37	-42.32	84.99	-50.18
		1.0H	1.0H	2.0H	24.87	-38.41	69.67	-49.37
		1.0H	1.0H	3.0H	19.52	-33.32	60.14	-47.22
		1.5H	1.5H	1.0H	32.01	-38.81	79.09	-47.13
		1.5H	1.5H	2.0H	24.00	-36.93	66.79	-47.62
		1.5H	1.5H	3.0H	18.95	-32.48	58.46	-46.14
		2.0H	2.0H	1.0H	29.83	-36.36	74.42	-44.87
		2.0H	2.0H	2.0H	23.24	-35.47	64.31	-45.99
		2.0H	2.0H	3.0H	18.45	-31.73	56.98	-45.06

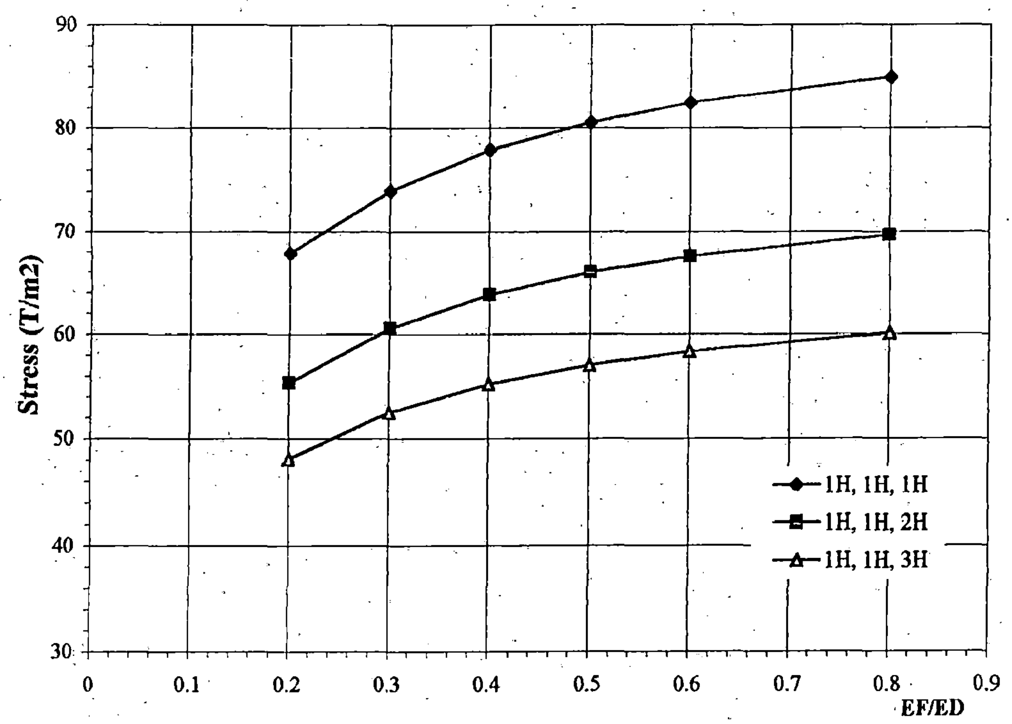


a. Heel

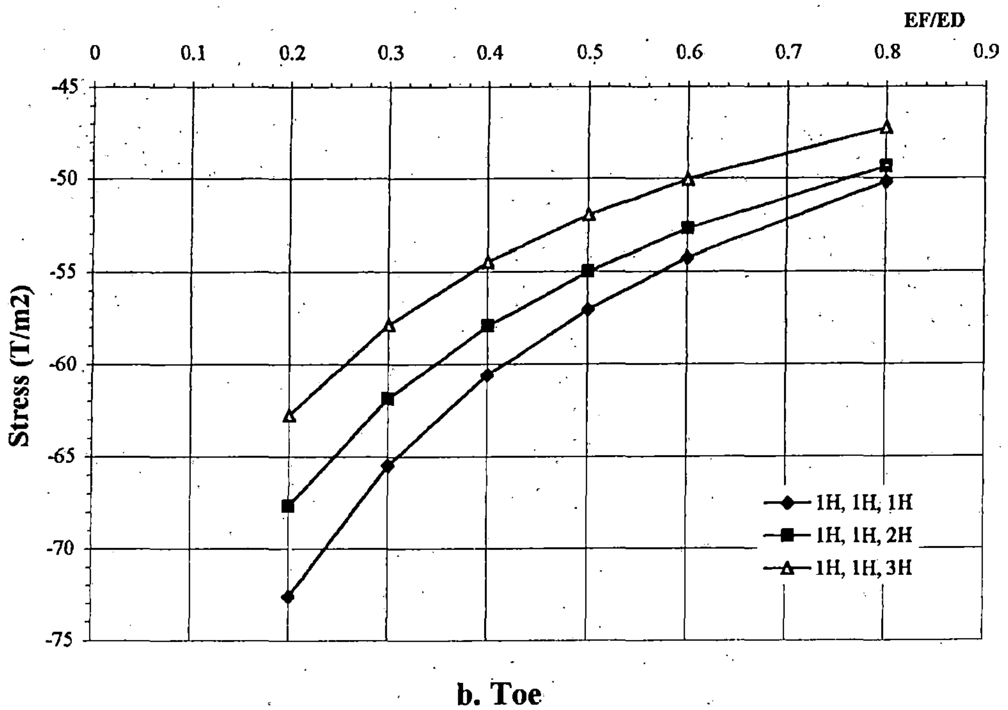


b. Toe

Fig. 3.13 Horizontal stress of Part-1B Study



a. Heel



b. Toe

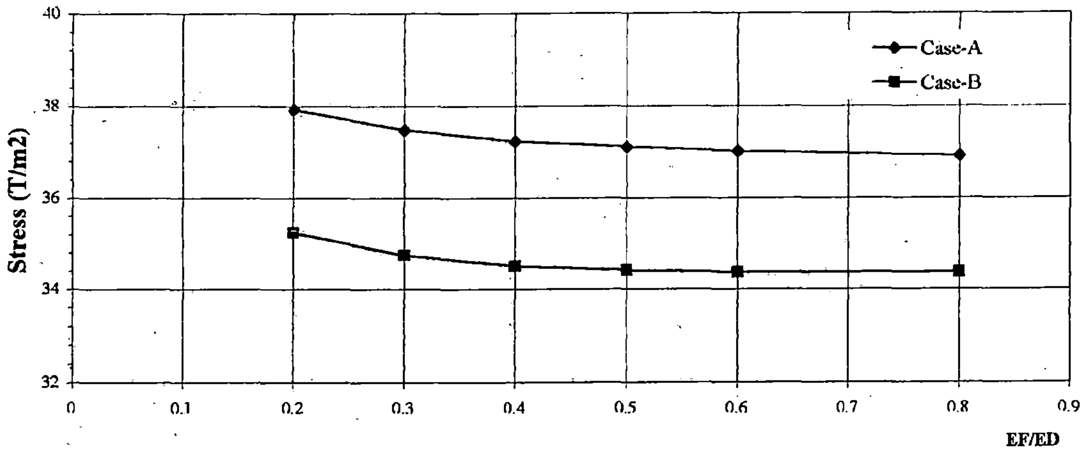
Figure 3.14 Vertical stress of Part-1B Study

Table 3.16 Comparison between Part -1A and Part -1B Study of Horizontal and Vertical Stresses with different Rigidity of Foundation in any Foundation Extent (Ton/m²)

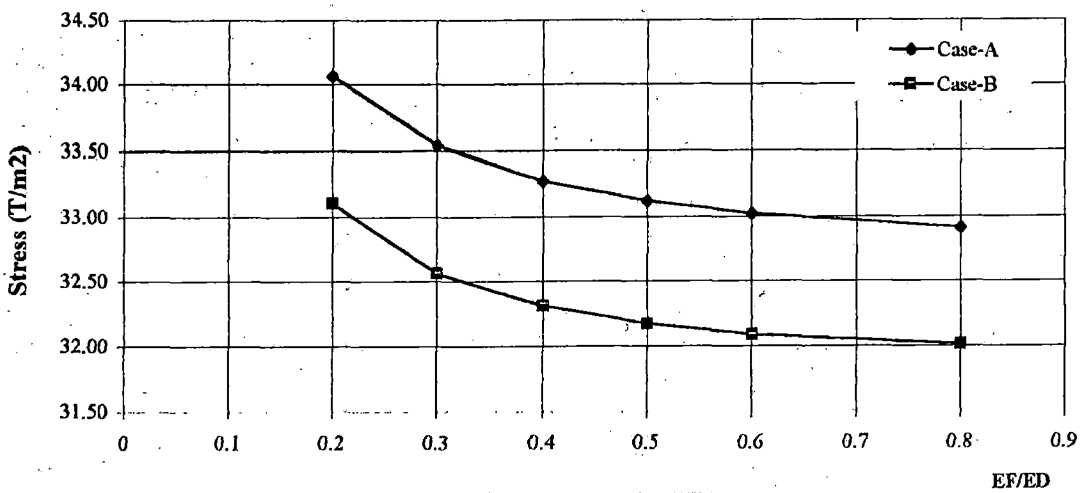
Case No.	Foundation Extent		EF/ED	Horizontal				Vertical			
				Heel		Toe		Heel		Toe	
				Case-A	Case-B	Case-A	Case-B	Case-A	Case-B	Case-A	Case-B
1	U/S	1H	0.2	37.93	35.25	-48.79	-51.82	68.19	67.85	-72.05	-72.62
	D/S	1H	0.3	37.48	34.75	-46.55	-49.60	74.54	74.06	-64.86	-65.47
	Bottom	1H	0.4	37.23	34.51	-44.67	-47.67	78.49	77.94	-59.96	-60.59
			0.5	37.11	34.42	-43.10	-46.03	81.19	80.59	-56.39	-57.01
			0.6	37.02	34.38	-41.75	-44.62	83.09	82.49	-53.63	-54.23
			0.8	36.91	34.37	-39.58	-42.32	85.58	84.99	-49.62	-50.18
2	U/S	1H	0.2	28.19	25.42	-43.31	-47.10	55.71	55.39	-67.07	-67.66
	D/S	1H	0.3	27.69	24.89	-41.27	-45.01	61.05	60.56	-61.23	-61.86
	Bottom	2H	0.4	27.48	24.73	-39.59	-43.22	64.35	63.79	-57.25	-57.90
			0.5	27.40	24.71	-38.19	-41.72	66.58	66.00	-54.34	-54.97
			0.6	27.36	24.74	-37.02	-40.44	68.15	67.56	-52.08	-52.69
			0.8	27.38	24.87	-35.18	-38.41	70.26	69.67	-48.81	-49.37
3	U/S	1H	0.2	21.68	19.68	-37.13	-41.20	48.30	48.12	-62.30	-62.78
	D/S	1H	0.3	21.29	19.26	-35.24	-39.21	52.86	52.54	-57.31	-57.83
	Bottom	3H	0.4	21.18	19.19	-33.74	-37.56	55.64	55.26	-53.94	-54.45
			0.5	21.17	19.24	-32.52	-36.20	57.50	57.09	-51.47	-51.97
			0.6	21.20	19.32	-31.52	-35.07	58.80	58.40	-49.56	-50.04
			0.8	21.29	19.52	-29.97	-33.32	60.53	60.14	-46.79	-47.22
4	U/S	1.5H	0.2	34.07	33.11	-46.43	-47.60	63.39	63.31	-67.70	-67.87
	D/S	1.5H	0.3	33.54	32.57	-44.35	-45.52	69.27	69.14	-61.02	-61.21
	Bottom	1H	0.4	33.28	32.31	-42.59	-43.75	72.92	72.77	-56.50	-56.70
			0.5	33.12	32.17	-41.10	-42.23	75.36	75.18	-53.20	-53.39
			0.6	33.02	32.09	-39.82	-40.92	77.06	76.88	-50.65	-50.84
			0.8	32.91	32.01	-37.75	-38.81	79.28	79.09	-46.95	-47.13
5	U/S	1.5H	0.2	26.53	24.49	-43.48	-45.68	53.36	53.13	-64.85	-65.22
	D/S	1.5H	0.3	26.02	24.01	-41.37	-43.52	58.45	58.13	-59.22	-59.61
	Bottom	2H	0.4	25.82	23.87	-39.64	-41.72	61.60	61.25	-55.41	-55.80
			0.5	25.75	23.85	-38.20	-40.21	63.71	63.34	-52.60	-52.99
			0.6	25.73	23.88	-36.99	-38.93	65.20	64.82	-50.44	-50.80
			0.8	25.78	24.00	-34.34	-36.93	67.83	66.79	-46.09	-47.62
6	U/S	1.5H	0.2	20.59	18.92	-38.39	-40.62	46.88	46.72	-61.11	-61.41
	D/S	1.5H	0.3	20.23	18.60	-36.35	-38.51	51.30	51.08	-56.22	-56.54
	Bottom	3H	0.4	20.15	18.57	-34.72	-36.80	54.00	53.75	-52.91	-53.23
			0.5	20.17	18.65	-33.41	-35.41	55.80	55.53	-50.48	-50.79
			0.6	20.22	18.74	-32.33	-34.25	57.06	56.79	-48.61	-48.89
			0.8	20.35	18.95	-30.67	-32.48	58.73	58.46	-45.88	-46.14
7	U/S	2H	0.2	31.42	31.06	-44.25	-44.70	59.78	59.75	-64.23	-64.28
	D/S	2H	0.3	30.87	30.50	-42.26	-42.71	65.33	65.28	-57.95	-58.02
	Bottom	1H	0.4	30.58	30.21	-40.58	-41.02	68.71	68.65	-53.72	-53.78
			0.5	30.41	30.05	-39.15	-39.58	70.94	70.88	-50.63	-50.70
			0.6	30.30	29.95	-37.93	-38.35	72.50	72.43	-48.26	-48.32
			0.8	30.17	29.83	-35.95	-36.36	74.48	74.42	-44.81	-44.87
8	U/S	2H	0.2	25.13	23.81	-42.72	-44.16	51.44	51.32	-62.69	-62.92
	D/S	2H	0.3	24.63	23.33	-40.60	-41.98	56.34	56.15	-57.27	-57.51
	Bottom	2H	0.4	24.43	23.17	-38.85	-40.18	59.33	59.12	-53.59	-53.83
			0.5	24.36	23.14	-37.40	-38.69	61.32	61.10	-50.90	-51.14
			0.6	24.34	23.15	-36.20	-37.44	62.72	62.49	-48.82	-49.04
			0.8	24.37	23.24	-34.30	-35.47	64.54	64.31	-45.79	-45.99
9	U/S	2H	0.2	19.76	18.37	-38.47	-40.04	45.74	45.61	-59.77	-60.01
	D/S	2H	0.3	19.43	18.09	-36.36	-37.85	50.08	49.89	-55.00	-55.24
	Bottom	3H	0.4	19.36	18.08	-34.67	-36.09	52.67	52.46	-51.75	-51.99
			0.5	19.39	18.15	-33.32	-34.68	54.40	54.17	-49.37	-49.59
			0.6	19.44	18.25	-32.20	-33.52	55.60	55.38	-47.54	-47.75
			0.8	19.58	18.45	-30.51	-31.73	57.19	56.98	-44.87	-45.06

Table 3.17 Comparison between Part-1A and Part-1B Study of Horizontal and Vertical Stresses with different Foundation Extent in any Rigidity of Foundation (Ton/m²)

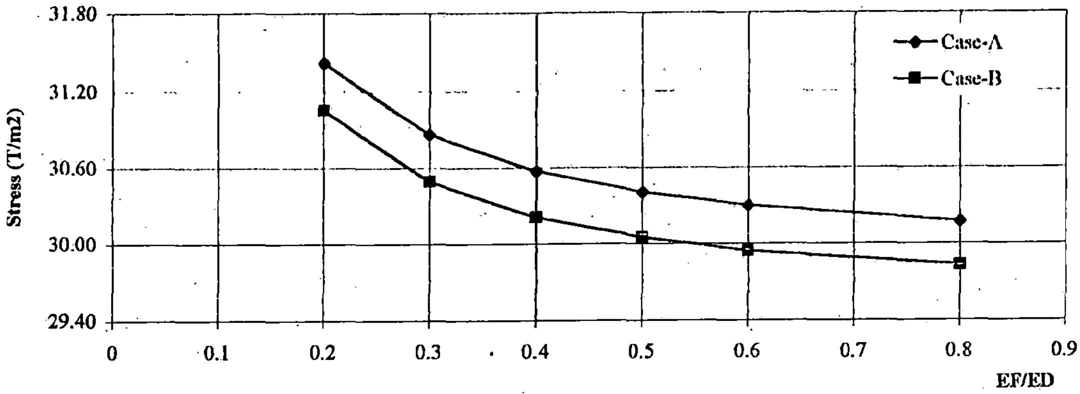
Case No.	EF/ED	Foundation Extent			Horizontal				Vertical			
					Heel		Toe		Heel		Toe	
		U/S	D/S	Bottom	Case-A	Case-B	Case-A	Case-B	Case-A	Case-B	Case-A	Case-B
1	0.2	1.0H	1.0H	1.0H	37.93	35.25	-48.79	-51.82	68.19	67.85	-72.05	-72.62
		1.0H	1.0H	2.0H	28.19	25.42	-43.31	-47.10	55.71	55.39	-67.07	-67.66
		1.0H	1.0H	3.0H	21.68	19.68	-37.13	-41.20	48.30	48.12	-62.30	-62.78
		1.5H	1.5H	1.0H	34.07	33.11	-46.43	-47.60	63.39	63.31	-67.70	-67.87
		1.5H	1.5H	2.0H	26.53	24.49	-43.48	-45.68	53.36	53.13	-64.85	-65.22
		1.5H	1.5H	3.0H	20.59	18.92	-38.39	-40.62	46.88	46.72	-61.11	-61.41
		2.0H	2.0H	1.0H	31.42	31.06	-44.25	-44.70	59.78	59.75	-64.23	-64.28
		2.0H	2.0H	2.0H	25.13	23.81	-42.72	-44.16	51.44	51.32	-62.69	-62.92
		2.0H	2.0H	3.0H	19.76	18.37	-38.47	-40.04	45.74	45.61	-59.77	-60.01
2	0.3	1.0H	1.0H	1.0H	37.48	34.75	-46.55	-49.60	74.54	74.06	-64.86	-65.47
		1.0H	1.0H	2.0H	27.69	24.89	-41.27	-45.01	61.05	60.56	-61.23	-61.86
		1.0H	1.0H	3.0H	21.29	19.26	-35.24	-39.21	52.86	52.54	-57.31	-57.83
		1.5H	1.5H	1.0H	33.54	32.57	-44.35	-45.52	69.27	69.14	-61.02	-61.21
		1.5H	1.5H	2.0H	26.02	24.01	-41.37	-43.52	58.45	58.13	-59.22	-59.61
		1.5H	1.5H	3.0H	20.23	18.60	-36.35	-38.51	51.30	51.08	-56.22	-56.54
		2.0H	2.0H	1.0H	30.87	30.50	-42.26	-42.71	65.33	65.28	-57.95	-58.02
		2.0H	2.0H	2.0H	24.63	23.33	-40.60	-41.98	56.34	56.15	-57.27	-57.51
		2.0H	2.0H	3.0H	19.43	18.09	-36.36	-37.85	50.08	49.89	-55.00	-55.24
3	0.4	1.0H	1.0H	1.0H	37.23	34.51	-44.67	-47.67	78.49	77.94	-59.96	-60.59
		1.0H	1.0H	2.0H	27.48	24.73	-39.59	-43.22	64.35	63.79	-57.25	-57.90
		1.0H	1.0H	3.0H	21.18	19.19	-33.74	-37.56	55.64	55.26	-53.94	-54.45
		1.5H	1.5H	1.0H	33.28	32.31	-42.59	-43.75	72.92	72.77	-56.50	-56.70
		1.5H	1.5H	2.0H	25.82	23.87	-39.64	-41.72	61.60	61.25	-55.41	-55.80
		1.5H	1.5H	3.0H	20.15	18.57	-34.72	-36.80	54.00	53.75	-52.91	-53.23
		2.0H	2.0H	1.0H	30.58	30.21	-40.58	-41.02	68.71	68.65	-53.72	-53.78
		2.0H	2.0H	2.0H	24.43	23.17	-38.85	-40.18	59.33	59.12	-53.59	-53.83
		2.0H	2.0H	3.0H	19.36	18.08	-34.67	-36.09	52.67	52.46	-51.75	-51.99
4	0.5	1.0H	1.0H	1.0H	37.11	34.42	-43.10	-46.03	81.19	80.59	-56.39	-57.01
		1.0H	1.0H	2.0H	27.40	24.71	-38.19	-41.72	66.58	66.00	-54.34	-54.97
		1.0H	1.0H	3.0H	21.17	19.24	-32.52	-36.20	57.50	57.09	-51.47	-51.97
		1.5H	1.5H	1.0H	33.12	32.17	-41.10	-42.23	75.36	75.18	-53.20	-53.39
		1.5H	1.5H	2.0H	25.75	23.85	-38.20	-40.21	63.71	63.34	-52.60	-52.99
		1.5H	1.5H	3.0H	20.17	18.65	-33.41	-35.41	55.80	55.53	-50.48	-50.79
		2.0H	2.0H	1.0H	30.41	30.05	-39.15	-39.58	70.94	70.88	-50.63	-50.70
		2.0H	2.0H	2.0H	24.36	23.14	-37.40	-38.69	61.32	61.10	-50.90	-51.14
		2.0H	2.0H	3.0H	19.39	18.15	-33.32	-34.68	54.40	54.17	-49.37	-49.59
5	0.6	1.0H	1.0H	1.0H	37.02	34.38	-41.75	-44.62	83.09	82.49	-53.63	-54.23
		1.0H	1.0H	2.0H	27.36	24.74	-37.02	-40.44	68.15	67.56	-52.08	-52.69
		1.0H	1.0H	3.0H	21.20	19.32	-31.52	-35.07	58.80	58.40	-49.56	-50.04
		1.5H	1.5H	1.0H	33.02	32.09	-39.82	-40.92	77.06	76.88	-50.65	-50.84
		1.5H	1.5H	2.0H	25.73	23.88	-36.99	-38.93	65.20	64.82	-50.44	-50.80
		1.5H	1.5H	3.0H	20.22	18.74	-32.33	-34.25	57.06	56.79	-48.61	-48.89
		2.0H	2.0H	1.0H	30.30	29.95	-37.93	-38.35	72.50	72.43	-48.26	-48.32
		2.0H	2.0H	2.0H	24.34	23.15	-36.20	-37.44	62.72	62.49	-48.82	-49.04
		2.0H	2.0H	3.0H	19.44	18.25	-32.20	-33.52	55.60	55.38	-47.54	-47.75
6	0.8	1.0H	1.0H	1.0H	36.91	34.37	-39.58	-42.32	85.58	84.99	-49.62	-50.18
		1.0H	1.0H	2.0H	27.38	24.87	-35.18	-38.41	70.26	69.67	-48.81	-49.37
		1.0H	1.0H	3.0H	21.29	19.52	-29.97	-33.32	60.53	60.14	-46.79	-47.22
		1.5H	1.5H	1.0H	32.91	32.01	-37.75	-38.81	79.28	79.09	-46.95	-47.13
		1.5H	1.5H	2.0H	25.78	24.00	-34.34	-36.93	67.83	66.79	-46.09	-47.62
		1.5H	1.5H	3.0H	20.35	18.95	-30.67	-32.48	58.73	58.46	-45.88	-46.14
		2.0H	2.0H	1.0H	30.17	29.83	-35.95	-36.36	74.48	74.42	-44.81	-44.87
		2.0H	2.0H	2.0H	24.37	23.24	-34.30	-35.47	64.54	64.31	-45.79	-45.99
		2.0H	2.0H	3.0H	19.58	18.45	-30.51	-31.73	57.19	56.98	-44.87	-45.06



a. 1H u/s. 1H d/s, 1H bottom

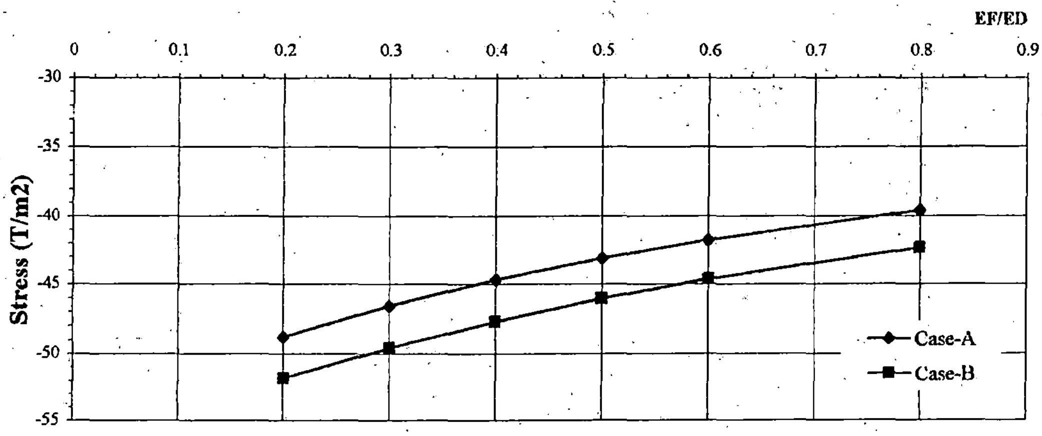


b. 1.5H u/s, 1.5H d/s, 1H bottom

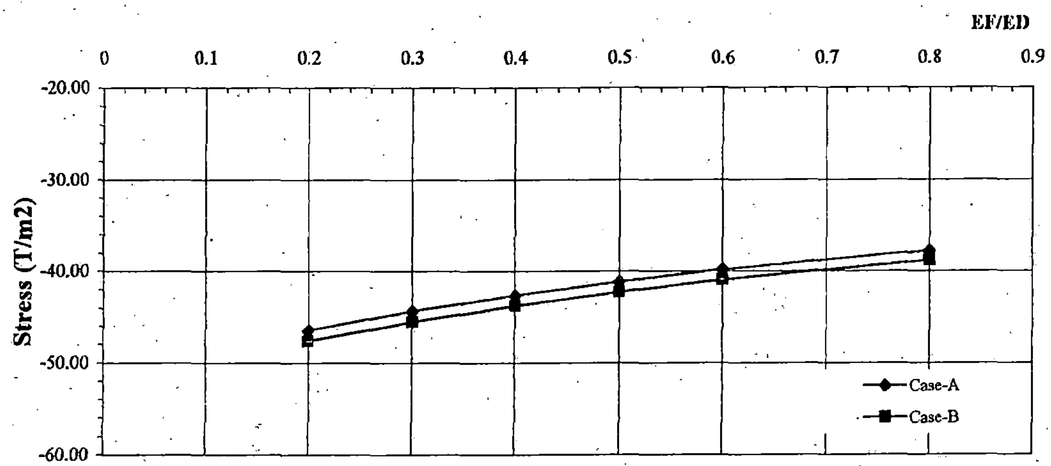


c. 2H u/s, 2H d/s 1H bottom

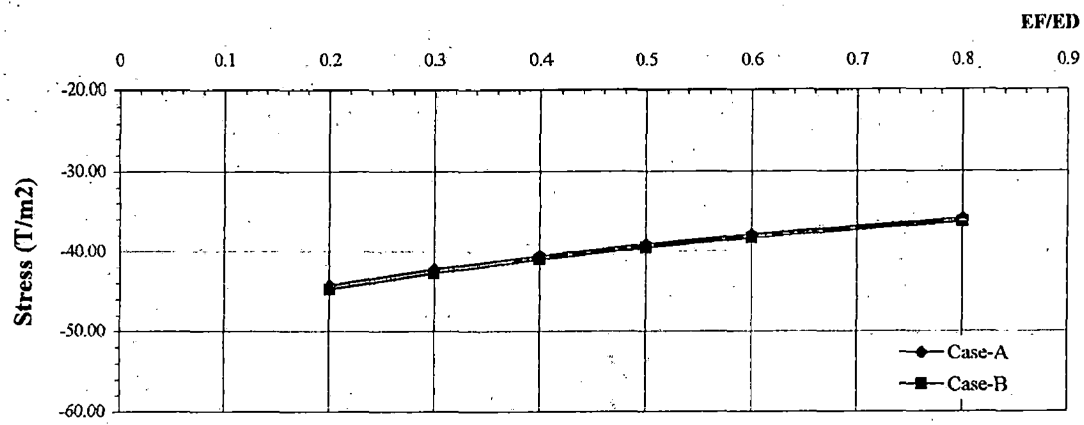
Figure 3.15 Comparison of Horizontal Stress between Part-1A and 1B Study at Heel



a. 1H u/s, 1H d/s, 1H bottom

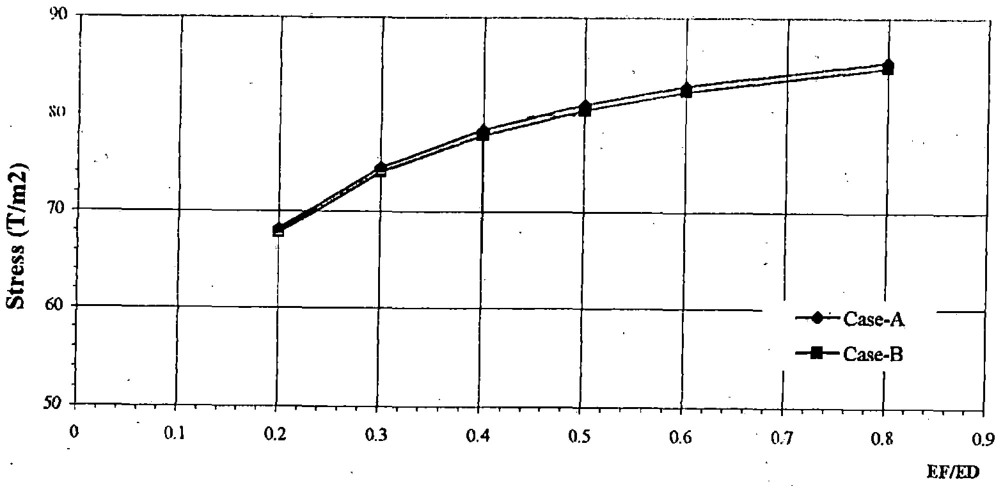


b. 1.5H u/s, 1.5H d/s, 1H bottom

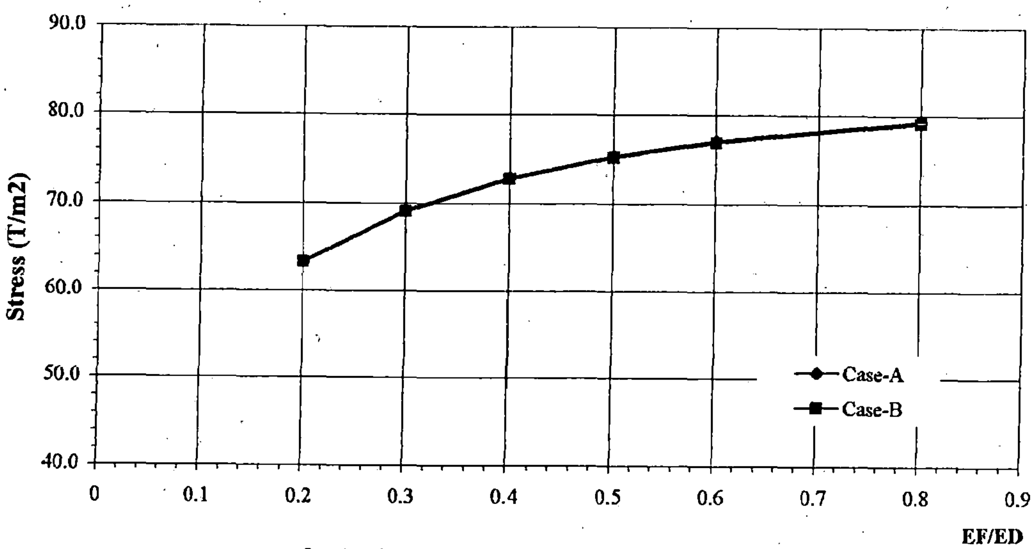


c. 2H u/s, 2H d/s, 1H bottom

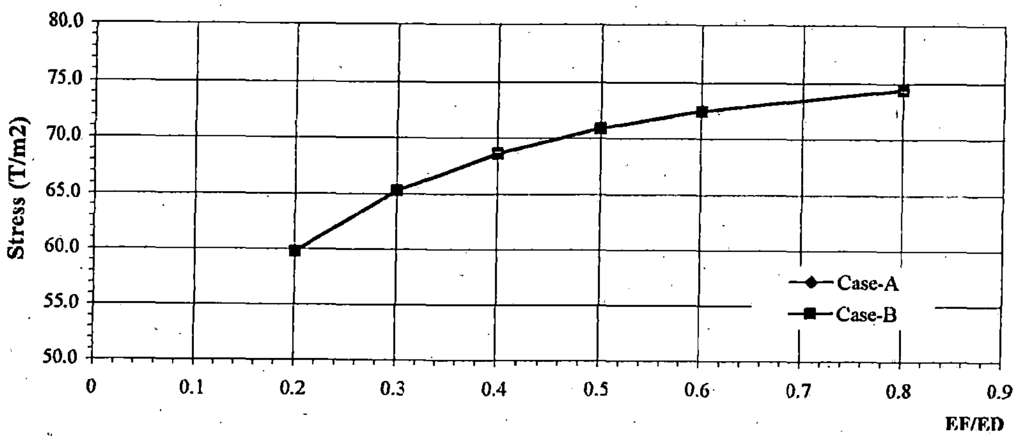
Figure 3.16 Comparison of Horizontal Stress between Part-1A and 1B Study at Toe



a. 1H u/s, 1H, D/S, 1H bottom

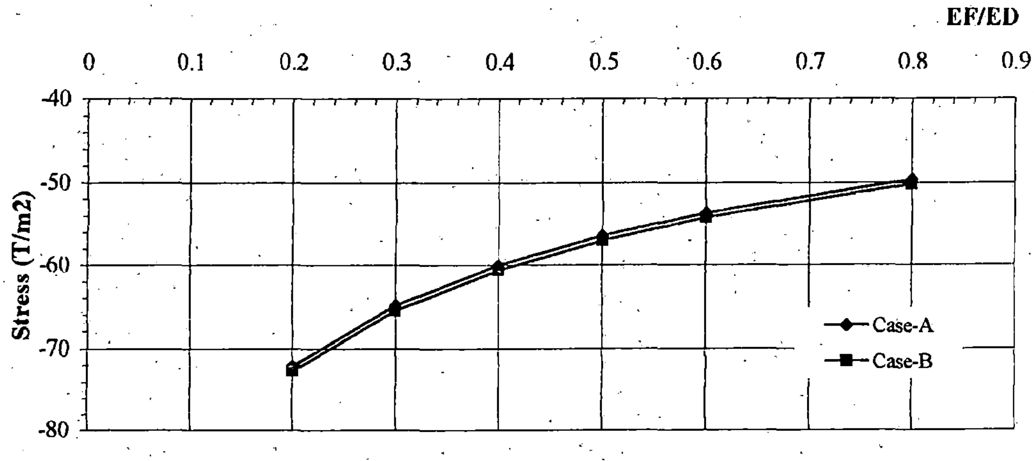


b. 1.5H u/s, 1.5H d/s, 1H bottom

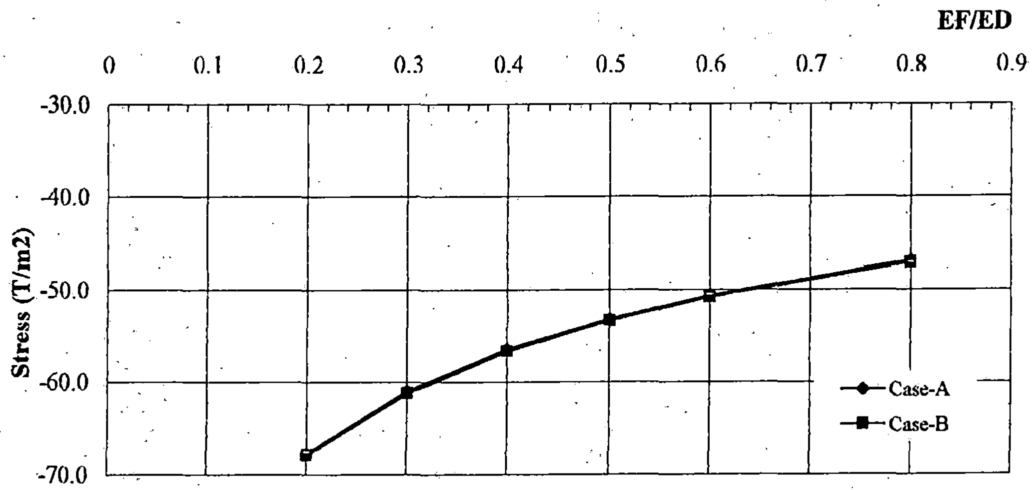


c. 2H u/s, 2H d/s, 1H bottom

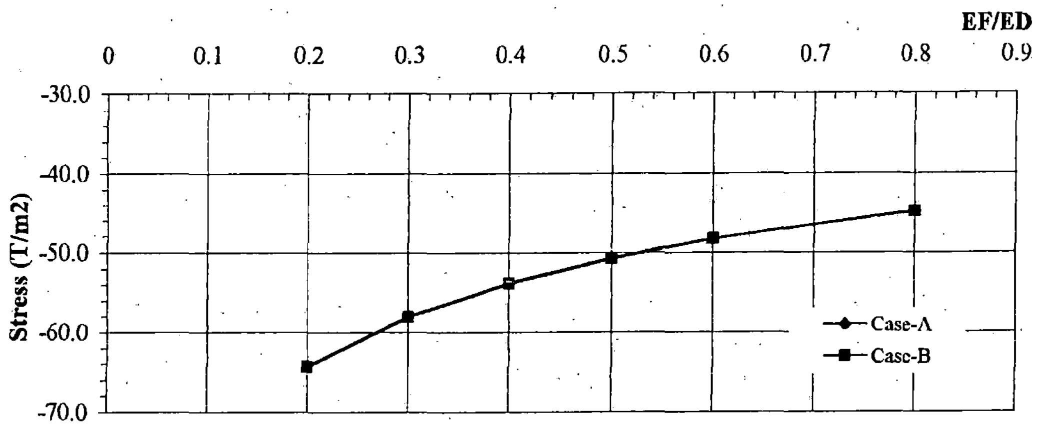
Figure 3.17 Comparison of Vertical Stress between Part-1A and 1B Study at Heel



a. 1H u/s, 1H d/s, 1H bottom



b. 1.5H u/s, 1.5H d/s, 1H bottom



c. 2H u/s, 2H d/s, 1H bottom

Figure 3.18 Comparison of Vertical Stress between Part-1A and 1B Study at Toe

Table 3.18 Shear and Principal Stresses at Heel and Toe with different Rigidity of Foundation in any Foundation Extent of Part -1A Study (Ton/m²)

Case No.	Foundation Extent		EF/ED	Shear		Major PS		Minor PS	
				Heel	Toe	Heel	Toe	Heel	Toe
1	U/S	1H	0.2	3.17	-40.45	81.93	-104.28	24.20	-16.56
	D/S	1H	0.3	3.69	-37.73	87.53	-95.53	24.49	-15.88
	Bottom	1H	0.4	4.06	-35.68	91.34	-89.50	24.38	-15.13
			0.5	4.32	-34.07	94.01	-85.04	24.28	-14.45
			0.6	4.55	-32.76	95.91	-81.52	24.20	-13.86
			0.8	4.90	-30.74	98.40	-76.31	24.09	-12.89
2	U/S	1H	0.2	3.72	-39.96	67.45	-98.33	16.45	-12.06
	D/S	1H	0.3	3.98	-37.17	72.51	-90.50	16.23	-12.00
	Bottom	2H	0.4	4.17	-35.16	75.79	-85.17	16.04	-11.67
			0.5	4.31	-33.63	78.03	-81.24	15.95	-11.30
			0.6	4.44	-32.41	79.62	-78.16	15.90	-10.93
			0.8	4.63	-30.58	81.74	-73.68	15.89	-10.31
3	U/S	1H	0.2	4.36	-38.73	58.44	-91.58	11.55	-7.85
	D/S	1H	0.3	4.57	-35.84	62.94	-84.36	11.20	-8.20
	Bottom	3H	0.4	4.72	-33.83	65.76	-79.51	11.07	-8.18
			0.5	4.86	-32.32	67.64	-75.95	11.03	-8.04
			0.6	4.98	-31.14	68.97	-73.20	11.03	-7.88
			0.8	5.17	-29.40	70.74	-69.21	11.08	-7.56
4	U/S	1.5H	0.2	5.11	-39.21	74.29	-99.01	23.16	-15.13
	D/S	1.5H	0.3	5.70	-36.56	79.69	-90.86	23.12	-14.50
	Bottom	1H	0.4	6.09	-34.56	83.26	-85.27	22.94	-13.82
			0.5	6.39	-32.99	85.67	-81.08	22.81	-13.21
			0.6	6.63	-31.70	87.36	-77.79	22.73	-12.68
			0.8	7.02	-29.72	89.55	-72.90	22.64	-11.81
5	U/S	1.5H	0.2	5.35	-39.16	63.36	-95.97	16.53	-12.36
	D/S	1.5H	0.3	5.66	-36.40	68.22	-88.38	16.25	-12.21
	Bottom	2H	0.4	5.87	-34.42	71.34	-83.21	16.09	-11.83
			0.5	6.04	-32.89	73.44	-79.38	16.02	-11.43
			0.6	6.18	-31.68	74.92	-76.39	16.00	-11.05
			0.8	6.49	-29.15	77.54	-70.30	16.07	-10.12
6	U/S	1.5H	0.2	5.75	-38.19	55.91	-90.62	11.56	-8.89
	D/S	1.5H	0.3	5.98	-35.31	60.26	-83.46	11.28	-9.11
	Bottom	3H	0.4	6.15	-33.29	62.96	-78.63	11.20	-9.00
			0.5	6.29	-31.78	64.76	-75.08	11.20	-8.81
			0.6	6.41	-30.59	66.04	-72.33	11.24	-8.60
			0.8	6.61	-28.84	67.72	-68.33	11.35	-8.22
7	U/S	2H	0.2	5.93	-38.45	68.94	-94.94	22.27	-13.53
	D/S	2H	0.3	6.53	-35.79	74.21	-87.21	21.98	-13.00
	Bottom	1H	0.4	6.94	-33.80	77.55	-81.89	21.74	-12.41
			0.5	7.25	-32.23	79.76	-77.91	21.59	-11.87
			0.6	7.51	-30.95	81.29	-74.77	21.50	-11.41
			0.8	7.91	-29.00	83.23	-70.11	21.42	-10.65
8	U/S	2H	0.2	6.15	-38.62	60.21	-93.59	16.37	-11.82
	D/S	2H	0.3	6.49	-35.86	64.94	-86.22	16.03	-11.65
	Bottom	2H	0.4	6.72	-33.87	67.90	-81.17	15.87	-11.27
			0.5	6.90	-32.35	69.87	-77.43	15.81	-10.88
			0.6	7.05	-31.13	71.25	-74.51	15.81	-10.51
			0.8	7.29	-29.31	73.04	-70.21	15.87	-9.89
9	U/S	2H	0.2	6.49	-37.77	53.92	-89.25	11.58	-9.00
	D/S	2H	0.3	6.73	-34.89	58.18	-82.20	11.33	-9.16
	Bottom	3H	0.4	6.92	-32.86	60.76	-77.40	11.27	-9.02
			0.5	7.07	-31.34	62.48	-73.88	11.30	-8.81
			0.6	7.21	-30.14	63.69	-71.15	11.36	-8.59
			0.8	7.42	-28.39	65.27	-67.18	11.49	-8.19

Table 3.19 Shear and Principal Stresses at Heel and Toe with different Foundation Extent in any Rigidity of Foundation of Part -1A Study (Ton/m²)

Case No.	EF/ED	Foundation Extent			Shear		Major PS		Minor PS	
		U/S	D/S	Bottom	Heel	Toe	Heel	Toe	Heel	Toe
1	0.2	1.0H	1.0H	1.0H	3.17	-40.45	81.93	-104.28	24.20	-16.56
		1.0H	1.0H	2.0H	3.72	-39.96	67.45	-98.33	16.45	-12.06
		1.0H	1.0H	3.0H	4.36	-38.73	58.44	-91.58	11.55	-7.85
		1.5H	1.5H	1.0H	5.11	-39.21	74.29	-99.01	23.16	-15.13
		1.5H	1.5H	2.0H	5.35	-39.16	63.36	-95.97	16.53	-12.36
		1.5H	1.5H	3.0H	5.75	-38.19	55.91	-90.62	11.56	-8.89
		2.0H	2.0H	1.0H	5.93	-38.45	68.94	-94.94	22.27	-13.53
		2.0H	2.0H	2.0H	6.15	-38.62	60.21	-93.59	16.37	-11.82
		2.0H	2.0H	3.0H	6.49	-37.77	53.92	-89.25	11.58	-9.00
2	0.3	1.0H	1.0H	1.0H	3.69	-37.73	87.53	-95.53	24.49	-15.88
		1.0H	1.0H	2.0H	3.98	-37.17	72.51	-90.50	16.23	-12.00
		1.0H	1.0H	3.0H	4.57	-35.84	62.94	-84.36	11.20	-8.20
		1.5H	1.5H	1.0H	5.70	-36.56	79.69	-90.86	23.12	-14.50
		1.5H	1.5H	2.0H	5.66	-36.40	68.22	-88.38	16.25	-12.21
		1.5H	1.5H	3.0H	5.98	-35.31	60.26	-83.46	11.28	-9.11
		2.0H	2.0H	1.0H	6.53	-35.79	74.21	-87.21	21.98	-13.00
		2.0H	2.0H	2.0H	6.49	-35.86	64.94	-86.22	16.03	-11.65
		2.0H	2.0H	3.0H	6.73	-34.89	58.18	-82.20	11.33	-9.16
3	0.4	1.0H	1.0H	1.0H	4.06	-35.68	91.34	-89.50	24.38	-15.13
		1.0H	1.0H	2.0H	4.17	-35.16	75.79	-85.17	16.04	-11.67
		1.0H	1.0H	3.0H	4.72	-33.83	65.76	-79.51	11.07	-8.18
		1.5H	1.5H	1.0H	6.09	-34.56	83.26	-85.27	22.94	-13.82
		1.5H	1.5H	2.0H	5.87	-34.42	71.34	-83.21	16.09	-11.83
		1.5H	1.5H	3.0H	6.15	-33.29	62.96	-78.63	11.20	-9.00
		2.0H	2.0H	1.0H	6.94	-33.80	77.55	-81.89	21.74	-12.41
		2.0H	2.0H	2.0H	6.72	-33.87	67.90	-81.17	15.87	-11.27
		2.0H	2.0H	3.0H	6.92	-32.86	60.76	-77.40	11.27	-9.02
4	0.5	1.0H	1.0H	1.0H	4.32	-34.07	94.01	-85.04	24.28	-14.45
		1.0H	1.0H	2.0H	4.31	-33.63	78.03	-81.24	15.95	-11.30
		1.0H	1.0H	3.0H	4.86	-32.32	67.64	-75.95	11.03	-8.04
		1.5H	1.5H	1.0H	6.39	-32.99	85.67	-81.08	22.81	-13.21
		1.5H	1.5H	2.0H	6.04	-32.89	73.44	-79.38	16.02	-11.43
		1.5H	1.5H	3.0H	6.29	-31.78	64.76	-75.08	11.20	-8.81
		2.0H	2.0H	1.0H	7.25	-32.23	79.76	-77.91	21.59	-11.87
		2.0H	2.0H	2.0H	6.90	-32.35	69.87	-77.43	15.81	-10.88
		2.0H	2.0H	3.0H	7.07	-31.34	62.48	-73.88	11.30	-8.81
5	0.6	1.0H	1.0H	1.0H	4.55	-32.76	95.91	-81.52	24.20	-13.86
		1.0H	1.0H	2.0H	4.44	-32.41	79.62	-78.16	15.90	-10.93
		1.0H	1.0H	3.0H	4.98	-31.14	68.97	-73.20	11.03	-7.88
		1.5H	1.5H	1.0H	6.63	-31.70	87.36	-77.79	22.73	-12.68
		1.5H	1.5H	2.0H	6.18	-31.68	74.92	-76.39	16.00	-11.05
		1.5H	1.5H	3.0H	6.41	-30.59	66.04	-72.33	11.24	-8.60
		2.0H	2.0H	1.0H	7.51	-30.95	81.29	-74.77	21.50	-11.41
		2.0H	2.0H	2.0H	7.05	-31.13	71.25	-74.51	15.81	-10.51
		2.0H	2.0H	3.0H	7.21	-30.14	63.69	-71.15	11.36	-8.59
6	0.8	1.0H	1.0H	1.0H	4.90	-30.74	98.40	-76.31	24.09	-12.89
		1.0H	1.0H	2.0H	4.63	-30.58	81.74	-73.68	15.89	-10.31
		1.0H	1.0H	3.0H	5.17	-29.40	70.74	-69.21	11.08	-7.56
		1.5H	1.5H	1.0H	7.02	-29.72	89.55	-72.90	22.64	-11.81
		1.5H	1.5H	2.0H	6.49	-29.15	77.54	-70.30	16.07	-10.12
		1.5H	1.5H	3.0H	6.61	-28.84	67.72	-68.33	11.35	-8.22
		2.0H	2.0H	1.0H	7.91	-29.00	83.23	-70.11	21.42	-10.65
		2.0H	2.0H	2.0H	7.29	-29.31	73.04	-70.21	15.87	-9.89
		2.0H	2.0H	3.0H	7.42	-28.39	65.27	-67.18	11.49	-8.19

Table 3.20 Shear and Principal Stresses at Heel and Toe with different Rigidity of Foundation in any Foundation Extent of Part -1B Study (Ton/m²)

Case No.	Foundation Extent		EF/ED	Shear		Major PS		Minor PS	
				Heel	Toe	Heel	Toe	Heel	Toe
1	U/S	1H	0.2	4.08	-41.33	81.27	-106.58	21.83	-17.86
	D/S	1H	0.3	4.56	-38.57	86.81	-97.92	22.00	-17.15
	Bottom	1H	0.4	4.87	-36.47	90.54	-91.90	21.92	-16.37
			0.5	5.08	-34.81	93.14	-87.38	21.87	-15.66
			0.6	5.25	-33.45	95.02	-83.82	21.84	-15.03
			0.8	5.51	-31.35	97.51	-78.49	21.85	-14.01
2	U/S	1H	0.2	4.70	-40.86	66.94	-100.92	13.87	-13.85
	D/S	1H	0.3	4.92	-38.03	71.81	-93.14	13.63	-13.73
	Bottom	2H	0.4	5.05	-35.98	75.00	-87.78	13.52	-13.34
			0.5	5.13	-34.39	77.19	-83.79	13.51	-12.91
			0.6	5.20	-33.12	78.75	-80.64	13.54	-12.49
			0.8	5.31	-31.21	80.87	-76.00	13.67	-11.78
3	U/S	1H	0.2	5.25	-39.42	58.18	-93.97	9.62	-10.01
	D/S	1H	0.3	5.42	-36.50	62.51	-86.75	9.29	-10.29
	Bottom	3H	0.4	5.53	-34.43	65.23	-81.83	9.22	-10.18
			0.5	5.62	-32.87	67.08	-78.19	9.25	-9.98
			0.6	5.70	-31.65	68.40	-75.36	9.33	-9.75
			0.8	5.82	-29.82	70.17	-71.21	9.49	-9.33
4	U/S	1.5H	0.2	5.44	-39.53	74.14	-99.84	22.28	-15.63
	D/S	1.5H	0.3	6.01	-36.85	79.50	-91.74	22.21	-14.99
	Bottom	1H	0.4	6.38	-34.84	83.03	-86.15	22.05	-14.30
			0.5	6.66	-33.24	85.41	-81.95	21.94	-13.68
			0.6	6.89	-31.94	87.09	-78.63	21.87	-13.13
			0.8	7.24	-29.93	89.28	-73.70	21.83	-12.24
5	U/S	1.5H	0.2	5.98	-39.73	63.01	-97.55	14.61	-13.35
	D/S	1.5H	0.3	6.25	-36.94	67.77	-89.97	14.37	-13.16
	Bottom	2H	0.4	6.42	-34.92	70.83	-84.77	14.29	-12.74
			0.5	6.54	-33.37	72.90	-80.90	14.29	-12.30
			0.6	6.64	-32.12	74.36	-77.85	14.33	-11.89
			0.8	6.80	-30.24	76.31	-73.35	14.47	-11.19
6	U/S	1.5H	0.2	6.32	-38.65	55.68	-92.04	9.96	-9.99
	D/S	1.5H	0.3	6.51	-35.76	59.94	-84.89	9.75	-10.17
	Bottom	3H	0.4	6.64	-33.71	62.58	-80.02	9.74	-10.01
			0.5	6.75	-32.16	64.36	-76.42	9.81	-9.78
			0.6	6.84	-30.95	65.62	-73.61	9.90	-9.54
			0.8	6.99	-29.15	67.31	-69.52	10.11	-9.10
7	U/S	2H	0.2	6.06	-38.57	68.89	-95.26	21.92	-13.73
	D/S	2H	0.3	6.65	-35.90	74.15	-87.55	21.63	-13.18
	Bottom	1H	0.4	7.06	-33.90	77.47	-82.22	21.39	-12.59
			0.5	7.36	-32.33	79.67	-78.23	21.25	-12.05
			0.6	7.61	-31.05	81.20	-75.10	21.18	-11.58
			0.8	8.00	-29.08	83.14	-70.42	21.11	-10.82
8	U/S	2H	0.2	6.55	-38.98	60.02	-94.61	15.10	-12.46
	D/S	2H	0.3	6.86	-36.19	64.67	-87.23	14.81	-12.26
	Bottom	2H	0.4	7.06	-34.18	67.59	-82.16	14.70	-11.85
			0.5	7.21	-32.64	69.55	-78.39	14.69	-11.44
			0.6	7.34	-31.40	70.92	-75.43	14.73	-11.05
			0.8	7.54	-29.54	72.70	-71.06	14.85	-10.40
9	U/S	2H	0.2	6.91	-38.13	53.73	-90.31	10.25	-9.74
	D/S	2H	0.3	7.12	-35.23	57.91	-83.24	10.07	-9.86
	Bottom	3H	0.4	7.28	-33.17	60.46	-78.40	10.08	-9.68
			0.5	7.40	-31.63	62.15	-74.83	10.16	-9.44
			0.6	7.51	-30.42	63.36	-72.07	10.27	-9.20
			0.8	7.68	-28.62	64.95	-68.03	10.48	-8.76

Table 3.21 Shear and Principal Stresses (Ton/m2) at Heel and Toe with different Foundation Extent in any Rigidity of Foundation of Part -1B Study

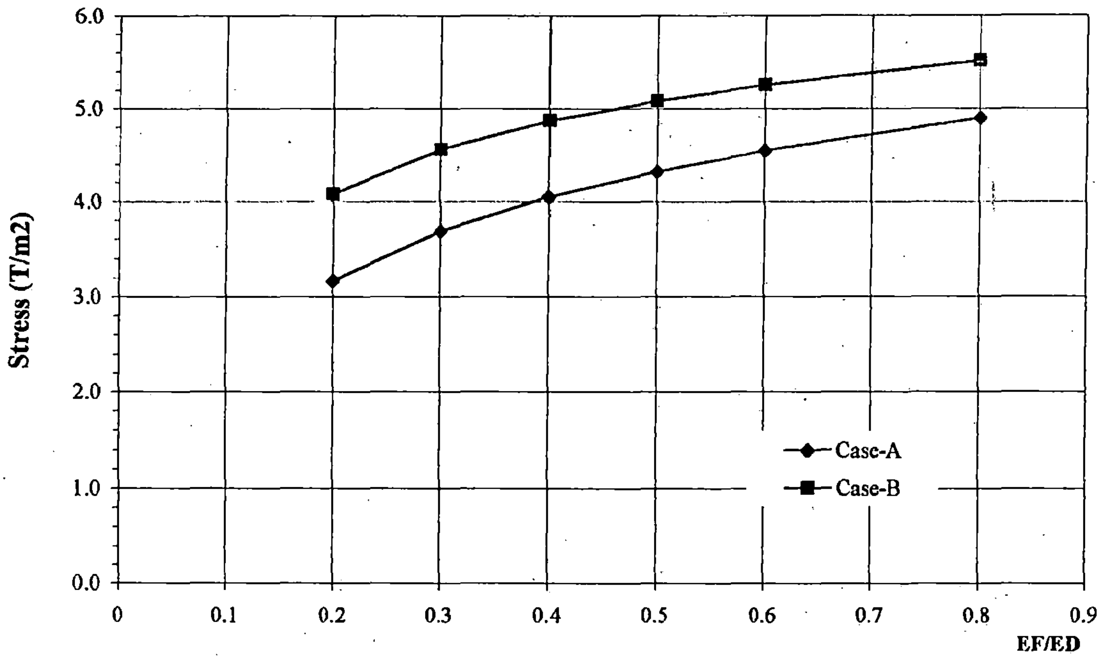
Case No.	EF/ED	Foundation Extent			Shear		Major PS		Minor PS	
		U/S	D/S	Bottom	Heel	Toe	Heel	Toe	Heel	Toe
1	0.2	1.0H	1.0H	1.0H	4.08	-41.33	81.27	-106.58	21.83	-17.86
		1.0H	1.0H	2.0H	4.70	-40.86	66.94	-100.92	13.87	-13.85
		1.0H	1.0H	3.0H	5.25	-39.42	58.18	-93.97	9.62	-10.01
		1.5H	1.5H	1.0H	5.44	-39.53	74.14	-99.84	22.28	-15.63
		1.5H	1.5H	2.0H	5.98	-39.73	63.01	-97.55	14.61	-13.35
		1.5H	1.5H	3.0H	6.32	-38.65	55.68	-92.04	9.96	-9.99
		2.0H	2.0H	1.0H	6.06	-38.57	68.89	-95.26	21.92	-13.73
		2.0H	2.0H	2.0H	6.55	-38.98	60.02	-94.61	15.10	-12.46
		2.0H	2.0H	3.0H	6.91	-38.13	53.73	-90.31	10.25	-9.74
2	0.3	1.0H	1.0H	1.0H	4.56	-38.57	86.81	-97.92	22.00	-17.15
		1.0H	1.0H	2.0H	4.92	-38.03	71.81	-93.14	13.63	-13.73
		1.0H	1.0H	3.0H	5.42	-36.50	62.51	-86.75	9.29	-10.29
		1.5H	1.5H	1.0H	6.01	-36.85	79.50	-91.74	22.21	-14.99
		1.5H	1.5H	2.0H	6.25	-36.94	67.77	-89.97	14.37	-13.16
		1.5H	1.5H	3.0H	6.51	-35.76	59.94	-84.89	9.75	-10.17
		2.0H	2.0H	1.0H	6.65	-35.90	74.15	-87.55	21.63	-13.18
		2.0H	2.0H	2.0H	6.86	-36.19	64.67	-87.23	14.81	-12.26
		2.0H	2.0H	3.0H	7.12	-35.23	57.91	-83.24	10.07	-9.86
3	0.4	1.0H	1.0H	1.0H	4.87	-36.47	90.54	-91.90	21.92	-16.37
		1.0H	1.0H	2.0H	5.05	-35.98	75.00	-87.78	13.52	-13.34
		1.0H	1.0H	3.0H	5.53	-34.43	65.23	-81.83	9.22	-10.18
		1.5H	1.5H	1.0H	6.38	-34.84	83.03	-86.15	22.05	-14.30
		1.5H	1.5H	2.0H	6.42	-34.92	70.83	-84.77	14.29	-12.74
		1.5H	1.5H	3.0H	6.64	-33.71	62.58	-80.02	9.74	-10.01
		2.0H	2.0H	1.0H	7.06	-33.90	77.47	-82.22	21.39	-12.59
		2.0H	2.0H	2.0H	7.06	-34.18	67.59	-82.16	14.70	-11.85
		2.0H	2.0H	3.0H	7.28	-33.17	60.46	-78.40	10.08	-9.68
4	0.5	1.0H	1.0H	1.0H	5.08	-34.81	93.14	-87.38	21.87	-15.66
		1.0H	1.0H	2.0H	5.13	-34.39	77.19	-83.79	13.51	-12.91
		1.0H	1.0H	3.0H	5.62	-32.87	67.08	-78.19	9.25	-9.98
		1.5H	1.5H	1.0H	6.66	-33.24	85.41	-81.95	21.94	-13.68
		1.5H	1.5H	2.0H	6.54	-33.37	72.90	-80.90	14.29	-12.30
		1.5H	1.5H	3.0H	6.75	-32.16	64.36	-76.42	9.81	-9.78
		2.0H	2.0H	1.0H	7.36	-32.33	79.67	-78.23	21.25	-12.05
		2.0H	2.0H	2.0H	7.21	-32.64	69.55	-78.39	14.69	-11.44
		2.0H	2.0H	3.0H	7.40	-31.63	62.15	-74.83	10.16	-9.44
5	0.6	1.0H	1.0H	1.0H	5.25	-33.45	95.02	-83.82	21.84	-15.03
		1.0H	1.0H	2.0H	5.20	-33.12	78.75	-80.64	13.54	-12.49
		1.0H	1.0H	3.0H	5.70	-31.65	68.40	-75.36	9.33	-9.75
		1.5H	1.5H	1.0H	6.89	-31.94	87.09	-78.63	21.87	-13.13
		1.5H	1.5H	2.0H	6.64	-32.12	74.36	-77.85	14.33	-11.89
		1.5H	1.5H	3.0H	6.84	-30.95	65.62	-73.61	9.90	-9.54
		2.0H	2.0H	1.0H	7.61	-31.05	81.20	-75.10	21.18	-11.58
		2.0H	2.0H	2.0H	7.34	-31.40	70.92	-75.43	14.73	-11.05
		2.0H	2.0H	3.0H	7.51	-30.42	63.36	-72.07	10.27	-9.20
6	0.8	1.0H	1.0H	1.0H	5.51	-31.35	97.51	-78.49	21.85	-14.01
		1.0H	1.0H	2.0H	5.31	-31.21	80.87	-76.00	13.67	-11.78
		1.0H	1.0H	3.0H	5.82	-29.82	70.17	-71.21	9.49	-9.33
		1.5H	1.5H	1.0H	7.24	-29.93	89.28	-73.70	21.83	-12.24
		1.5H	1.5H	2.0H	6.80	-30.24	76.31	-73.35	14.47	-11.19
		1.5H	1.5H	3.0H	6.99	-29.15	67.31	-69.52	10.11	-9.10
		2.0H	2.0H	1.0H	8.00	-29.08	83.14	-70.42	21.11	-10.82
		2.0H	2.0H	2.0H	7.54	-29.54	72.70	-71.06	14.85	-10.40
		2.0H	2.0H	3.0H	7.68	-28.62	64.95	-68.03	10.48	-8.76

Table 3.22 Comparison between Part -1A and Part -1B Study of Shear Stresses (Ton/m2) with different Rigidity of Foundation in any Foundation Extent

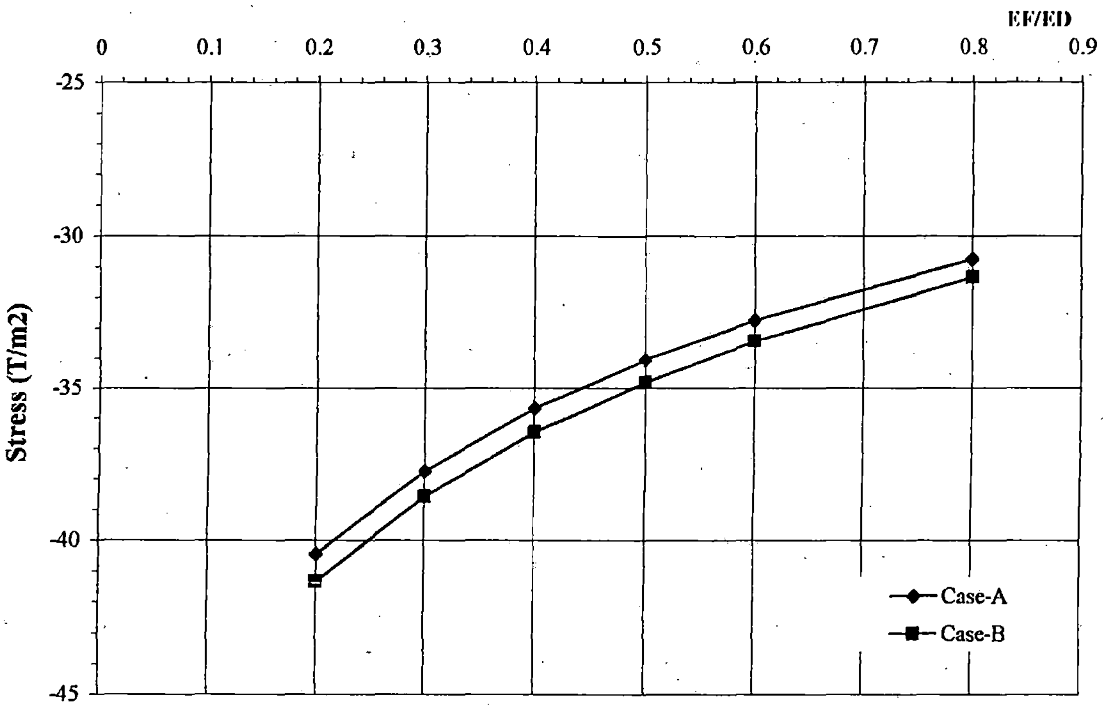
Case No.	Foundation Extent		EF/ED	Shear			
				Heel		Toe	
				Case-A	Case-B	Case-A	Case-B
1	U/S	1H	0.2	3.17	4.08	-40.45	-41.33
	D/S	1H	0.3	3.69	4.56	-37.73	-38.57
	Bottom	1H	0.4	4.06	4.87	-35.68	-36.47
			0.5	4.32	5.08	-34.07	-34.81
			0.6	4.55	5.25	-32.76	-33.45
			0.8	4.90	5.51	-30.74	-31.35
2	U/S	1H	0.2	3.72	4.70	-39.96	-40.86
	D/S	1H	0.3	3.98	4.92	-37.17	-38.03
	Bottom	2H	0.4	4.17	5.05	-35.16	-35.98
			0.5	4.31	5.13	-33.63	-34.39
			0.6	4.44	5.20	-32.41	-33.12
			0.8	4.63	5.31	-30.58	-31.21
3	U/S	1H	0.2	4.36	5.25	-38.73	-39.42
	D/S	1H	0.3	4.57	5.42	-35.84	-36.50
	Bottom	3H	0.4	4.72	5.53	-33.83	-34.43
			0.5	4.86	5.62	-32.32	-32.87
			0.6	4.98	5.70	-31.14	-31.65
			0.8	5.17	5.82	-29.40	-29.82
4	U/S	1.5H	0.2	5.11	5.44	-39.21	-39.53
	D/S	1.5H	0.3	5.70	6.01	-36.56	-36.85
	Bottom	1H	0.4	6.09	6.38	-34.56	-34.84
			0.5	6.39	6.66	-32.99	-33.24
			0.6	6.63	6.89	-31.70	-31.94
			0.8	7.02	7.24	-29.72	-29.93
5	U/S	1.5H	0.2	5.35	5.98	-39.16	-39.73
	D/S	1.5H	0.3	5.66	6.25	-36.40	-36.94
	Bottom	2H	0.4	5.87	6.42	-34.42	-34.92
			0.5	6.04	6.54	-32.89	-33.37
			0.6	6.18	6.64	-31.68	-32.12
			0.8	6.49	6.80	-29.15	-30.24
6	U/S	1.5H	0.2	5.75	6.32	-38.19	-38.65
	D/S	1.5H	0.3	5.98	6.51	-35.31	-35.76
	Bottom	3H	0.4	6.15	6.64	-33.29	-33.71
			0.5	6.29	6.75	-31.78	-32.16
			0.6	6.41	6.84	-30.59	-30.95
			0.8	6.61	6.99	-28.84	-29.15
7	U/S	2H	0.2	5.93	6.06	-38.45	-38.57
	D/S	2H	0.3	6.53	6.65	-35.79	-35.90
	Bottom	1H	0.4	6.94	7.06	-33.80	-33.90
			0.5	7.25	7.61	-32.23	-31.05
			0.6	7.51	7.61	-30.95	-31.05
			0.8	7.91	8.00	-29.00	-29.08
8	U/S	2H	0.2	6.15	6.55	-38.62	-38.98
	D/S	2H	0.3	6.49	6.86	-35.86	-36.19
	Bottom	2H	0.4	6.72	7.06	-33.87	-34.18
			0.5	6.90	7.21	-32.35	-32.64
			0.6	7.05	7.34	-31.13	-31.40
			0.8	7.29	7.54	-29.31	-29.54
9	U/S	2H	0.2	6.49	6.91	-37.77	-38.13
	D/S	2H	0.3	6.73	7.12	-34.89	-35.23
	Bottom	3H	0.4	6.92	7.28	-32.86	-33.17
			0.5	7.07	7.40	-31.34	-31.63
			0.6	7.21	7.51	-30.14	-30.42
			0.8	7.42	7.68	-28.39	-28.62

Table 3.23 Comparison between Part -1A and Part -1B Study of Shear Stresses (Ton/m2) with different Foundation Extent in any Rigidity of Foundation

Case No.	EF/ED	Foundation Extent			Shear			
					Heel		Toe	
		U/S	D/S	Bottom	Case-A	Case-B	Case-A	Case-A
1	0.2	1.0H	1.0H	1.0H	3.17	4.08	-40.45	-41.33
		1.0H	1.0H	2.0H	3.72	4.70	-39.96	-40.86
		1.0H	1.0H	3.0H	4.36	5.25	-38.73	-39.42
		1.5H	1.5H	1.0H	5.11	5.44	-39.21	-39.53
		1.5H	1.5H	2.0H	5.35	5.98	-39.16	-39.73
		1.5H	1.5H	3.0H	5.75	6.32	-38.19	-38.65
		2.0H	2.0H	1.0H	5.93	6.06	-38.45	-38.57
		2.0H	2.0H	2.0H	6.15	6.55	-38.62	-38.98
		2.0H	2.0H	3.0H	6.49	6.91	-37.77	-38.13
2	0.3	1.0H	1.0H	1.0H	3.69	4.56	-37.73	-38.57
		1.0H	1.0H	2.0H	3.98	4.92	-37.17	-38.03
		1.0H	1.0H	3.0H	4.57	5.42	-35.84	-36.50
		1.5H	1.5H	1.0H	5.70	6.01	-36.56	-36.85
		1.5H	1.5H	2.0H	5.66	6.25	-36.40	-36.94
		1.5H	1.5H	3.0H	5.98	6.51	-35.31	-35.76
		2.0H	2.0H	1.0H	6.53	6.65	-35.79	-35.90
		2.0H	2.0H	2.0H	6.49	6.86	-35.86	-36.19
		2.0H	2.0H	3.0H	6.73	7.12	-34.89	-35.23
3	0.4	1.0H	1.0H	1.0H	4.06	4.87	-35.68	-36.47
		1.0H	1.0H	2.0H	4.17	5.05	-35.16	-35.98
		1.0H	1.0H	3.0H	4.72	5.53	-33.83	-34.43
		1.5H	1.5H	1.0H	6.09	6.38	-34.56	-34.84
		1.5H	1.5H	2.0H	5.87	6.42	-34.42	-34.92
		1.5H	1.5H	3.0H	6.15	6.64	-33.29	-33.71
		2.0H	2.0H	1.0H	6.94	7.06	-33.80	-33.90
		2.0H	2.0H	2.0H	6.72	7.06	-33.87	-34.18
		2.0H	2.0H	3.0H	6.92	7.28	-32.86	-33.17
4	0.5	1.0H	1.0H	1.0H	4.32	5.08	-34.07	-34.81
		1.0H	1.0H	2.0H	4.31	5.13	-33.63	-34.39
		1.0H	1.0H	3.0H	4.86	5.62	-32.32	-32.87
		1.5H	1.5H	1.0H	6.39	6.66	-32.99	-33.24
		1.5H	1.5H	2.0H	6.04	6.54	-32.89	-33.37
		1.5H	1.5H	3.0H	6.29	6.75	-31.78	-32.16
		2.0H	2.0H	1.0H	7.25	7.61	-32.23	-31.05
		2.0H	2.0H	2.0H	6.90	7.21	-32.35	-32.64
		2.0H	2.0H	3.0H	7.07	7.40	-31.34	-31.63
5	0.6	1.0H	1.0H	1.0H	4.55	5.25	-32.76	-33.45
		1.0H	1.0H	2.0H	4.44	5.20	-32.41	-33.12
		1.0H	1.0H	3.0H	4.98	5.70	-31.14	-31.65
		1.5H	1.5H	1.0H	6.63	6.89	-31.70	-31.94
		1.5H	1.5H	2.0H	6.18	6.64	-31.68	-32.12
		1.5H	1.5H	3.0H	6.41	6.84	-30.59	-30.95
		2.0H	2.0H	1.0H	7.51	7.61	-30.95	-31.05
		2.0H	2.0H	2.0H	7.05	7.34	-31.13	-31.40
		2.0H	2.0H	3.0H	7.21	7.51	-30.14	-30.42
6	0.8	1.0H	1.0H	1.0H	4.90	5.51	-30.74	-31.35
		1.0H	1.0H	2.0H	4.63	5.31	-30.58	-31.21
		1.0H	1.0H	3.0H	5.17	5.82	-29.40	-29.82
		1.5H	1.5H	1.0H	7.02	7.24	-29.72	-29.93
		1.5H	1.5H	2.0H	6.49	6.80	-29.15	-30.24
		1.5H	1.5H	3.0H	6.61	6.99	-28.84	-29.15
		2.0H	2.0H	1.0H	7.91	8.00	-29.00	-29.08
		2.0H	2.0H	2.0H	7.29	7.54	-29.31	-29.54
		2.0H	2.0H	3.0H	7.42	7.68	-28.39	-28.62



a. Heel



b. Toe

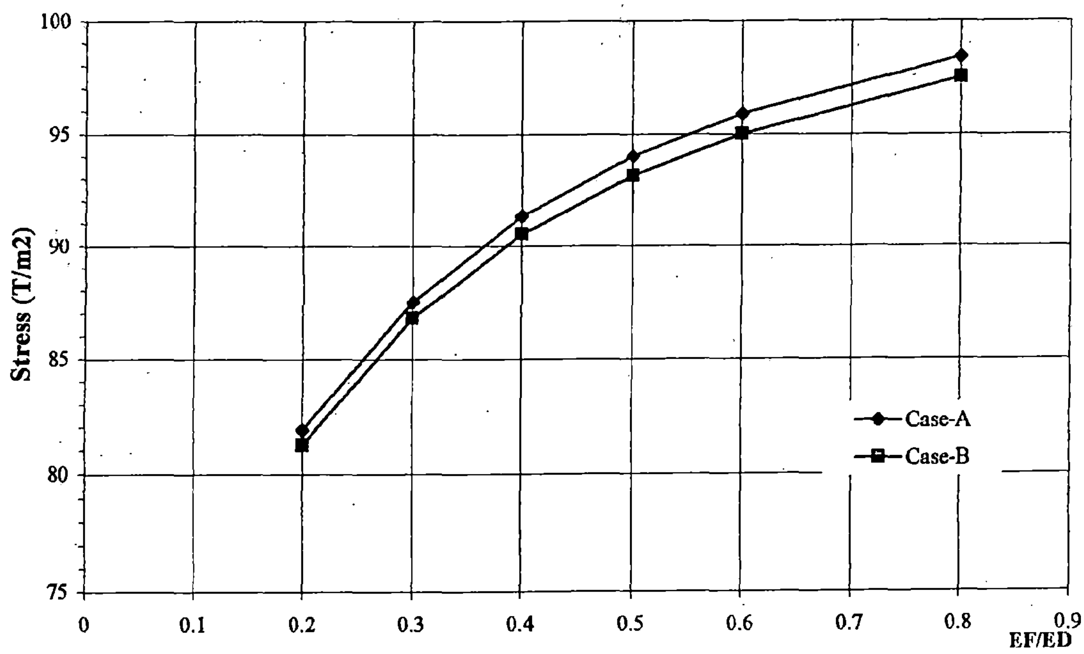
Figure 3.19 Comparison of Shear Stress between Part-1A and 1B Study with Foundation Extent of 1H u/s, 1H d/s, 1H bottom

Table 3.24 Comparison between Part -1A and Part -1B Study of Principal Stresses (Ton/m2) with different Rigidity of Foundation in any Foundation Extent

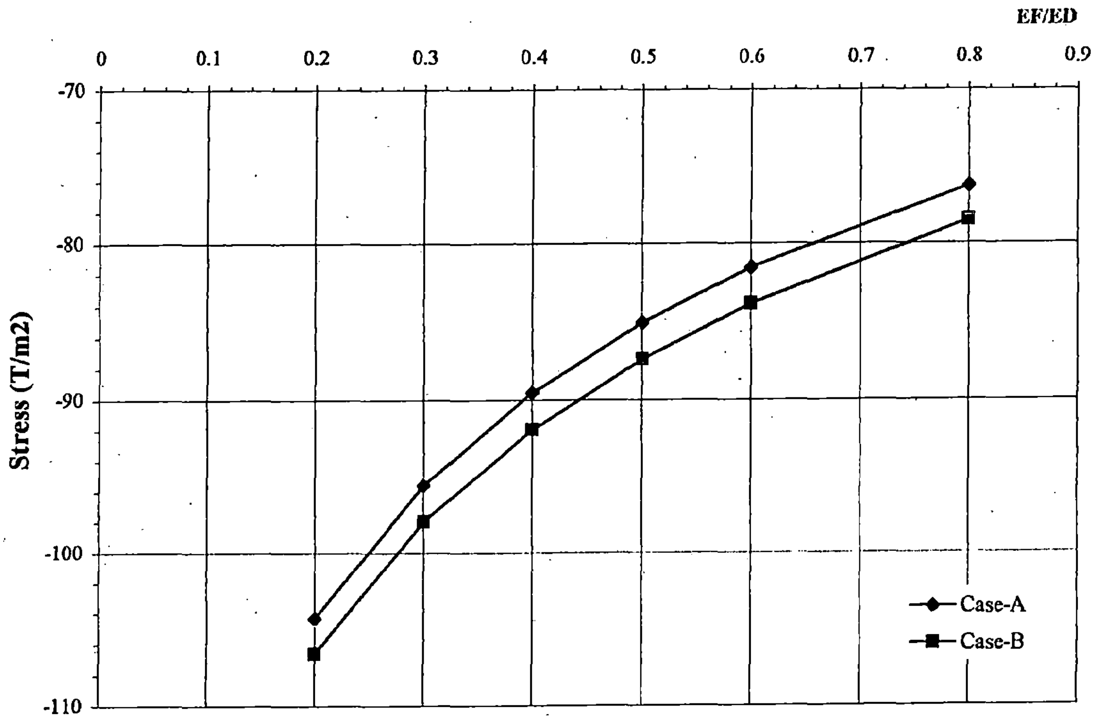
Case No.	Foundation Extent	EF/ED	Major Principal				Minor Principal			
			Heel		Toe		Heel		Toe	
			Case-A	Case-B	Case-A	Case-B	Case-A	Case-B	Case-A	Case-B
1	U/S 1H	0.2	81.93	81.27	-104.28	-106.58	24.20	21.83	-16.56	-17.86
	D/S 1H	0.3	87.53	86.81	-95.53	-97.92	24.49	22.00	-15.88	-17.15
	Bottom 1H	0.4	91.34	90.54	-89.50	-91.90	24.38	21.92	-15.13	-16.37
		0.5	94.01	93.14	-85.04	-87.38	24.28	21.87	-14.45	-15.66
		0.6	95.91	95.02	-81.52	-83.82	24.20	21.84	-13.86	-15.03
		0.8	98.40	97.51	-76.31	-78.49	24.09	21.85	-12.89	-14.01
2	U/S 1H	0.2	67.45	66.94	-98.33	-100.92	16.45	13.87	-12.06	-13.85
	D/S 1H	0.3	72.51	71.81	-90.50	-93.14	16.23	13.63	-12.00	-13.73
	Bottom 2H	0.4	75.79	75.00	-85.17	-87.78	16.04	13.52	-11.67	-13.34
		0.5	78.03	77.19	-81.24	-83.79	15.95	13.51	-11.30	-12.91
		0.6	79.62	78.75	-78.16	-80.64	15.90	13.54	-10.93	-12.49
		0.8	81.74	80.87	-73.68	-76.00	15.89	13.67	-10.31	-11.78
3	U/S 1H	0.2	58.44	58.18	-91.58	-93.97	11.55	9.62	-7.85	-10.01
	D/S 1H	0.3	62.94	62.51	-84.36	-86.75	11.20	9.29	-8.20	-10.29
	Bottom 3H	0.4	65.76	65.23	-79.51	-81.83	11.07	9.22	-8.18	-10.18
		0.5	67.64	67.08	-75.95	-78.19	11.03	9.25	-8.04	-9.98
		0.6	68.97	68.40	-73.20	-75.36	11.03	9.33	-7.88	-9.75
		0.8	70.74	70.17	-69.21	-71.21	11.08	9.49	-7.56	-9.33
4	U/S 1.5H	0.2	74.29	74.14	-99.01	-99.84	23.16	22.28	-15.13	-15.63
	D/S 1.5H	0.3	79.69	79.50	-90.86	-91.74	23.12	22.21	-14.50	-14.99
	Bottom 1H	0.4	83.26	83.03	-85.27	-86.15	22.94	22.05	-13.82	-14.30
		0.5	85.67	85.41	-81.08	-81.95	22.81	21.94	-13.21	-13.68
		0.6	87.36	87.09	-77.79	-78.63	22.73	21.87	-12.68	-13.13
		0.8	89.55	89.28	-72.90	-73.70	22.64	21.83	-11.81	-12.24
5	U/S 1.5H	0.2	63.36	63.01	-95.97	-97.55	16.53	14.61	-12.36	-13.35
	D/S 1.5H	0.3	68.22	67.77	-88.38	-89.97	16.25	14.37	-12.21	-13.16
	Bottom 2H	0.4	71.34	70.83	-83.21	-84.77	16.09	14.29	-11.83	-12.74
		0.5	73.44	72.90	-79.38	-80.90	16.02	14.29	-11.43	-12.30
		0.6	74.92	74.36	-76.39	-77.85	16.00	14.33	-11.05	-11.89
		0.8	77.54	76.31	-70.30	-73.35	16.07	14.47	-10.12	-11.19
6	U/S 1.5H	0.2	55.91	55.68	-90.62	-92.04	11.56	9.96	-8.89	-9.99
	D/S 1.5H	0.3	60.26	59.94	-83.46	-84.89	11.28	9.75	-9.11	-10.17
	Bottom 3H	0.4	62.96	62.58	-78.63	-80.02	11.20	9.74	-9.00	-10.01
		0.5	64.76	64.36	-75.08	-76.42	11.20	9.81	-8.81	-9.78
		0.6	66.04	65.62	-72.33	-73.61	11.24	9.90	-8.60	-9.54
		0.8	67.72	67.31	-68.33	-69.52	11.35	10.11	-8.22	-9.10
7	U/S 2H	0.2	68.94	68.89	-94.94	-95.26	22.27	21.92	-13.53	-13.73
	D/S 2H	0.3	74.21	74.15	-87.21	-87.55	21.98	21.63	-13.00	-13.18
	Bottom 1H	0.4	77.55	77.47	-81.89	-82.22	21.74	21.39	-12.41	-12.59
		0.5	79.76	81.20	-77.91	-75.10	21.59	21.18	-11.87	-11.58
		0.6	81.29	81.20	-74.77	-75.10	21.50	21.18	-11.41	-11.58
		0.8	83.23	83.14	-70.11	-70.42	21.42	21.11	-10.65	-10.82
8	U/S 2H	0.2	60.21	60.02	-93.59	-94.61	16.37	15.10	-11.82	-12.46
	D/S 2H	0.3	64.94	64.67	-86.22	-87.23	16.03	14.81	-11.65	-12.26
	Bottom 2H	0.4	67.90	67.59	-81.17	-82.16	15.87	14.70	-11.27	-11.85
		0.5	69.87	69.55	-77.43	-78.39	15.81	14.69	-10.88	-11.44
		0.6	71.25	70.92	-74.51	-75.43	15.81	14.73	-10.51	-11.05
		0.8	73.04	72.70	-70.21	-71.06	15.87	14.85	-9.89	-10.40
9	U/S 2H	0.2	53.92	53.73	-89.25	-90.31	11.58	10.25	-9.00	-9.74
	D/S 2H	0.3	58.18	57.91	-82.20	-83.24	11.33	10.07	-9.16	-9.86
	Bottom 3H	0.4	60.76	60.46	-77.40	-78.40	11.27	10.08	-9.02	-9.68
		0.5	62.48	62.15	-73.88	-74.83	11.30	10.16	-8.81	-9.44
		0.6	63.69	63.36	-71.15	-72.07	11.36	10.27	-8.59	-9.20
		0.8	65.27	64.95	-67.18	-68.03	11.49	10.48	-8.19	-8.76

Table 3.25 Comparison between Part -1A and Part -1B Study of Principal Stresses (Ton/m2) with Different Foundation Extent in any Rigidity of Foundation

Case No.	EF/ED	Foundation Extent			Major Principal				Minor Principal			
					Heel		Toe		Heel		Toe	
		U/S	D/S	Bottom	Case-A	Case-B	Case-A	Case-B	Case-A	Case-B	Case-A	Case-B
1	0.2	1.0H	1.0H	1.0H	81.93	81.27	-104.28	-106.58	24.20	21.83	-16.56	-17.86
		1.0H	1.0H	2.0H	67.45	66.94	-98.33	-100.92	16.45	13.87	-12.06	-13.85
		1.0H	1.0H	3.0H	58.44	58.18	-91.58	-93.97	11.55	9.62	-7.85	-10.01
		1.5H	1.5H	1.0H	74.29	74.14	-99.01	-99.84	23.16	22.28	-15.13	-15.63
		1.5H	1.5H	2.0H	63.36	63.01	-95.97	-97.55	16.53	14.61	-12.36	-13.35
		1.5H	1.5H	3.0H	55.91	55.68	-90.62	-92.04	11.56	9.96	-8.89	-9.99
		2.0H	2.0H	1.0H	68.94	68.89	-94.94	-95.26	22.27	21.92	-13.53	-13.73
		2.0H	2.0H	2.0H	60.21	60.02	-93.59	-94.61	16.37	15.10	-11.82	-12.46
		2.0H	2.0H	3.0H	53.92	53.73	-89.25	-90.31	11.58	10.25	-9.00	-9.74
2	0.3	1.0H	1.0H	1.0H	87.53	86.81	-95.53	-97.92	24.49	22.00	-15.88	-17.15
		1.0H	1.0H	2.0H	72.51	71.81	-90.50	-93.14	16.23	13.63	-12.00	-13.73
		1.0H	1.0H	3.0H	62.94	62.51	-84.36	-86.75	11.20	9.29	-8.20	-10.29
		1.5H	1.5H	1.0H	79.69	79.50	-90.86	-91.74	23.12	22.21	-14.50	-14.99
		1.5H	1.5H	2.0H	68.22	67.77	-88.38	-89.97	16.25	14.37	-12.21	-13.16
		1.5H	1.5H	3.0H	60.26	59.94	-83.46	-84.89	11.28	9.75	-9.11	-10.17
		2.0H	2.0H	1.0H	74.21	74.15	-87.21	-87.55	21.98	21.63	-13.00	-13.18
		2.0H	2.0H	2.0H	64.94	64.67	-86.22	-87.23	16.03	14.81	-11.65	-12.26
		2.0H	2.0H	3.0H	58.18	57.91	-82.20	-83.24	11.33	10.07	-9.16	-9.86
3	0.4	1.0H	1.0H	1.0H	91.34	90.54	-89.50	-91.90	24.38	21.92	-15.13	-16.37
		1.0H	1.0H	2.0H	75.79	75.00	-85.17	-87.78	16.04	13.52	-11.67	-13.34
		1.0H	1.0H	3.0H	65.76	65.23	-79.51	-81.83	11.07	9.22	-8.18	-10.18
		1.5H	1.5H	1.0H	83.26	83.03	-85.27	-86.15	22.94	22.05	-13.82	-14.30
		1.5H	1.5H	2.0H	71.34	70.83	-83.21	-84.77	16.09	14.29	-11.83	-12.74
		1.5H	1.5H	3.0H	62.96	62.58	-78.63	-80.02	11.20	9.74	-9.00	-10.01
		2.0H	2.0H	1.0H	77.55	77.47	-81.89	-82.22	21.74	21.39	-12.41	-12.59
		2.0H	2.0H	2.0H	67.90	67.59	-81.17	-82.16	15.87	14.70	-11.27	-11.85
		2.0H	2.0H	3.0H	60.76	60.46	-77.40	-78.40	11.27	10.08	-9.02	-9.68
4	0.5	1.0H	1.0H	1.0H	94.01	93.14	-85.04	-87.38	24.28	21.87	-14.45	-15.66
		1.0H	1.0H	2.0H	78.03	77.19	-81.24	-83.79	15.95	13.51	-11.30	-12.91
		1.0H	1.0H	3.0H	67.64	67.08	-75.95	-78.19	11.03	9.25	-8.04	-9.98
		1.5H	1.5H	1.0H	85.67	85.41	-81.08	-81.95	22.81	21.94	-13.21	-13.68
		1.5H	1.5H	2.0H	73.44	72.90	-79.38	-80.90	16.02	14.29	-11.43	-12.30
		1.5H	1.5H	3.0H	64.76	64.36	-75.08	-76.42	11.20	9.81	-8.81	-9.78
		2.0H	2.0H	1.0H	79.76	81.20	-77.91	-75.10	21.59	21.18	-11.87	-11.58
		2.0H	2.0H	2.0H	69.87	69.55	-77.43	-78.39	15.81	14.69	-10.88	-11.44
		2.0H	2.0H	3.0H	62.48	62.15	-73.88	-74.83	11.30	10.16	-8.81	-9.44
5	0.6	1.0H	1.0H	1.0H	95.91	95.02	-81.52	-83.82	24.20	21.84	-13.86	-15.03
		1.0H	1.0H	2.0H	79.62	78.75	-78.16	-80.64	15.90	13.54	-10.93	-12.49
		1.0H	1.0H	3.0H	68.97	68.40	-73.20	-75.36	11.03	9.33	-7.88	-9.75
		1.5H	1.5H	1.0H	87.36	87.09	-77.79	-78.63	22.73	21.87	-12.68	-13.13
		1.5H	1.5H	2.0H	74.92	74.36	-76.39	-77.85	16.00	14.33	-11.05	-11.89
		1.5H	1.5H	3.0H	66.04	65.62	-72.33	-73.61	11.24	9.90	-8.60	-9.54
		2.0H	2.0H	1.0H	81.29	81.20	-74.77	-75.10	21.50	21.18	-11.41	-11.58
		2.0H	2.0H	2.0H	71.25	70.92	-74.51	-75.43	15.81	14.73	-10.51	-11.05
		2.0H	2.0H	3.0H	63.69	63.36	-71.15	-72.07	11.36	10.27	-8.59	-9.20
6	0.8	1.0H	1.0H	1.0H	98.40	97.51	-76.31	-78.49	24.09	21.85	-12.89	-14.01
		1.0H	1.0H	2.0H	81.74	80.87	-73.68	-76.00	15.89	13.67	-10.31	-11.78
		1.0H	1.0H	3.0H	70.74	70.17	-69.21	-71.21	11.08	9.49	-7.56	-9.33
		1.5H	1.5H	1.0H	89.55	89.28	-72.90	-73.70	22.64	21.83	-11.81	-12.24
		1.5H	1.5H	2.0H	77.54	76.31	-70.30	-73.35	16.07	14.47	-10.12	-11.19
		1.5H	1.5H	3.0H	67.72	67.31	-68.33	-69.52	11.35	10.11	-8.22	-9.10
		2.0H	2.0H	1.0H	83.23	83.14	-70.11	-70.42	21.42	21.11	-10.65	-10.82
		2.0H	2.0H	2.0H	73.04	72.70	-70.21	-71.06	15.87	14.85	-9.89	-10.40
		2.0H	2.0H	3.0H	65.27	64.95	-67.18	-68.03	11.49	10.48	-8.19	-8.76



a. Heel

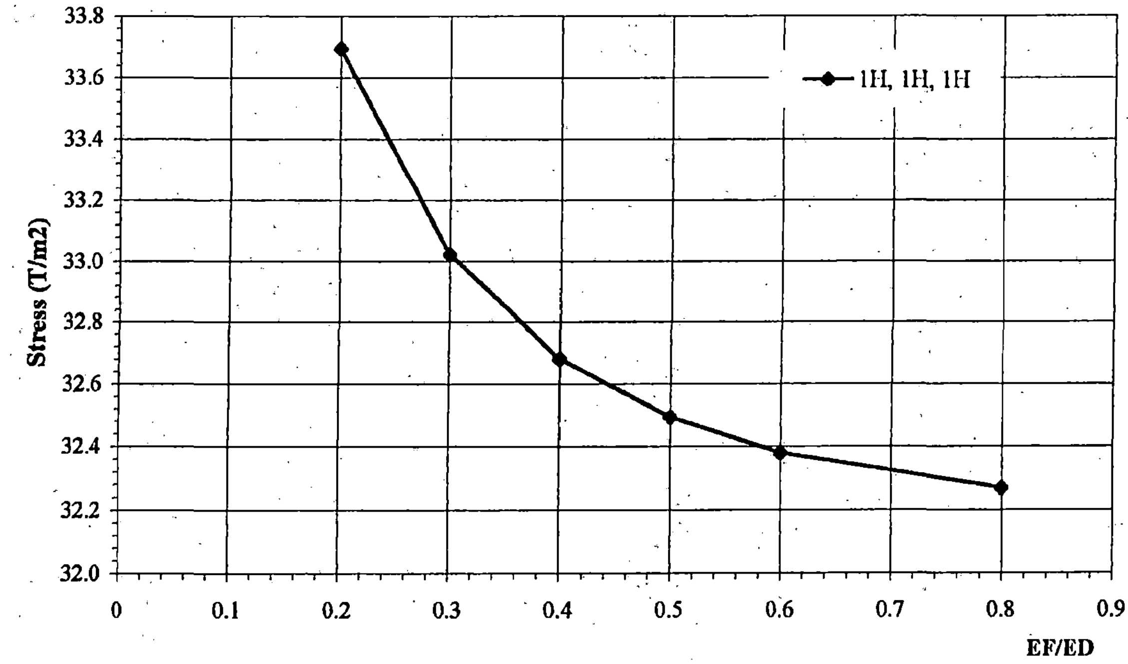


b. Toe

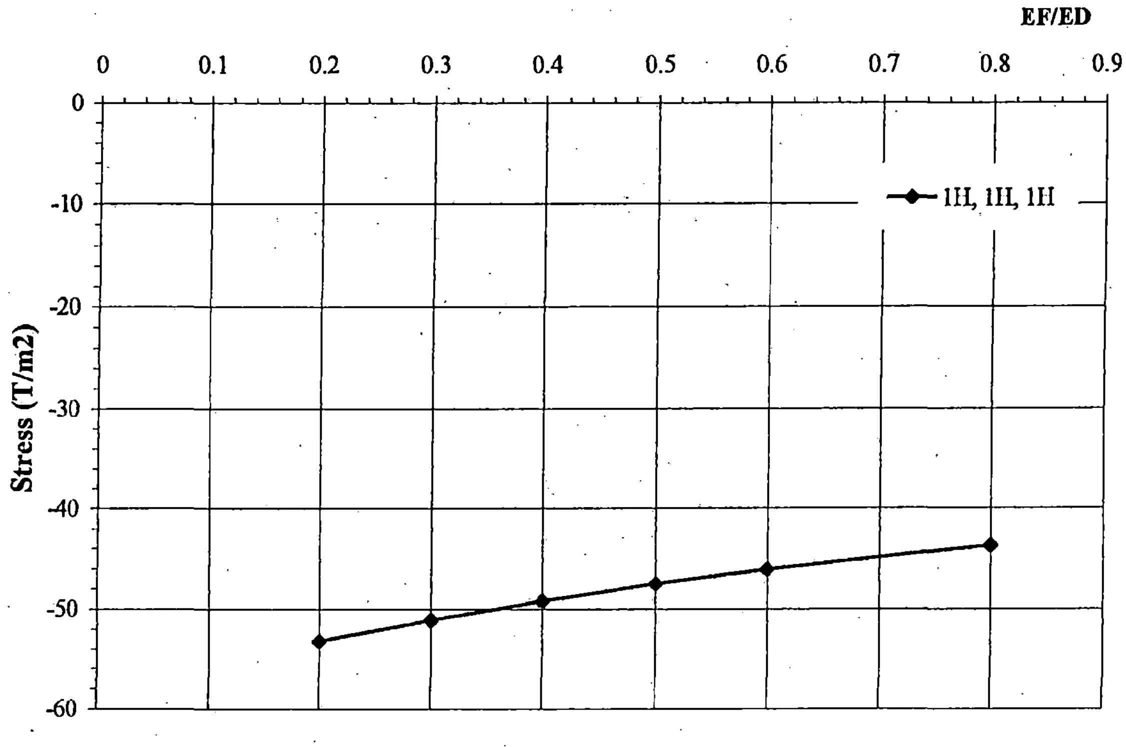
Figure 3.20 Comparison of Major Principal Stress between Part-1A and 1B Study with Foundation Extent of 1H u/s, 1H d/s, 1H bottom

Table 3.26 Stresses (Ton/m2) at Heel and Toe of Part-1C Study (Poisson's ratio 0.2)

Case No.	Foundation Extent	EF/ED	Horizontal		Vertical		Shear		Major Principal		Minor Principal	
			Heel	Toe	Heel	Toe	Heel	Toe	Heel	Toe	Heel	Toe
1	U/S 1 H	0.2	33.69	-53.24	64.90	-70.80	2.36	-44.03	80.14	-109.33	18.46	-14.72
	D/S 1 H	0.3	33.02	-51.12	71.20	-64.13	2.86	-41.12	85.21	-100.70	19.01	-14.55
	Bottom 1 H	0.4	32.68	-49.22	75.17	-59.57	3.20	-38.89	88.94	-94.62	18.91	-14.17
		0.5	32.49	-47.56	77.88	-56.20	3.47	-37.11	91.60	-90.00	18.77	-13.76
		0.6	32.38	-46.11	79.82	-53.57	3.68	-35.64	93.54	-86.33	18.66	-13.36
		0.8	32.27	-43.71	82.40	-49.71	4.04	-33.36	96.14	-80.79	18.53	-12.64

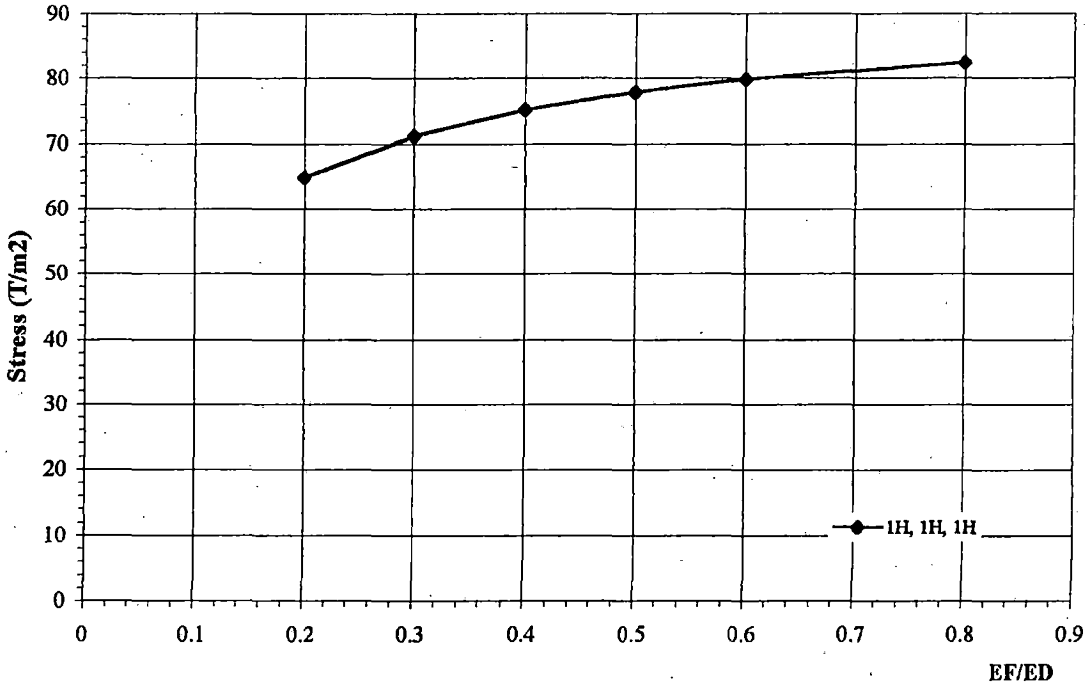


a. Heel

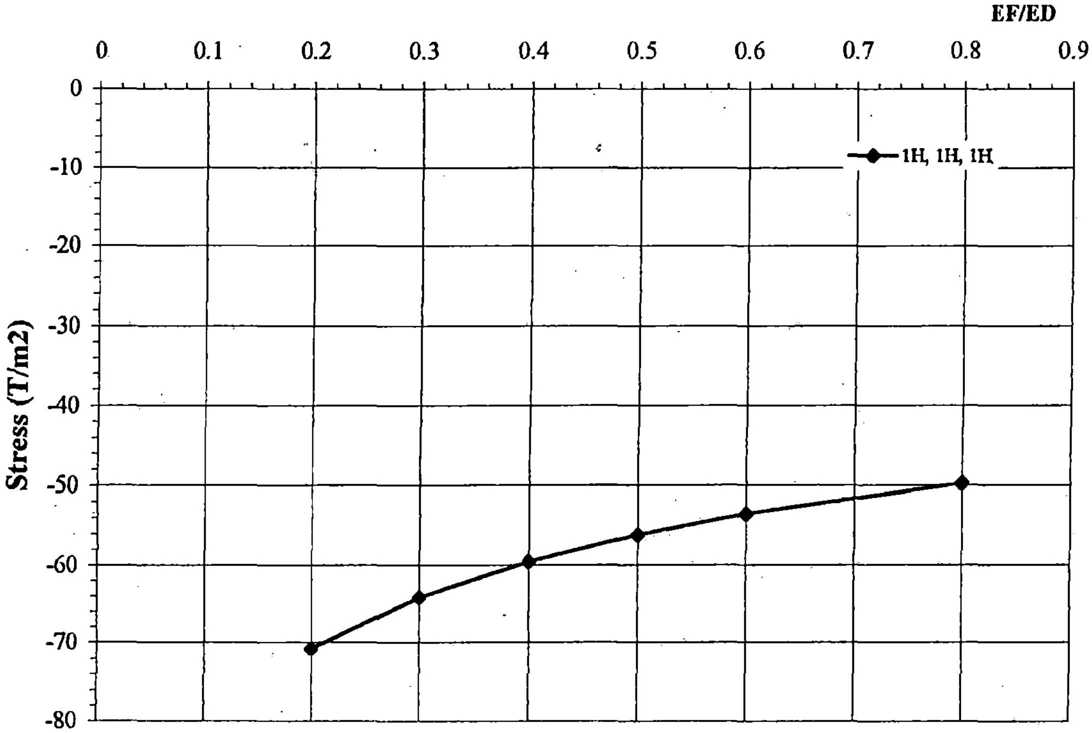


b. Toe

Figure 3.21 Horizonal Stress of Part-1C Study

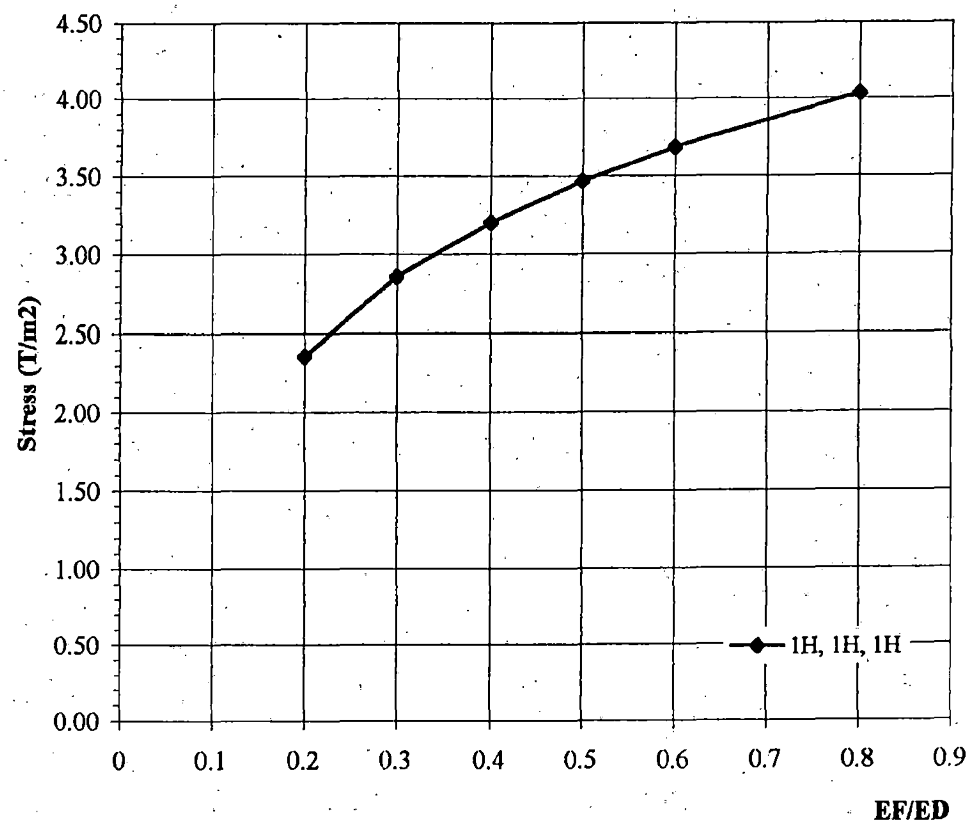


a. Heel

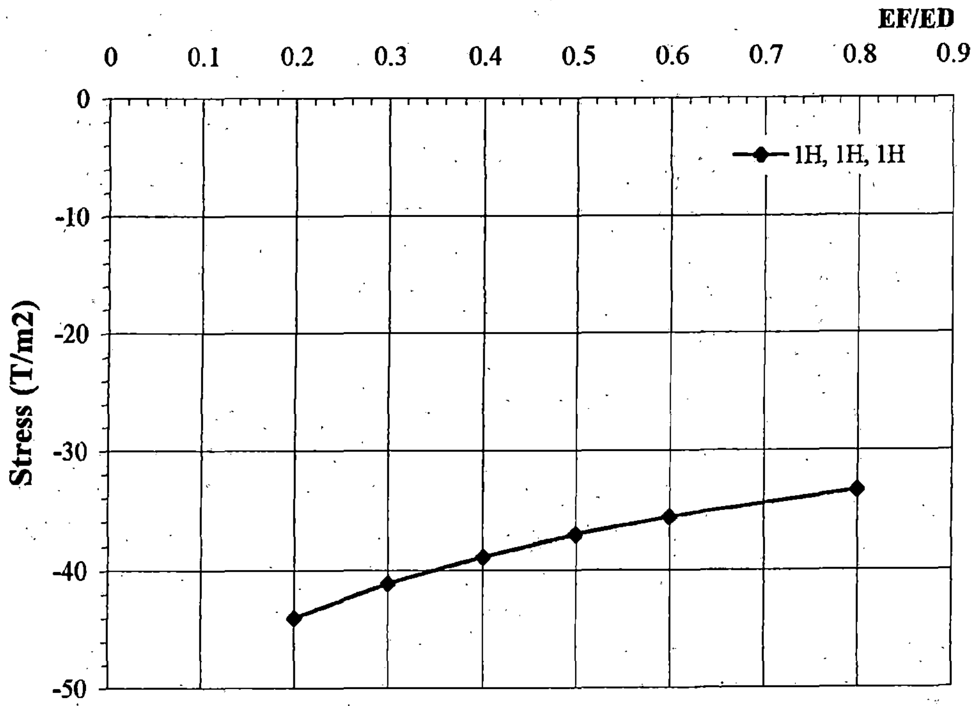


b. Toe

Figure 3.22 Vertical Stress of Part-1C Study

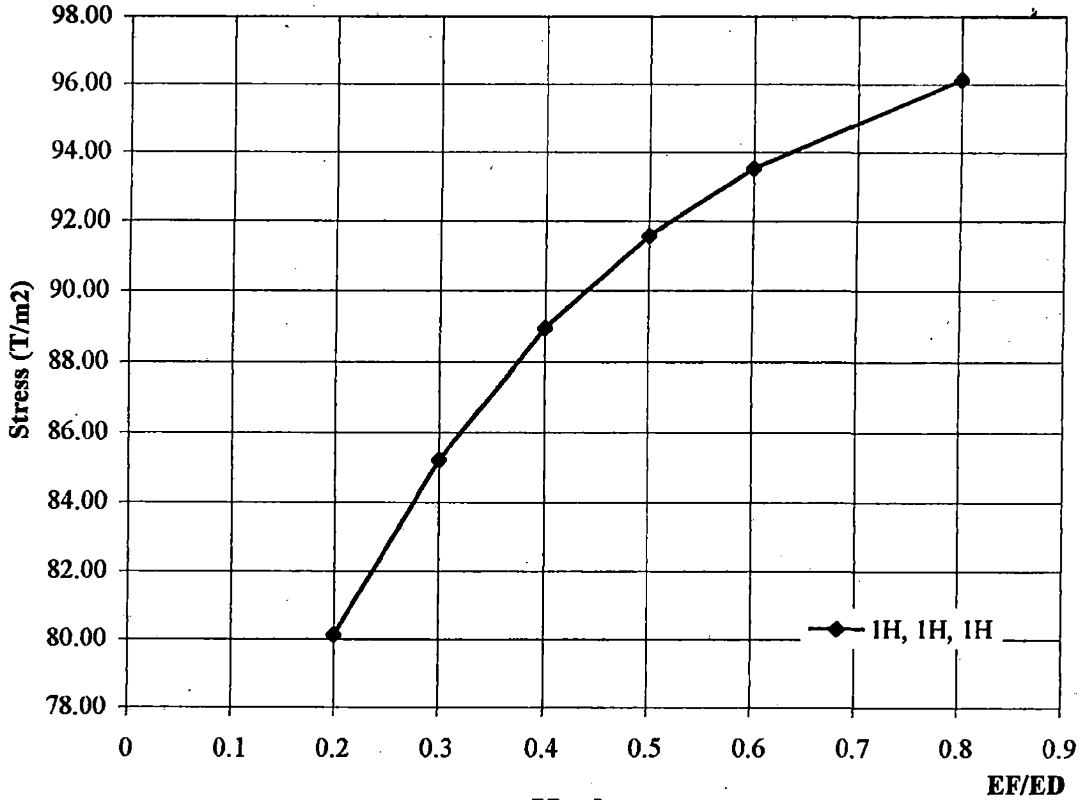


a. Heel

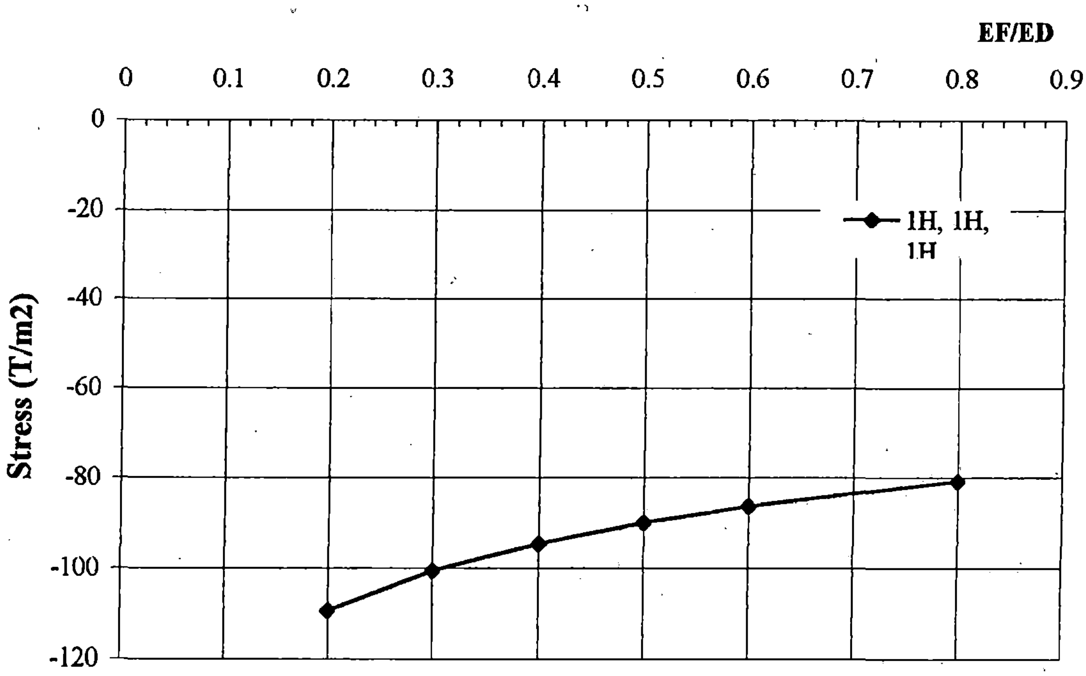


b. Toe

Figure 3.23 Shear Stress of Part-1C Study



a. Heel

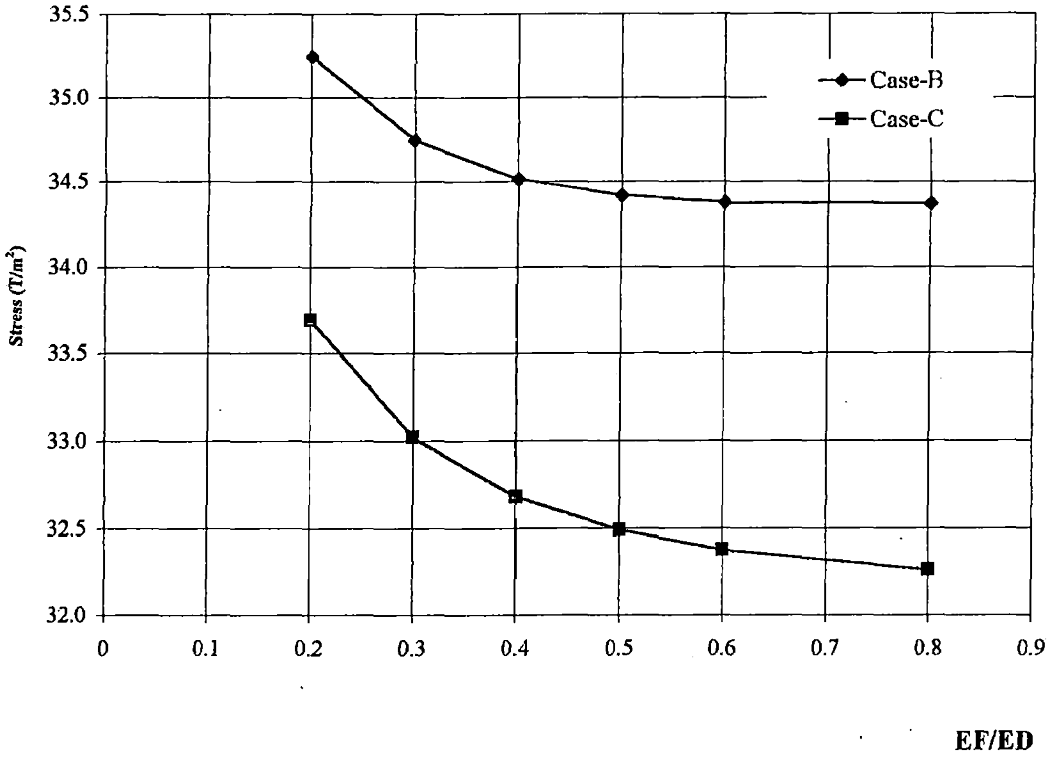


b. Toe

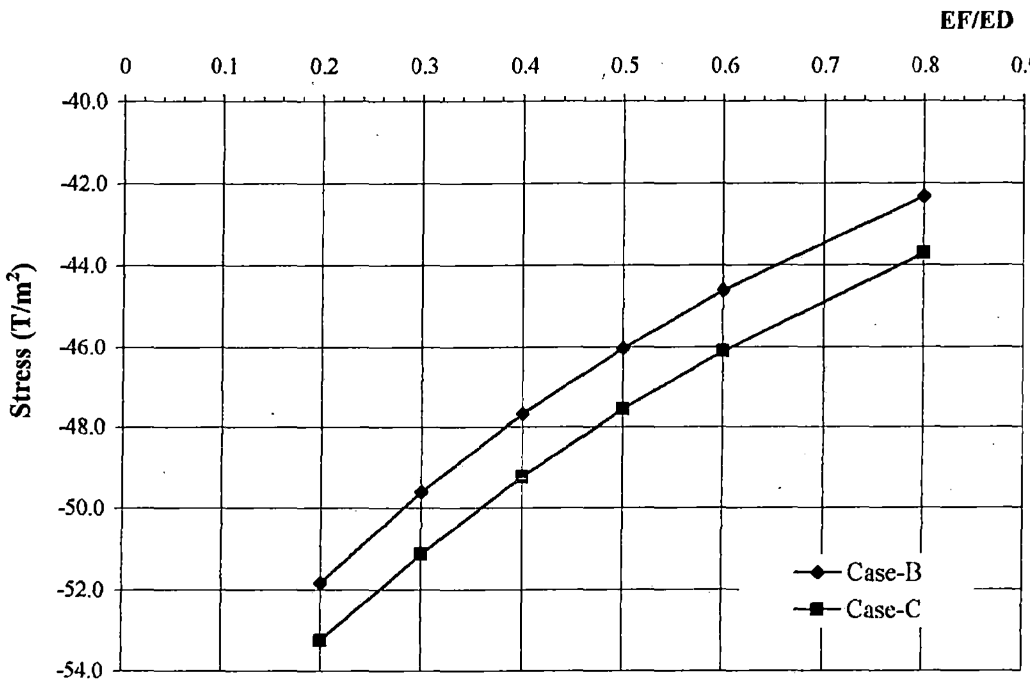
Figure 3.24 Major Principal Stress of Part-1C Study

Table 3.27 Comparison between Part-1B and Part-1C Study of Horizontal and Vertical Stresses (Ton/m2) with Different Rigidity of Foundation in any Foundation Extent

Case No.	Foundation Extent		EF/ED	Horizontal				Vertical			
				Heel		Toe		Heel		Toe	
				Case-B	Case-C	Case-B	Case-C	Case-B	Case-C	Case-B	Case-C
1	U/S	1H	0.2	35.25	33.69	-51.82	-53.24	67.85	64.90	-72.62	-70.80
	D/S	1H	0.3	34.75	33.02	-49.60	-51.12	74.06	71.20	-65.47	-64.13
	Bottom	1H	0.4	34.51	32.68	-47.67	-49.22	77.94	75.17	-60.59	-59.57
			0.5	34.42	32.49	-46.03	-47.56	80.59	77.88	-57.01	-56.20
			0.6	34.38	32.38	-44.62	-46.11	82.49	79.82	-54.23	-53.57
			0.8	34.37	32.27	-42.32	-43.71	84.99	82.40	-50.18	-49.71

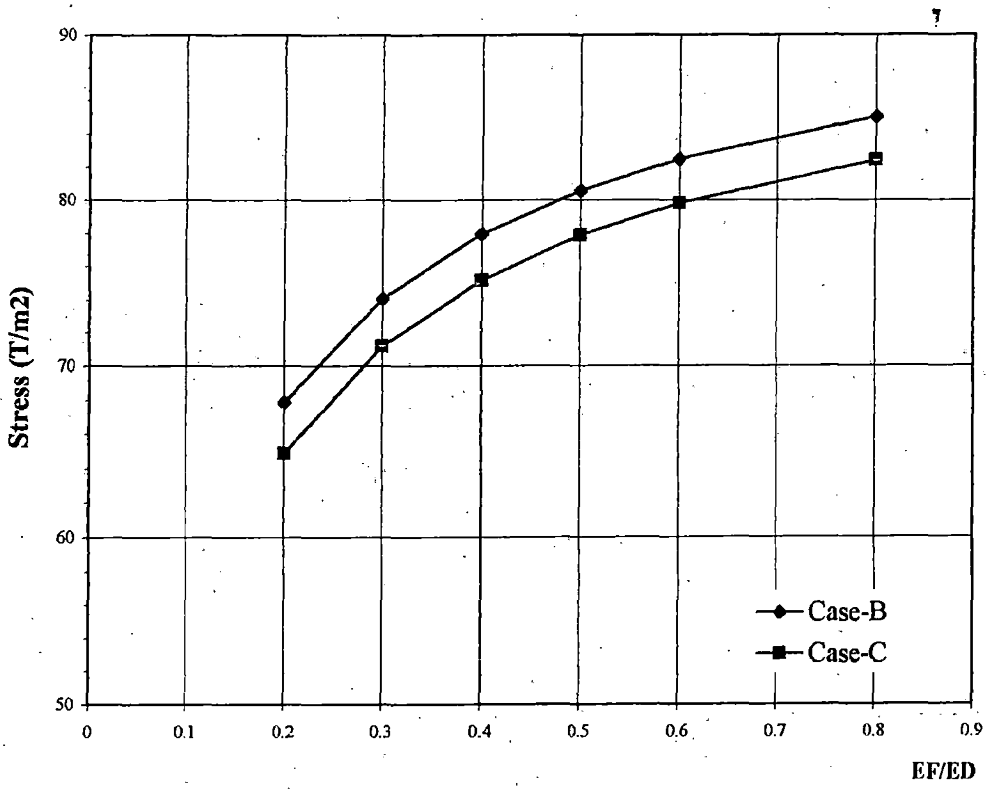


a. Heel

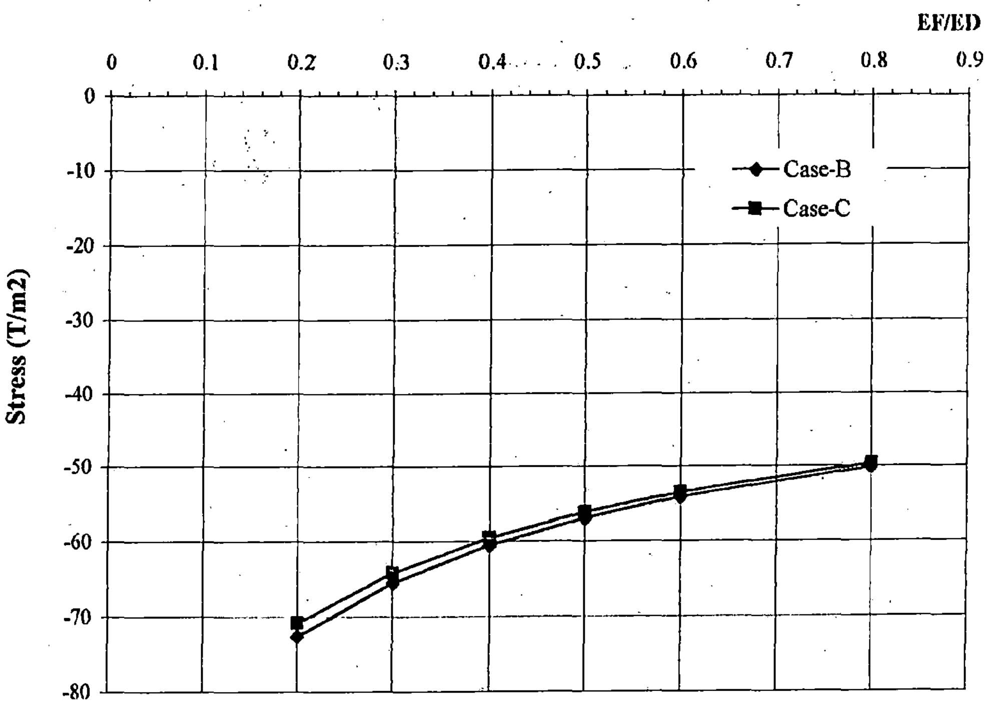


b. Toe

Figure 3.25 Comparison of Horizontal Stress between Part-1B and 1C Study with Foundaion Extent of 1H u/s, 1H d/s, 1H bottom



a. Heel



b. Toe

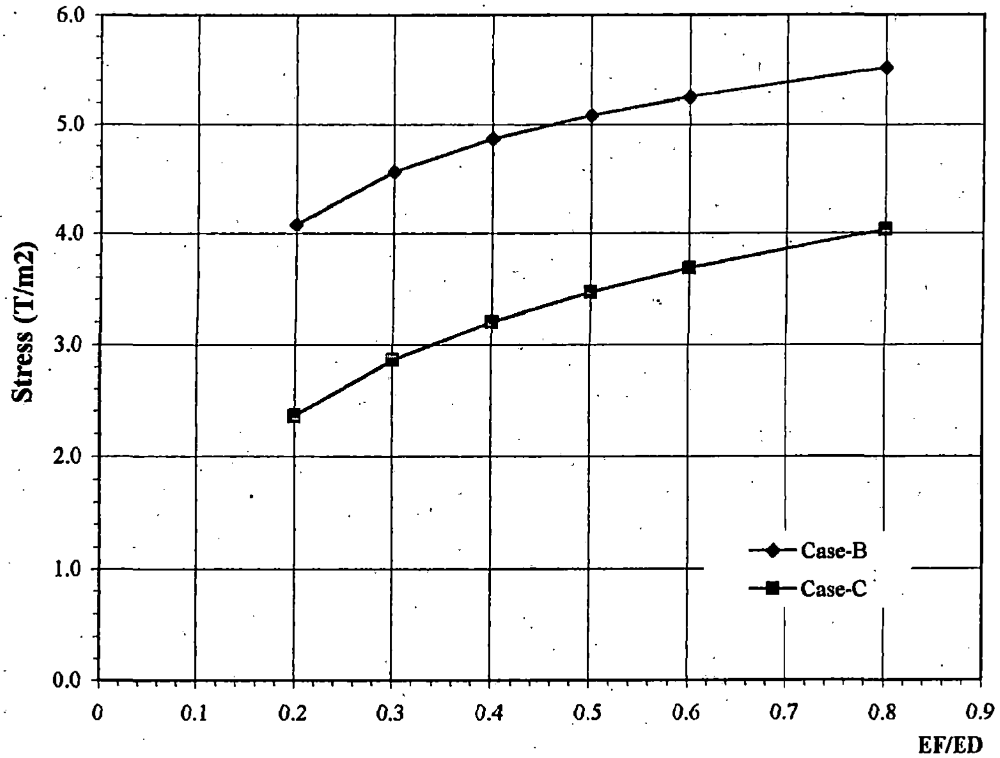
Figure 3.26 Comparison of Vertical Stress between Part-1B and 1C Study with Foundaion Extent of 1H u/s, 1H d/s, 1H bottom

Table 3.28 Comparison between Part -1B and Part -1C Study of Shear Stresses (Ton/m2) with different Rigidity of Foundation in any Foundation Extent

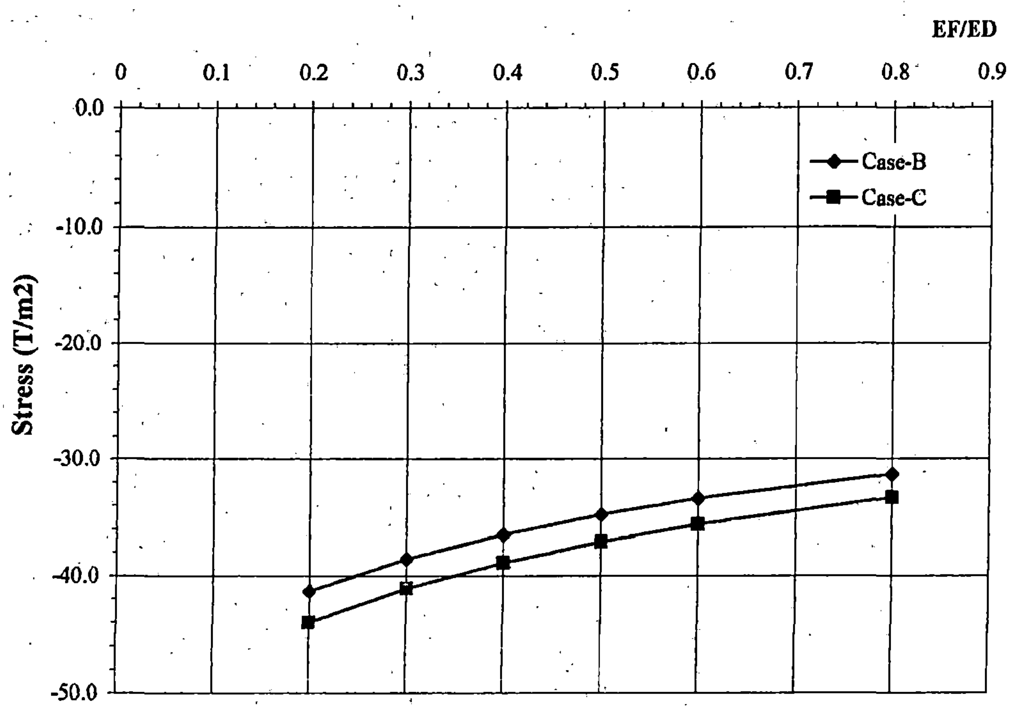
Case No.	Foundation Extent		EF/ED	Shear			
				Heel		Toe	
				Case-B	Case-C	Case-A	Case-B
1	U/S	1H	0.2	4.08	2.36	-41.33	-44.03
	D/S	1H	0.3	4.56	2.86	-38.57	-41.12
	Bottom	1H	0.4	4.87	3.20	-36.47	-38.89
			0.5	5.08	3.47	-34.81	-37.11
			0.6	5.25	3.68	-33.45	-35.64
			0.8	5.51	4.04	-31.35	-33.36

Table 3.29 Comparison between Part -1B and Part -1C Study of Principal Stresses (Ton/m2) with different Rigidity of Foundation in any Foundation Extent

Case No.	Foundation Extent		EF/ED	Major Principal				Minor Principal			
				Heel		Toe		Heel		Toe	
				Case-B	Case-C	Case-B	Case-C	Case-B	Case-C	Case-B	Case-C
1	U/S	1H	0.2	81.27	80.14	-106.58	-109.33	21.83	18.46	-17.86	-14.72
	D/S	1H	0.3	86.81	85.21	-97.92	-100.70	22.00	19.01	-17.15	-14.55
	Bottom	1H	0.4	90.54	88.94	-91.90	-94.62	21.92	18.91	-16.37	-14.17
			0.5	93.14	91.60	-87.38	-90.00	21.87	18.77	-15.66	-13.76
			0.6	95.02	93.54	-83.82	-86.33	21.84	18.66	-15.03	-13.36
			0.8	97.51	96.14	-78.49	-80.79	21.85	18.53	-14.01	-12.64

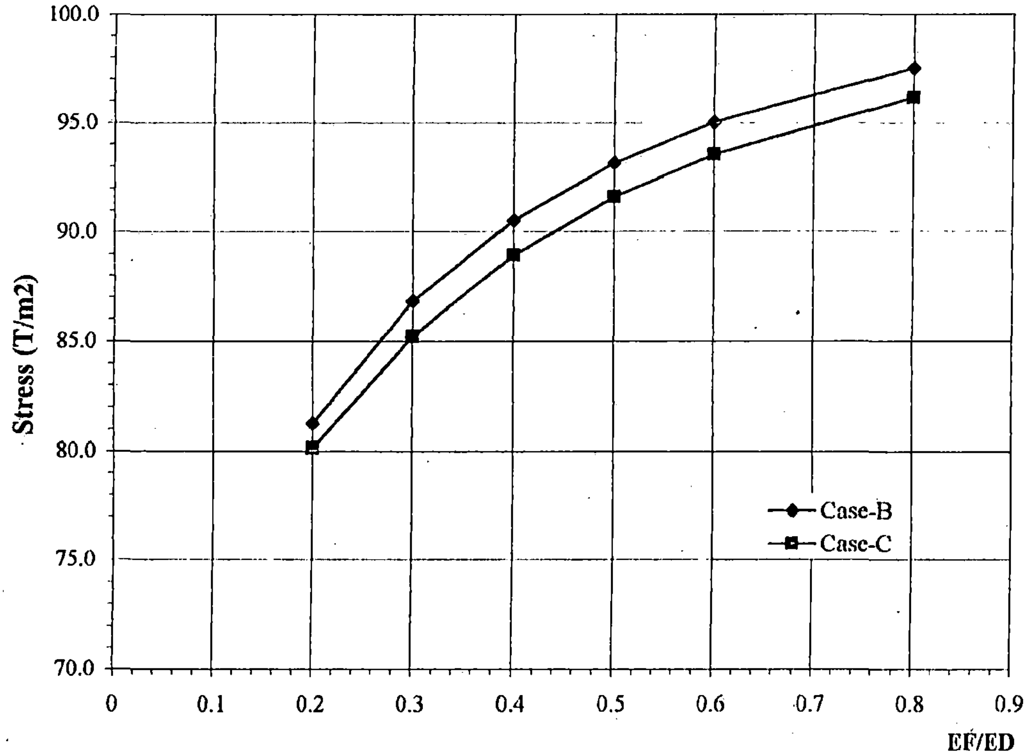


a. Heel

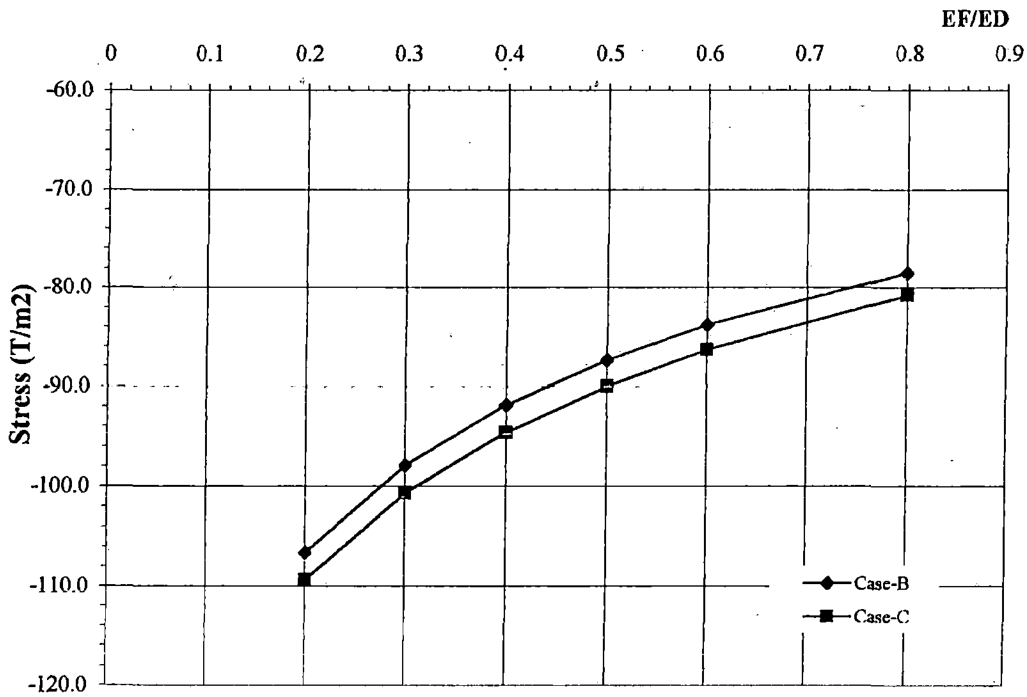


b. Toe

Figure 3.27 Comparison of Shear Stress between Part-1B and 1C Study with Foundaion Extent of 1H u/s, 1H d/s, 1H bottom



a. Heel



b. Toe

Figure 3.28 Comparison of Major Principal Stress between Part-1B and 1C Study with Foundaion Extent of 1H u/s, 1H d/s, 1H bottom

3.3 Discussions on the Results of Part – 2 Study

As explained before that in this part, some of case in part-1 are continued to be studied. Here, modified uplift (uplift pressure with condition of any drainage gallery in dam body) is applied together with the water pressure as external pressures. The foundation elasticity is taken 0.4 of dam elasticity (weak foundation rock) and foundation extent is varied in depth and lateral extension. The initial foundation extent of this part to be studied is :

- 1H u/s
- 1H d/s
- 1H depth.

And then for comparative study, the foundation extent is increased to 2H and 3H. To study effect of wider foundation, the foundation extent is increase to 2H. Here, displacements both horizontal and vertical at crest, heel and toe and also stresses at heel and toe are worked out and analyzed.

3.3.1 Displacement

Table 3.30 shows the horizontal and vertical displacements at crest, heel and toe. From the table, it can be seen that as deeper the foundation extent, the horizontal displacement increases at crest and toe but, decreases at heel. But, if lateral foundation extent is increased, the horizontal displacement reduces slightly at crest but increases slightly at heel and toe. No change of direction of horizontal displacement has been found in all the cases of foundation extent. In case of vertical displacement, it can be noted that, there is the change of direction at the heel from upward to downward. At crest and toe, the downward settlement tend to increase with deeper foundation extent but no appreciable effect of increasing lateral foundation extent is observed. Figures 3.29 up to 3.32 show the magnified deflected shape of dam and foundation of all cases of this part of study.

3.3.2 Stresses

Table 3.31 shows the stresses at heel and toe of this part. Tensile stresses have developed at heel and compressive stresses at toe. The horizontal stress at heel and toe in deeper and wider foundation extents have shown in decreasing trend. In comparison to case 1 (1H u/s, 1H d/s, 1H depth), the reduction in horizontal stress at heel is around 56%, 76% and 3.4% for case 2, case 3 and case 4, while at toe the reduction is around 5%, 16.5% and 15%. The vertical stresses developed are tensile at heel and compressive at toe. These vertical stresses have also shown decreasing trend with foundation extents. In comparison to case 1, the reduction in vertical stress at heel is around 30%, 45.5% and 13.7% for case 2, case 3 and case 4, while at toe, it is around 2.2%, 7.1% and 11.1%.

Figures 3.33 to 3.36 show the contour of horizontal stress in dam and foundation in all cases of this part. From these figures, the stress concentration at heel and toe can be seen. The tension zone is concentrated at heel and compression at toe. The region of compressive stress is around 75% in dam body and around 90% in foundation.

Figures 3.37 to 3.40 show the contours of vertical stress in dam and foundation. Here, the region of compressive stress is more dominant, that is around 95% in dam body and around 98% in foundation. It can also be noted that the stress concentration in foundation is below the dam base. The stressed zone in upstream and downstream direction for both horizontal and vertical stresses at the base is small. Shear stresses at heel and toe can also be seen in Table 3.31. From this table, it can be seen that the shear stresses are of the same order in all cases. At heel, if it is compared with case 1, the shear stress has increased around 6.6%, 7.8% and 3.3% for case 2, case 3 and case 4.

The major and minor principal stresses in all the four cases of this part of study are shown in Table 3.31. It can be seen from the table that with the deeper and wider foundation extents, the major principal stress has decreased both at heel and toe. But the minor principal stress, at heel has increased and decreased at toe with deeper and wider foundation extent. The contours of major principal stress in all four cases can be seen in Figures 3.41 to 3.44. It can be seen from these figures that tensile principal stress is concentrated at heel and compressive around toe and downstream face. Here also, the stresses in foundation are concentrate just below of the dam base and stresses reduce sharply in upstream and downstream side.

Table 3.30 Horizontal and Vertical Displacements (mm) at Crest, Heel and Toe of Part-2 Study

Case No.	EF/ED	Foundation Extent			Horizontal			Vertical		
		U/S	D/S	Bottom	Crest	Heel	Toe	Crest	Heel	Toe
1	0.4	1H	1H	1H	12.90	-0.56	0.59	-0.54	0.61	-3.68
2		1H	1H	2H	13.42	-0.29	0.68	-1.76	-0.64	-5.18
3		1H	1H	3H	13.43	-0.17	0.76	-2.91	-1.83	-6.30
4		2H	2H	1H	12.72	-0.58	0.63	-0.65	0.47	-3.57

Table 3.30A Horizontal and Vertical Displacements (mm) at Crest, Heel and Toe of Part-1B Study

Case No.	EF/ED	Foundation Extent			Horizontal (mm)			Vertical (mm)		
		U/S	D/S	Bottom	Crest	Heel	Toe	Crest	Heel	Toe
1	0.4	1.0H	1.0H	1.0H	14.09	-0.54	0.63	1.71	2.50	-2.83
2		1.0H	1.0H	2.0H	14.75	-0.26	0.80	1.34	2.09	-3.57
3		1.0H	1.0H	3.0H	14.75	-0.11	0.90	0.86	1.55	-4.03
4		2.0H	2.0H	1.0H	13.83	-0.53	0.65	1.57	2.31	-2.72

Table 3.31 Stresses (Ton/m2) at Heel and Toe of Part-2 Study

Case No.	EF/ED	Foundation Extent			Horizontal		Vertical		Shear		PS Max		PS Min	
		U/S	D/S	Bottom	Heel	Toe	Heel	Toe	Heel	Toe	Heel	Toe	Heel	Toe
1	0.4	1H	1H	1H	16.37	-54.09	42.06	-69.18	19.75	-42.52	62.77	-105.54	-4.34	-17.72
2		1H	1H	2H	7.21	-51.41	29.33	-67.67	21.05	-43.65	48.88	-104.42	-12.35	-14.66
3		1H	1H	3H	3.95	-45.19	22.92	-64.28	21.29	-42.43	41.37	-98.56	-14.49	-10.91
4		2H	2H	1H	15.81	-45.99	36.29	-61.52	20.43	-39.46	55.04	-94.26	-2.93	-13.25

Table 3.31A Stresses (Ton/m2) at Heel and Toe of Part-1B Study

Case No.	EF/ED	Foundation Extent			Horizontal		Vertical		Shear		PS Max		PS Min	
		U/S	D/S	Bottom	Heel	Toe	Heel	Toe	Heel	Toe	Heel	Toe	Heel	Toe
1	0.4	1.0H	1.0H	1.0H	34.51	-47.67	77.94	-60.59	4.87	-36.47	90.54	-91.90	21.92	-16.37
2		1.0H	1.0H	2.0H	24.73	-43.22	63.79	-57.90	5.05	-35.98	75.00	-87.78	13.52	-13.34
3		1.0H	1.0H	3.0H	19.19	-37.56	55.26	-54.45	5.53	-34.43	65.23	-81.83	9.22	-10.18
4		2.0H	2.0H	1.0H	30.21	-41.02	68.65	-53.78	7.06	-33.90	77.47	-82.22	21.39	-12.59

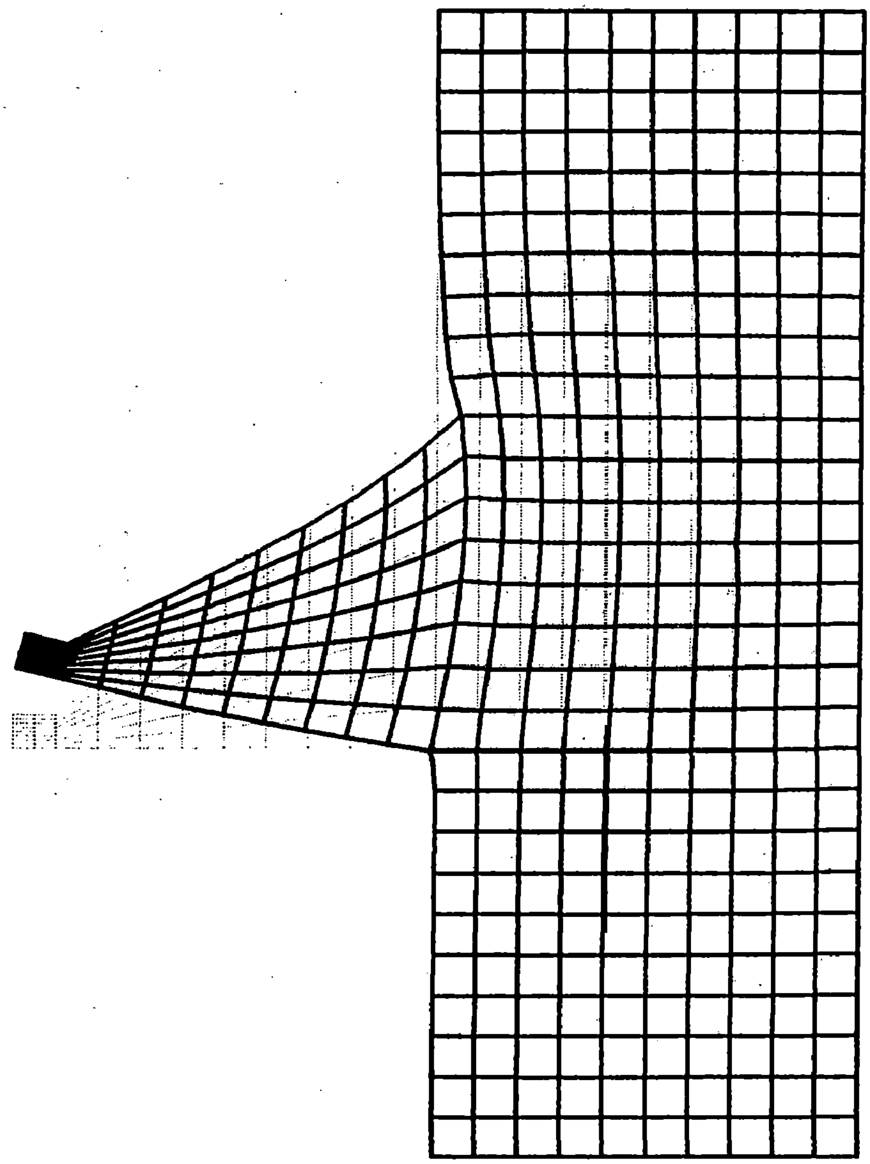


Figure 3.29 Deflected Shape of Dam of Part-2, Case-1 Study
Delection magnified by 1500 times

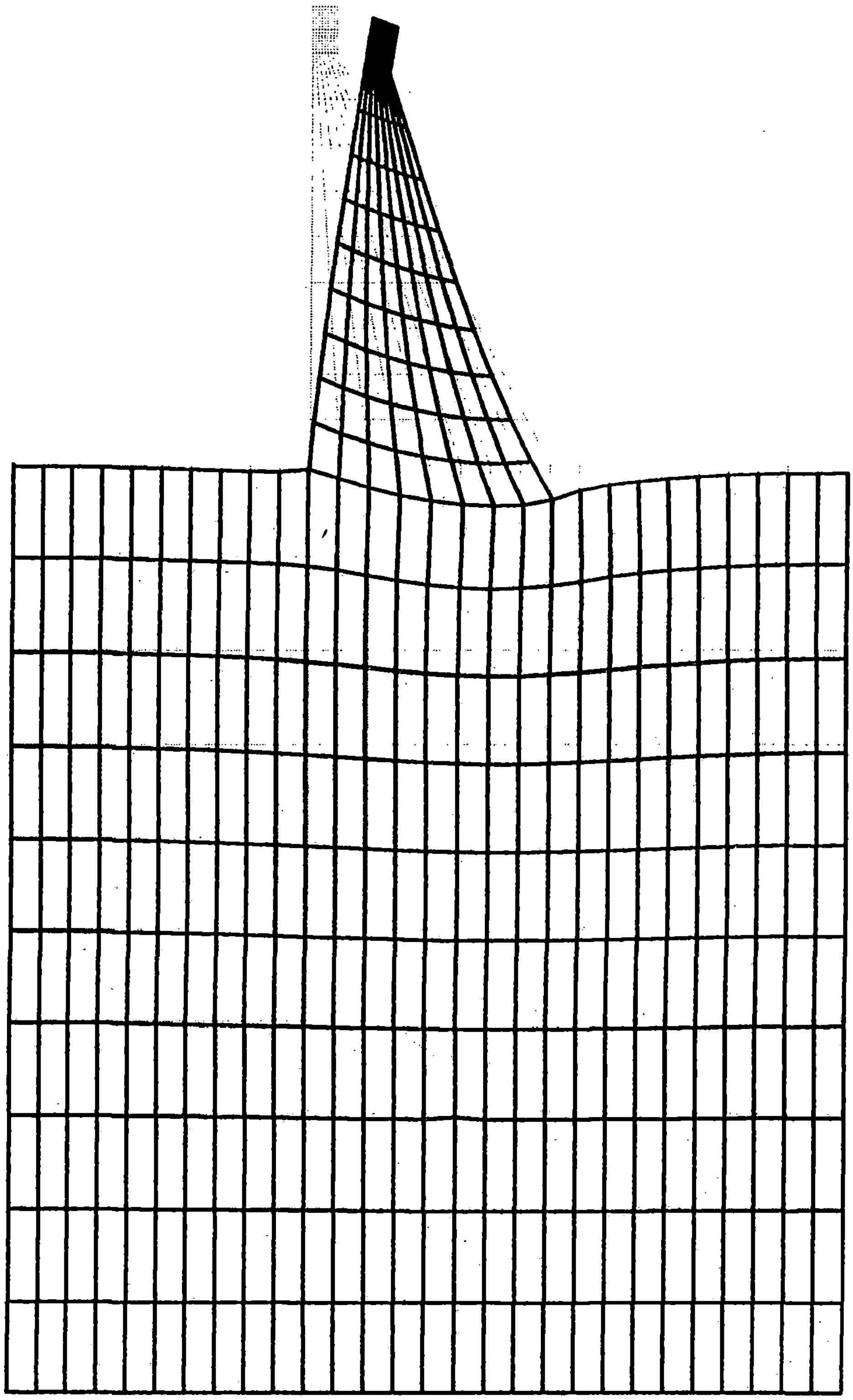


Figure 3.30 Deflected Shaped of Dam of Part-2,
Case-2 Study
Deflection magnified by 1500

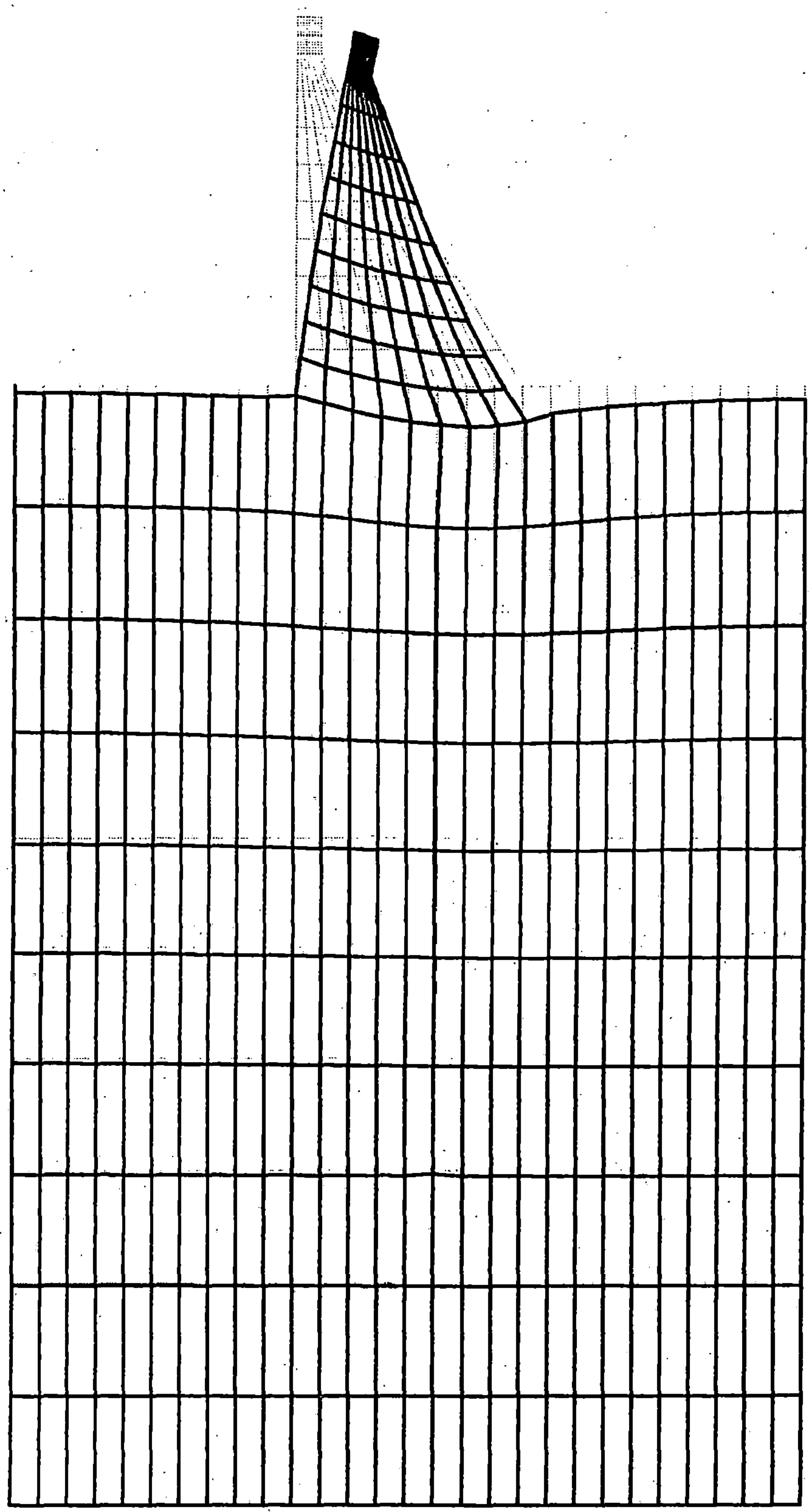


Figure 3.31 Deflected Shape of Dam of Part-2,
Case 3 Study
Deflection magnified by 1500 times

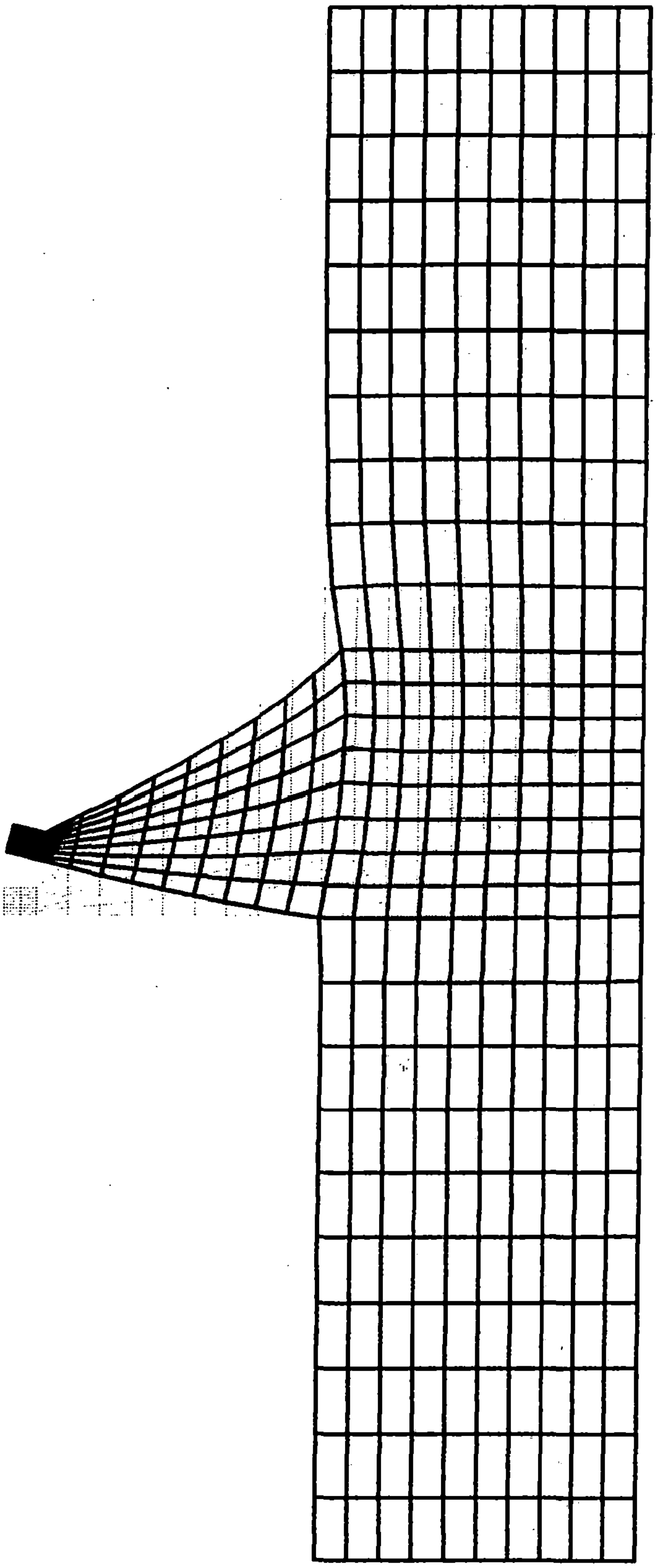


Figure 3.32 Deflected Shape of Dam of Part-2,
Case 4 Study
Deflection magnified by 1500 times

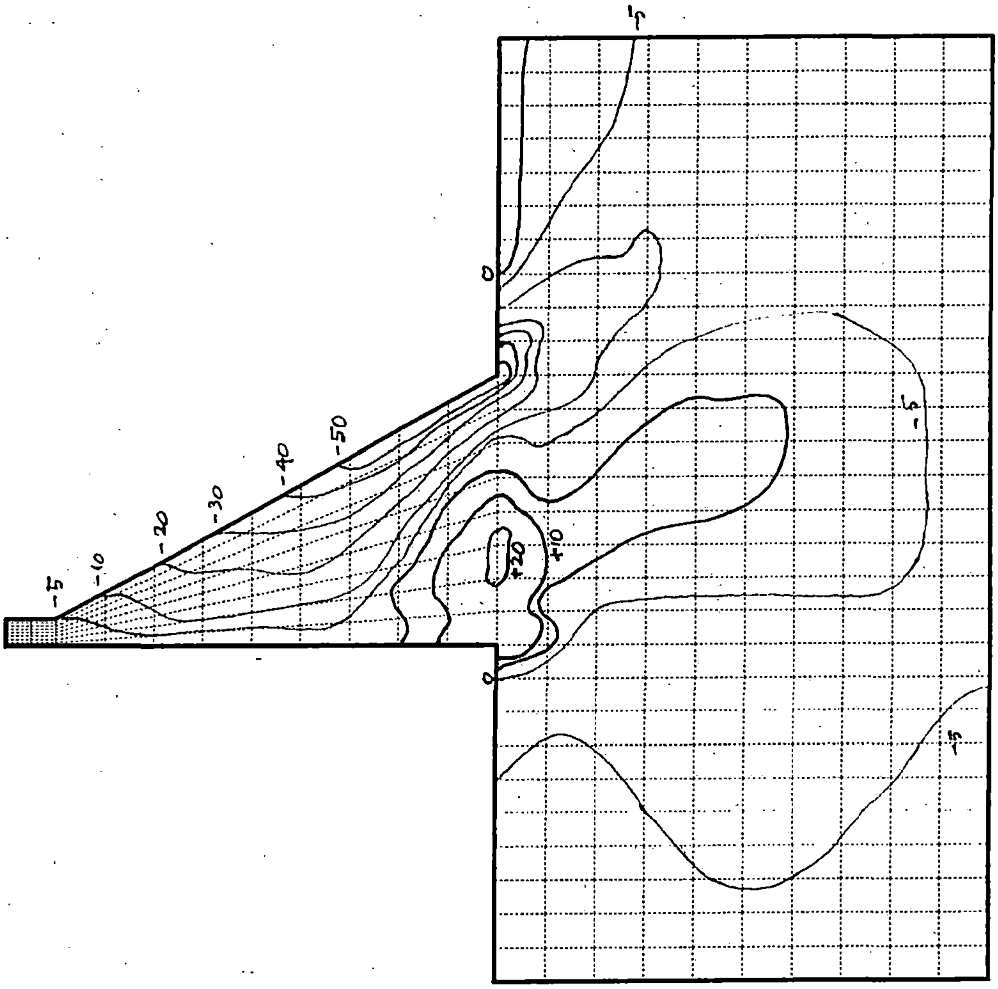


Figure 3.33 Contour of Horizontal Stress in Dam and Foundation of Part-2, Case 1 Study

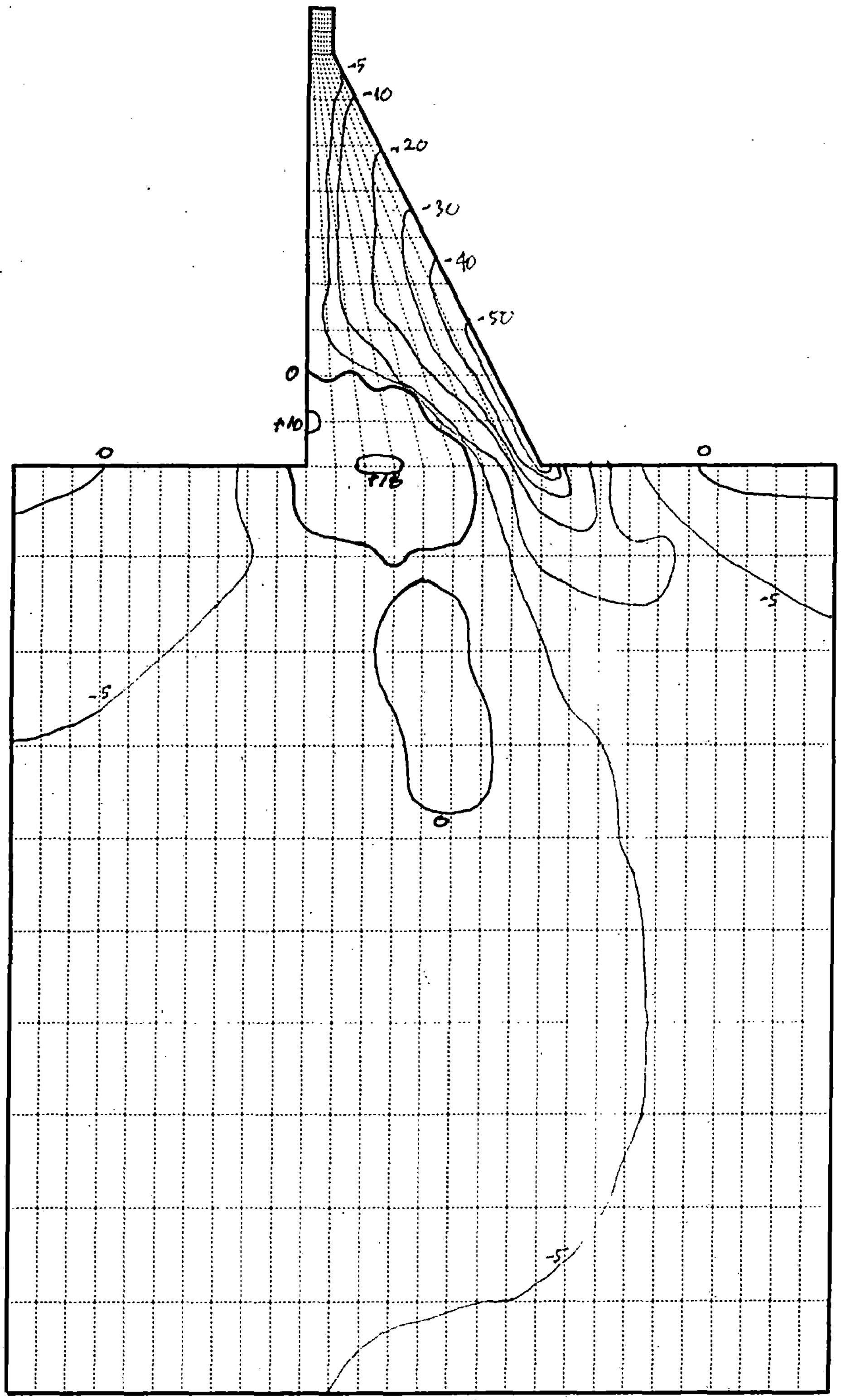


Figure 3.34 Contour of Horizontal Stress in Dam and Foundation of Part-2, Case 2 Studv

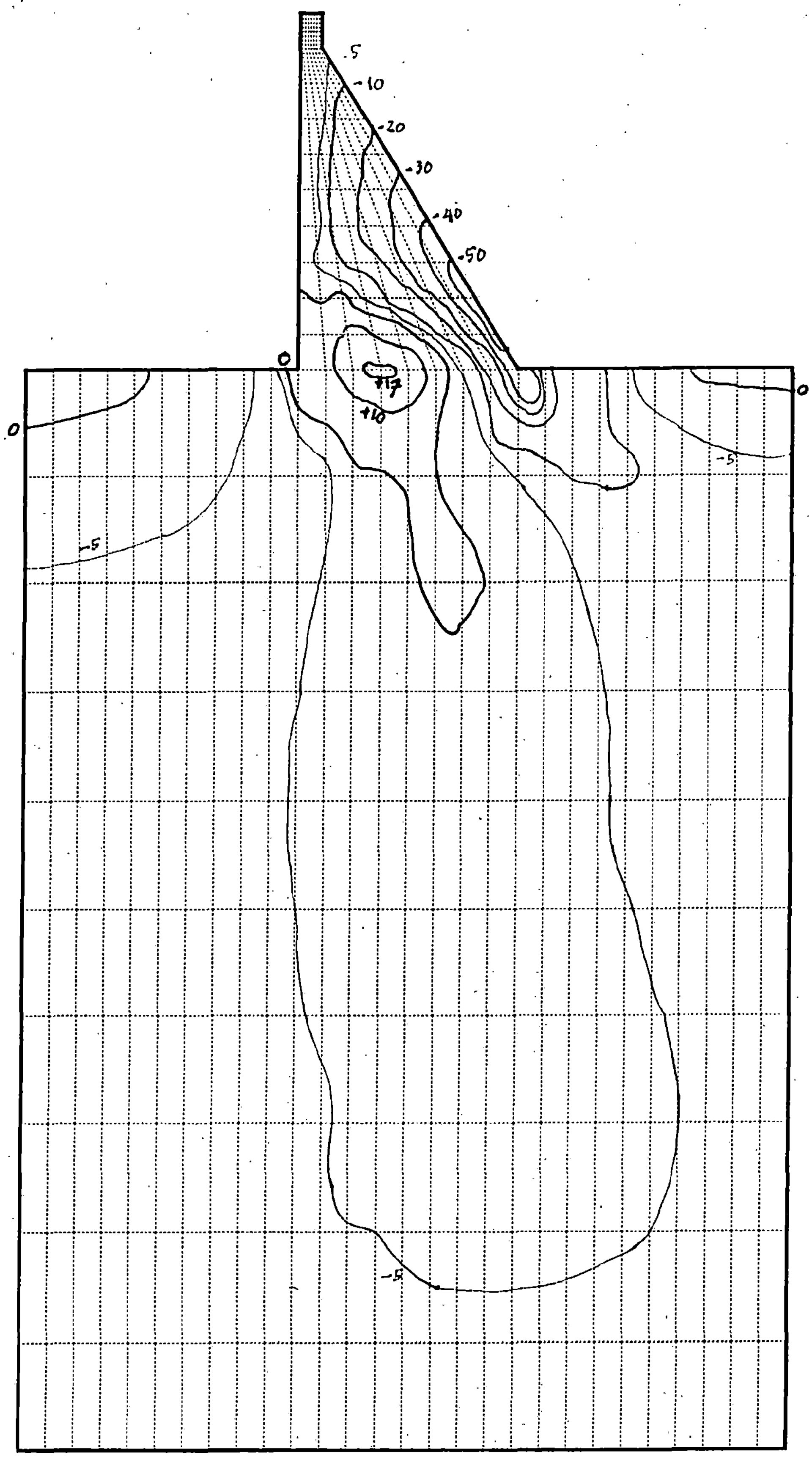


Figure 3.35 **Contour of Horizontal Stress in Dam and Foundation of Part-2, Case 3 Study**

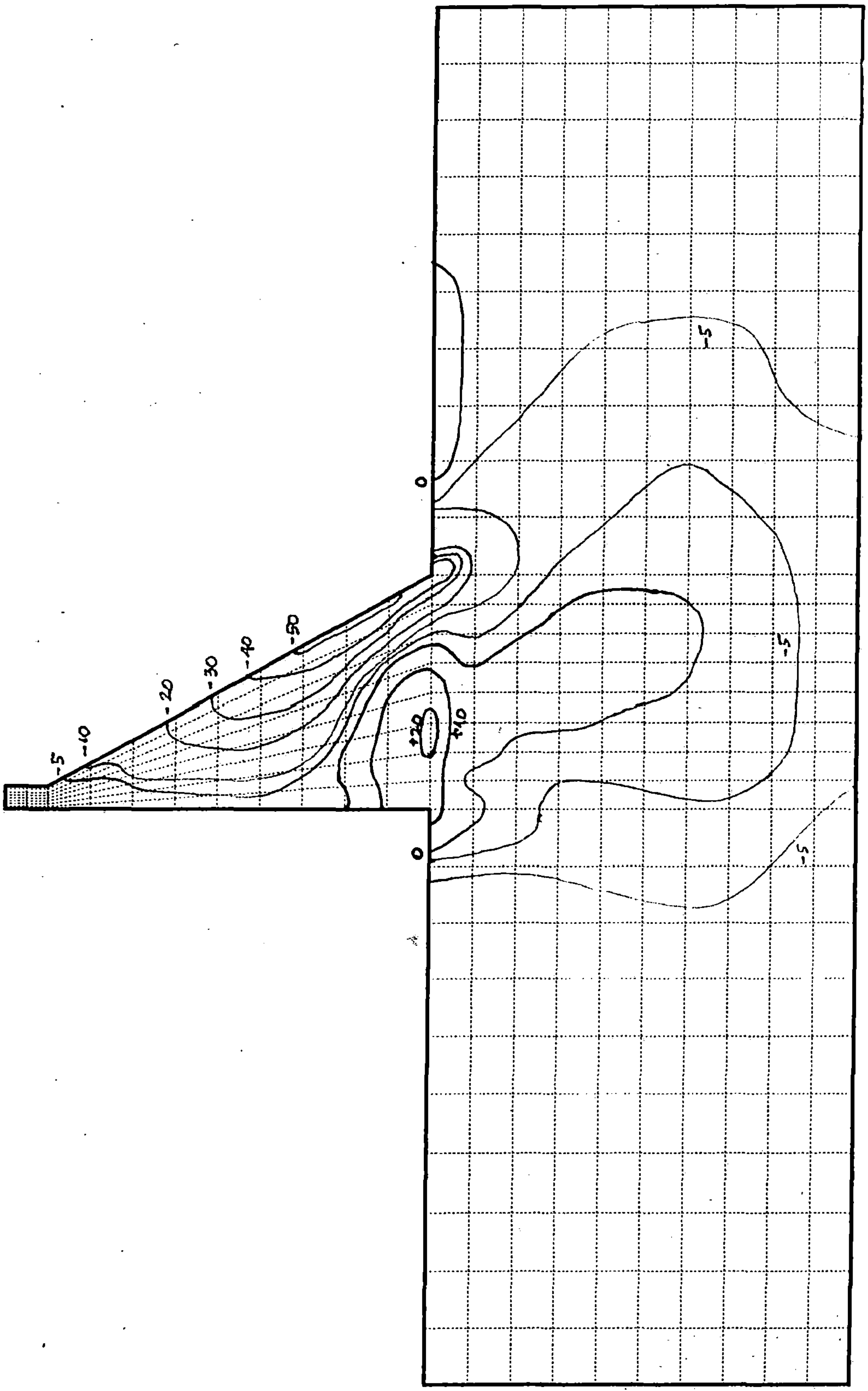


Figure 3.36 Contour of Horizontal Stress in Dam and Foundation of Part-2, Case 4 Study

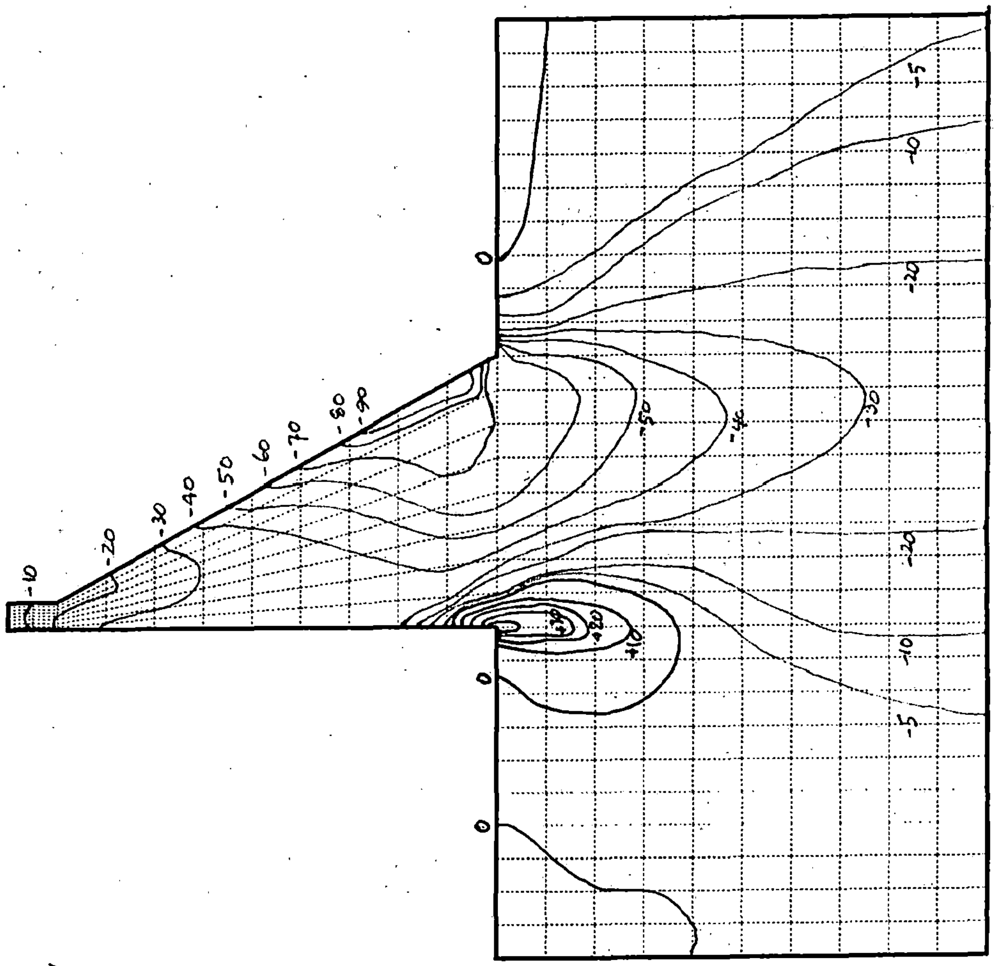


Figure 3.37 Contour of Vertical Stress in Dam and Foundation of Part-2, Case 1 Study

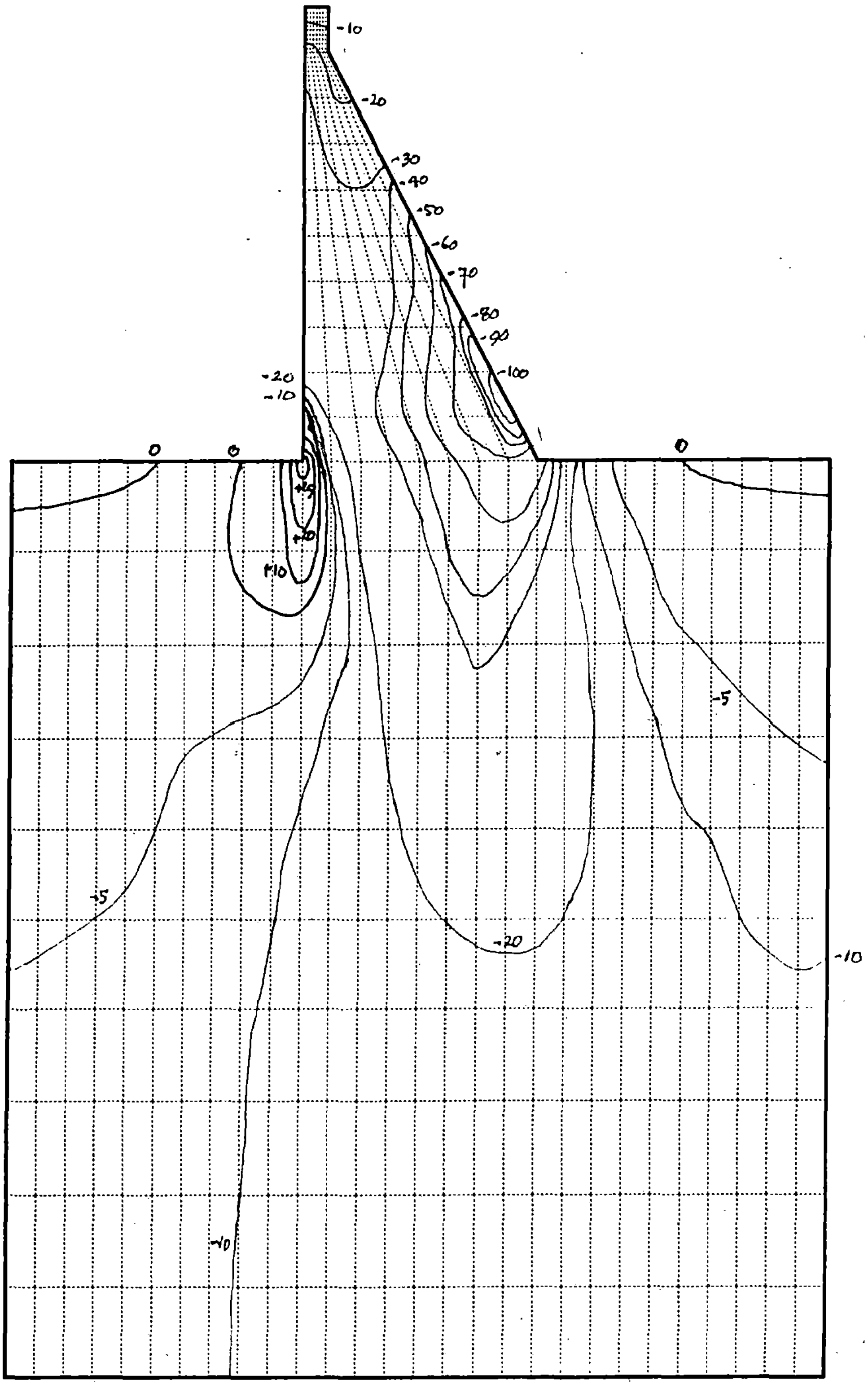


Figure 3.38 **Contour of Vertical Stress in Dam and Foundation of Part-2, Case 2 Study**

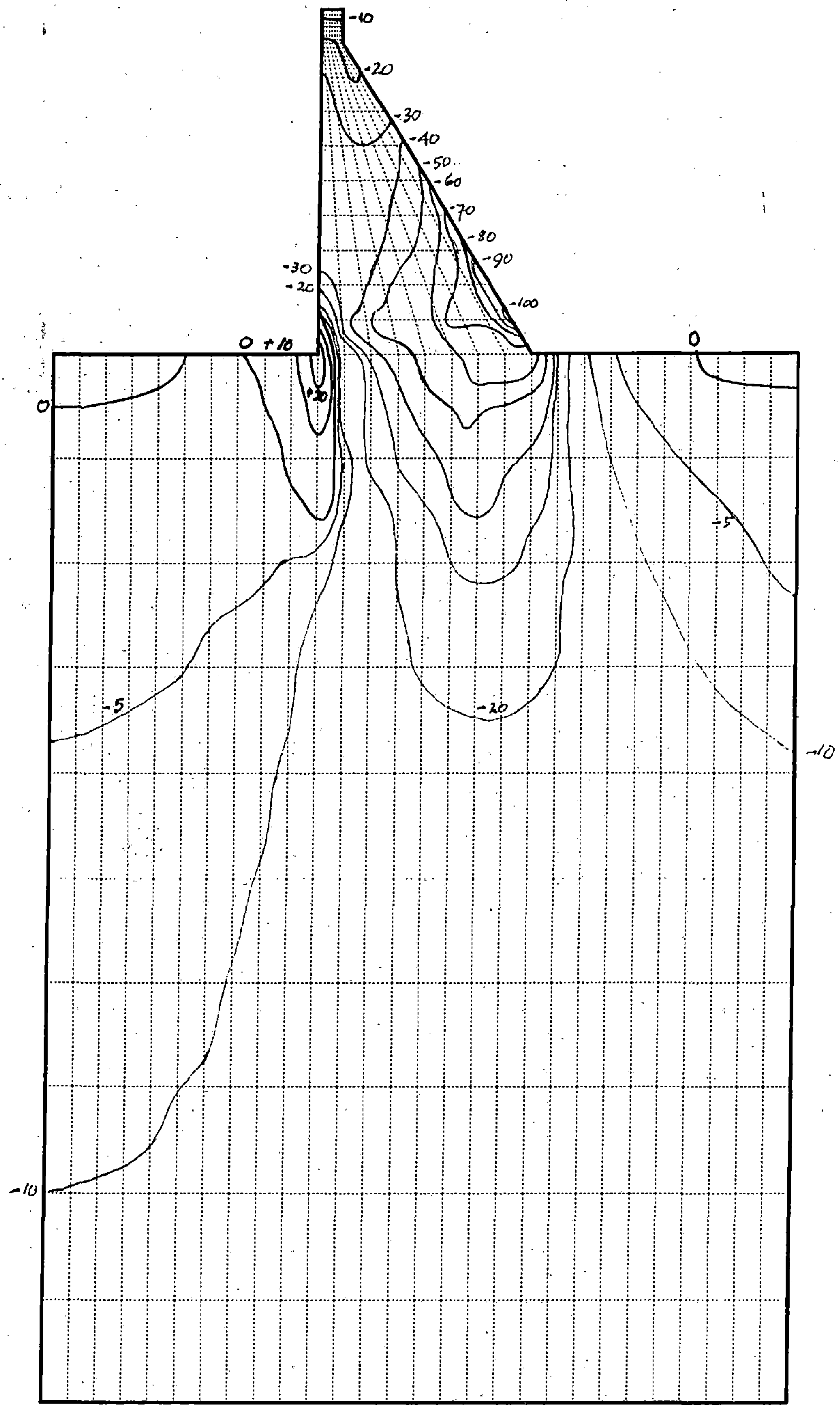


Figure 3.39 Contour of Vertical Stress in Dam and Foundation of Part-2, Case 3 Study

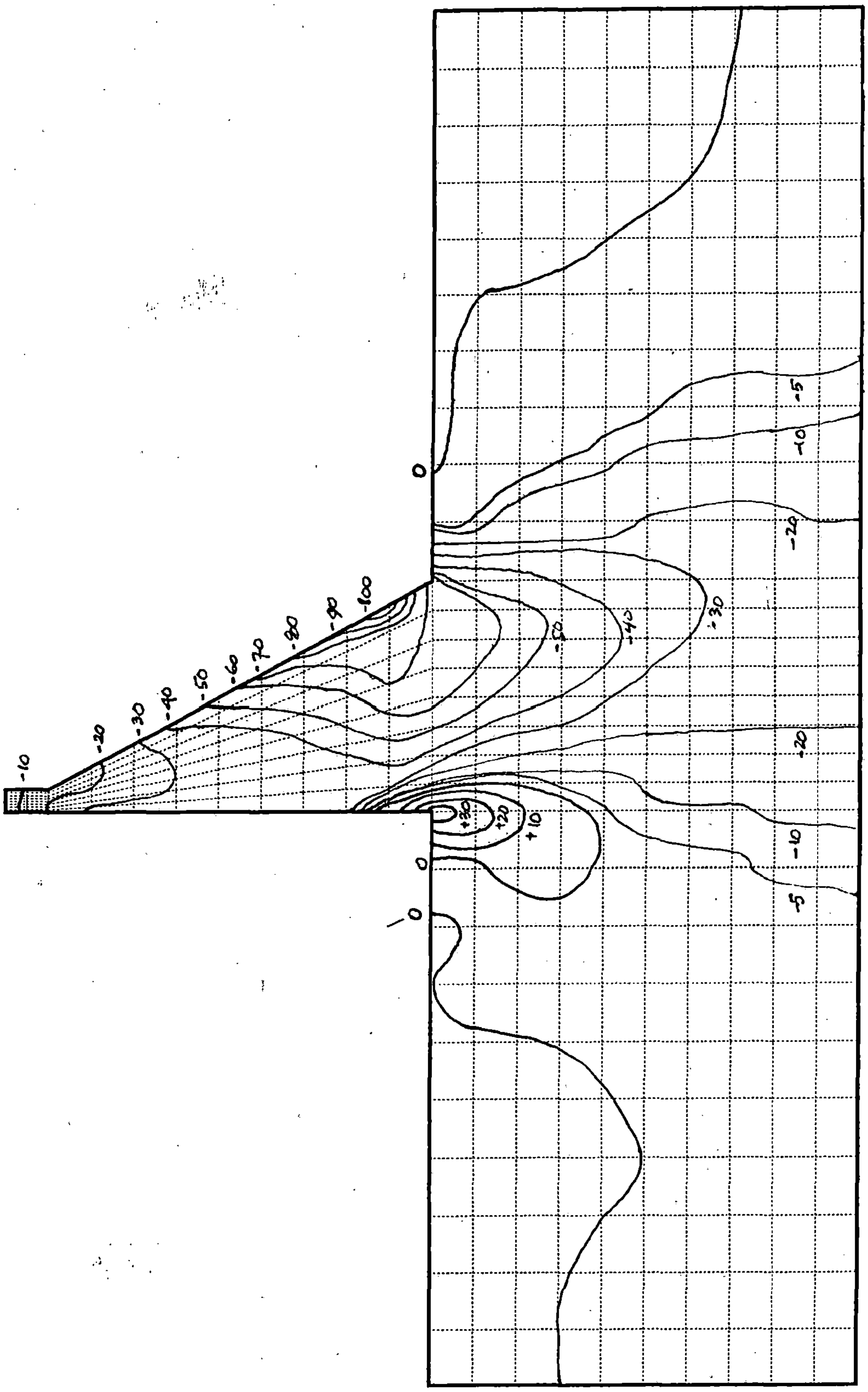


Figure 3.40 Contour of Vertical Stress in Dam and Foundation of Part-2, Case 4 Study

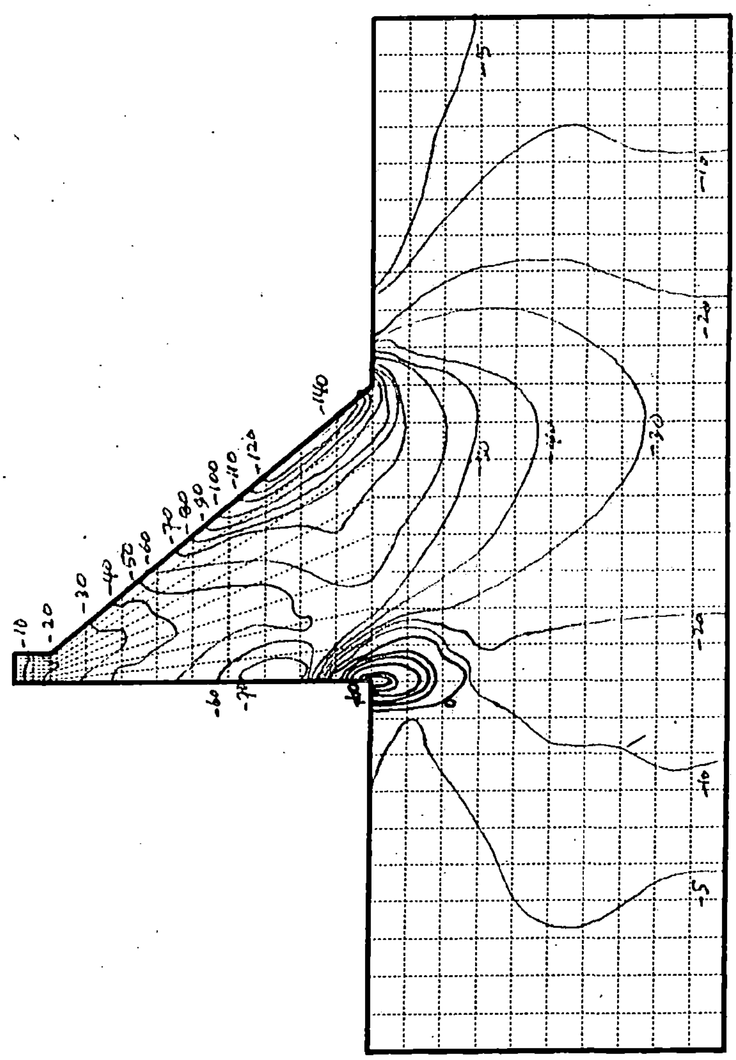


Figure 3.41 Contour of Major Principal Stress in Dam and Foundation of Part-2, Case 1 Study

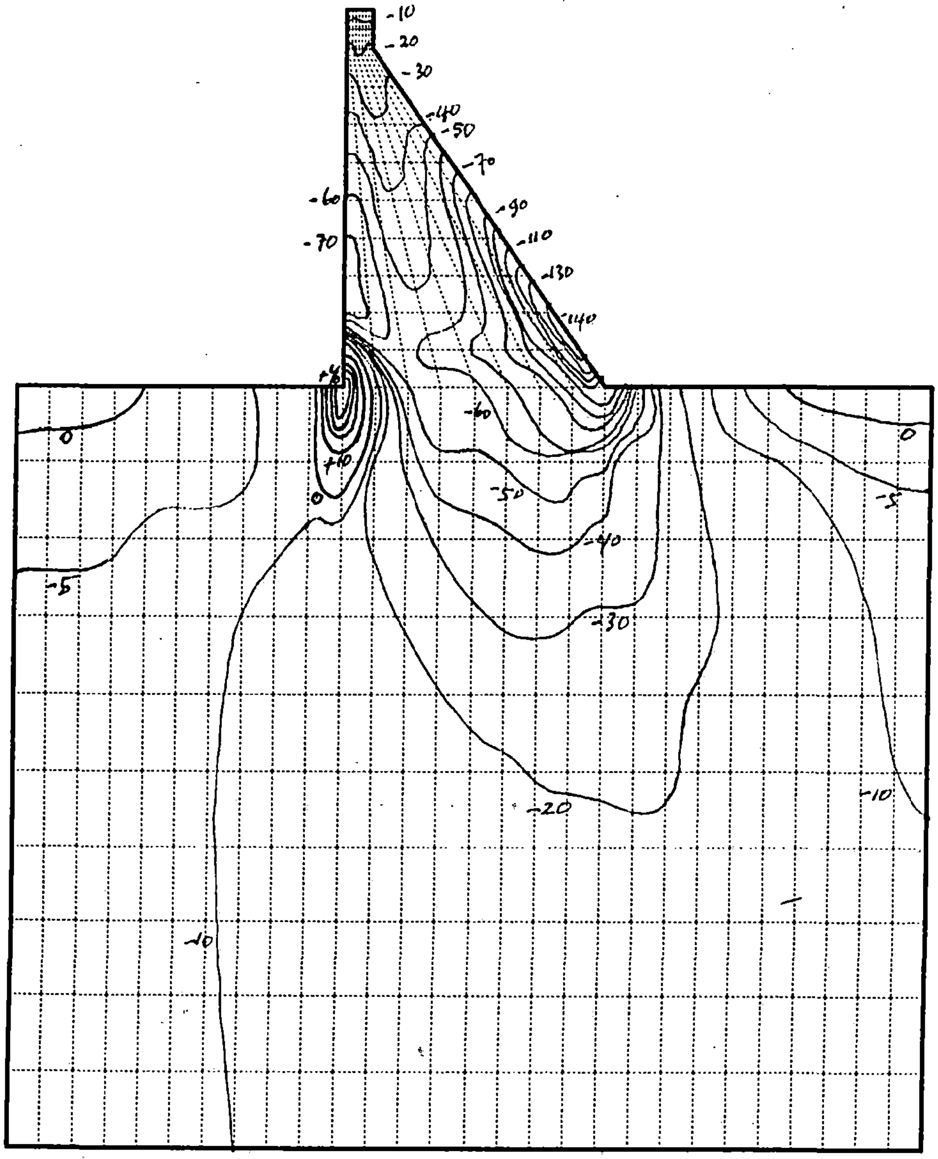


Figure 3.42 Contour of Major Principal Stress in Dam and Foundation of Part-2, Case 2 Study

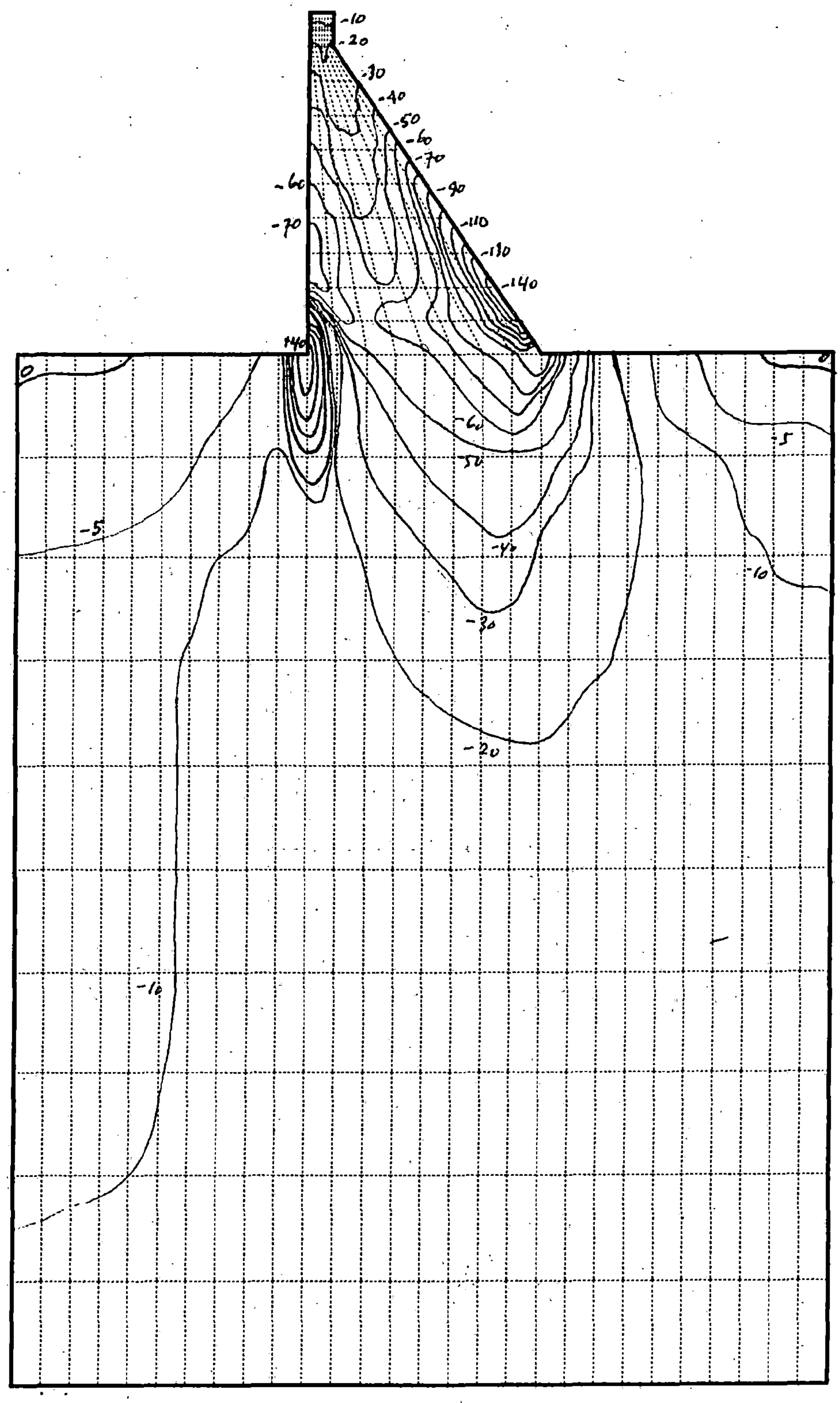


Figure 3.43 Contour of Major Principal Stress in Dam and Foundation of Part-2, Case 3 Study

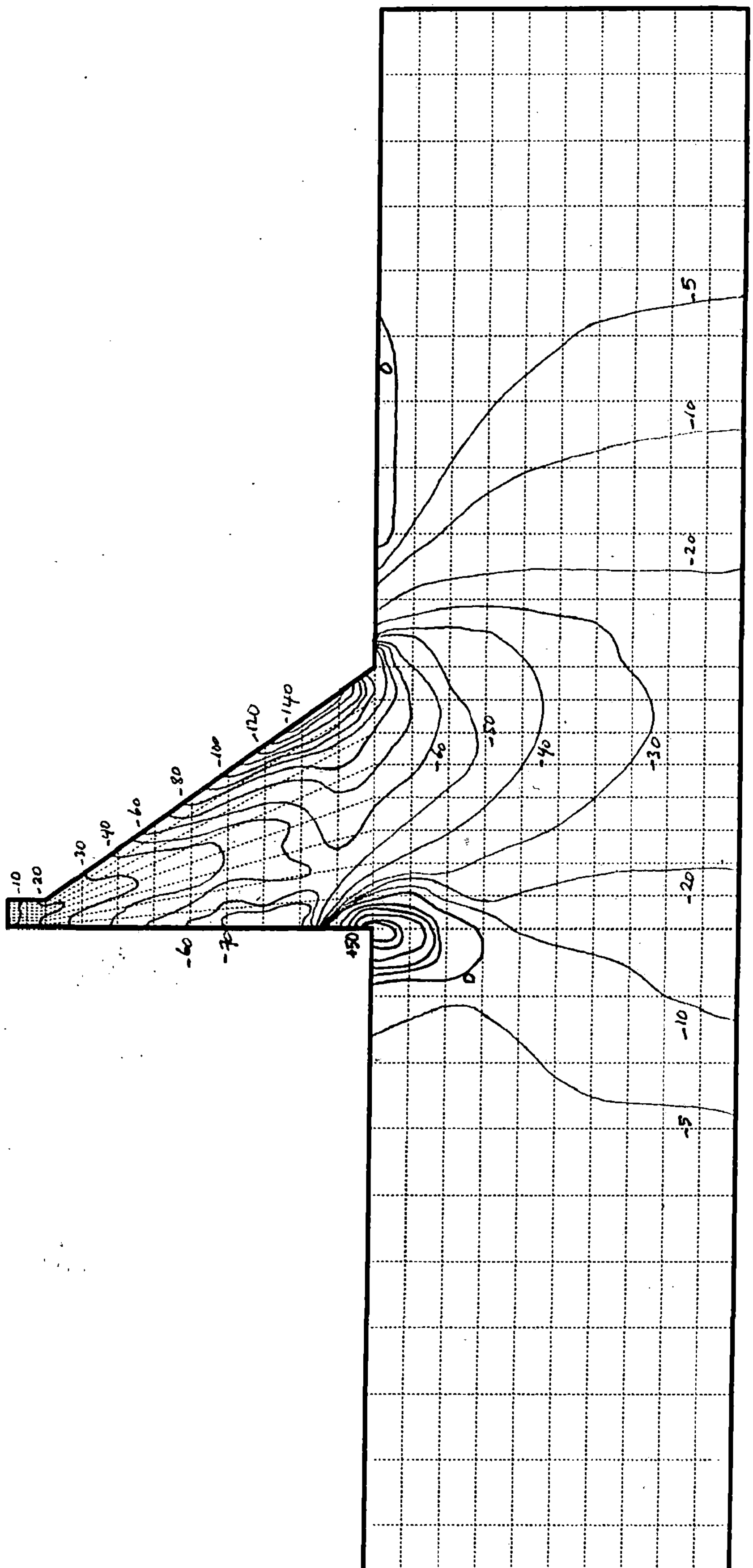


Figure 3.44 Contour of Major Principal Stress in Dam and Foundation of Part-2, Case 4 Study

3.4 Discussion on the Results of Part–3 Study

In this part, a shear zone 1 m wide with inclination of 45 degree is assumed to be located at different locations. It is located at 10 m from toe on the downstream side, at the center of dam base and 10 m from heel on upstream side. The foundation extent is taken in this part of study as 2H in lateral direction on both sides and 1H in depth, with fixed at the bottom and roller on lateral side. Foundation elasticity is taken 0.4 of dam elasticity and of shear zone as 1% of dam elasticity. Here, the displacement of crest, heel and toe and stresses at heel and toe are worked out in the three cases and analyzed.

3.4.1 Displacements

Table 3.32 shows the horizontal and vertical displacements at crest, heel and toe in all the three cases. From this table, it can be seen that the horizontal displacement at crest and toe in case 1 is the maximum among all the three cases and the vertical displacement at toe in case 1 is also the maximum among all the cases but it is practically same at the crest in all the cases. Here, it can be noted that in the condition of shear zone at the downstream end is the maximum and so it is a critical location.

Figures 3.45 to 3.47 show the deflected shape of dam and foundation of all cases and indicate that downstream location of shear zone is critical. The displacements with the shear zone in foundation have also been compared with the displacement without any shear zone in Table 3.32. The comparison shows that horizontal displacement of the crest and settlement at toe have increased with the presence of shear zone at the downstream location.

3.4.2 Stresses

Table 3.33 shows the stresses in all cases of this part of study. From this table, it is clear that in horizontal and vertical stresses are maximum tensile stresses when shear zone is in downstream location (case 1). Contours of horizontal stress in dam and foundation are shown in Figures 3.48 to 3.50. The tensile stress is concentrate around the heel and compressive around the toe in the case when shear zone is in downstream. In the other two cases where shear zone is in the center and upstream location, the entire foundation below the dam is subjected to horizontal tensile stress.

Figures 3.51 to 3.53 show the contours of vertical stress in dam and foundation system. From these figures, it can be seen that distribution of compressive stress dominates the dam and foundation system. Stress in foundation is also concentrated below of dam base and stressed zones in the sides are small. In fact, from these figures, it can be seen that the maximum tensile stress in case 1 is at heel and maximum compressive stress is at the toe. But in cases 2 and 3, both heel and toe are subjected to tensile stresses and the dam base is under compression. The maximum tensile stress on upstream of toe is 72.4 ton/m2 and the maximum compressive stress is 133.6 ton/m2. In case 2, this condition actually is somewhat similar with case 3 where the maximum tensile stress is 71.1 ton/m2 and maximum compressive stress is 132.2 ton/m2. These stresses are more in magnitude than those obtained without a shear zone. So, it can be inferred that so far as vertical stresses are concerned, the shear zone in the center or upstream location is more critical than case 1. In case of shear stress also, case 1 is critical as compared to other cases.

The principal stresses in all cases in this part of study are also given in Table 3.33. From this table, it can be seen that major principal stress in case 1 is the maximum both at heel and toe. The contours of major principal stresses are shown in Figure 3.54 to 3.56. From these figures, it can be noted that in case 1, tensile principal stress occurs at heel and compressive stress at toe. But in cases 2 and 3, tensile stresses seem both heel and toe with maximum compressive stress of 186.4 ton/m2 at around 20 m above the toe on the downstream face (Figure 3.55). The principal stresses are more than those worked out in the case with no shear zone in the foundation.

Table 3.32 Horizontal and vertical displacements (mm) at Crest, Heel and Toe of Part-3 Study

Case No.	LOCATION SHEAR ZONE	Horizontal			Vertical		
		Crest	Heel	Toe	Crest	Heel	Toe
1	D/S	14.00	-0.12	0.95	-1.08	-0.11	-4.97
2	CENTRE	6.64	-0.85	0.68	-1.19	0.11	-0.25
3	U/S	6.66	-0.78	0.62	-1.09	0.15	-0.26
	NO SHEAR ZONE	12.74	-0.59	0.65	-0.66	0.47	-3.58

Table 3.33 Stresses (Ton/m2) at Heel and Toe of Part-3 Study

Case No.	LOCATION SHEAR ZONE	Horizontal		Vertical		Shear		PS Max		PS Min	
		Heel	Toe	Heel	Toe	Heel	Toe	Heel	Toe	Heel	Toe
1	D/S	14.57	-45.36	46.75	-83.30	18.39	-43.11	57.49	-111.84	3.82	-16.83
2	CENTRE	2.41	0.18	26.55	47.72	23.65	-7.61	42.93	53.57	-13.97	-5.67
3	U/S	3.69	-0.12	28.44	46.87	23.47	-8.77	44.22	52.99	-12.08	-6.25
	NO SHEAR ZONE	16.48	-45.24	36.39	-61.41	20.23	-39.28	55.17	-93.69	-2.29	-12.95

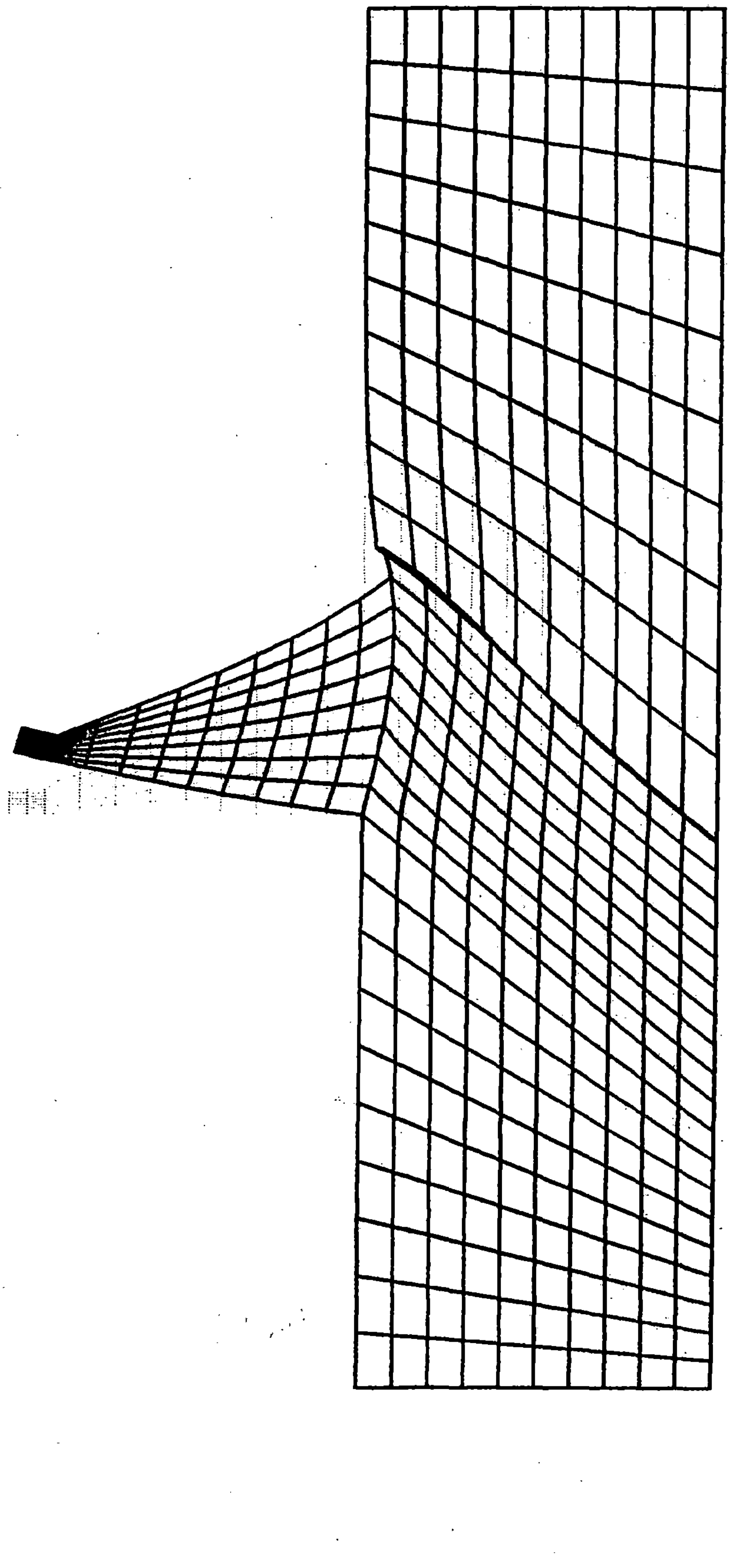


Figure 3.45 Deflected Shape of Dam of Part-3 Study
(d/s Shear Zone)
Deflection magniied by 1500 times

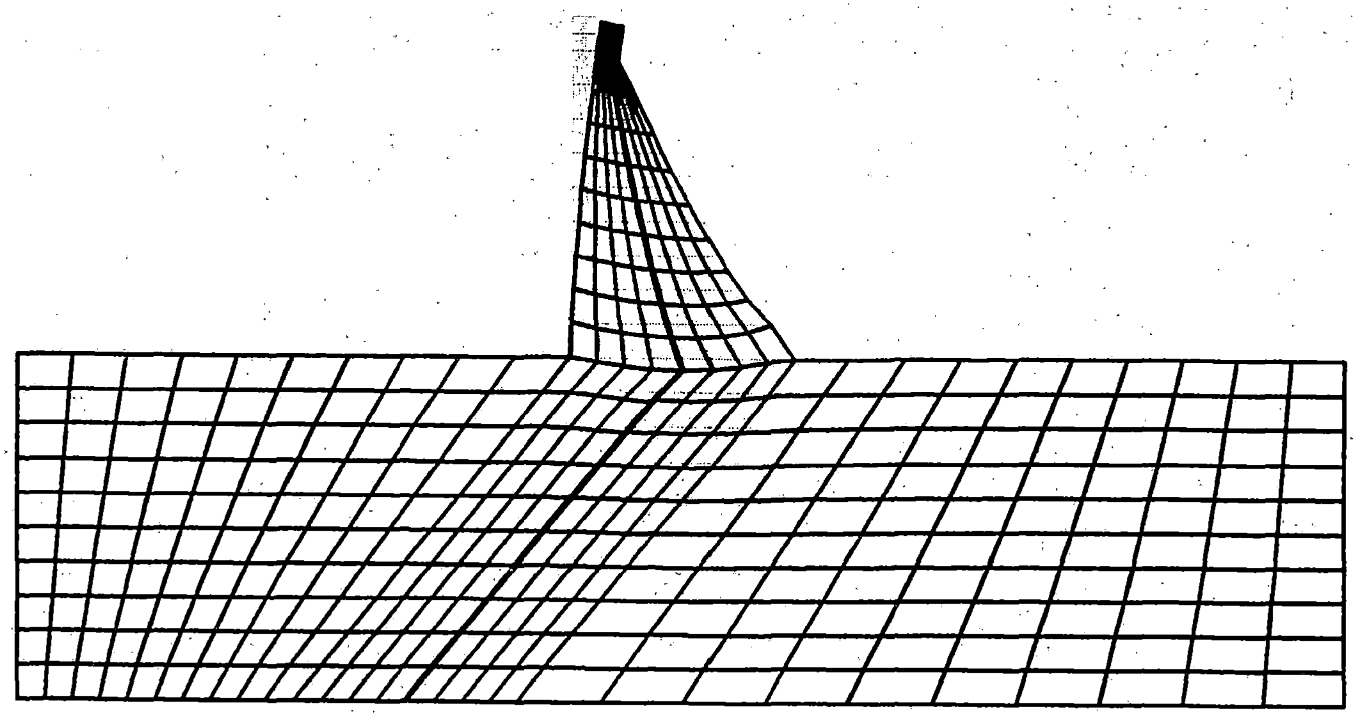


Figure 3.46 Deflected Shape of Dam of Part-3 Study
(Center Shear Zone)
Deflection magnified by 1500 times

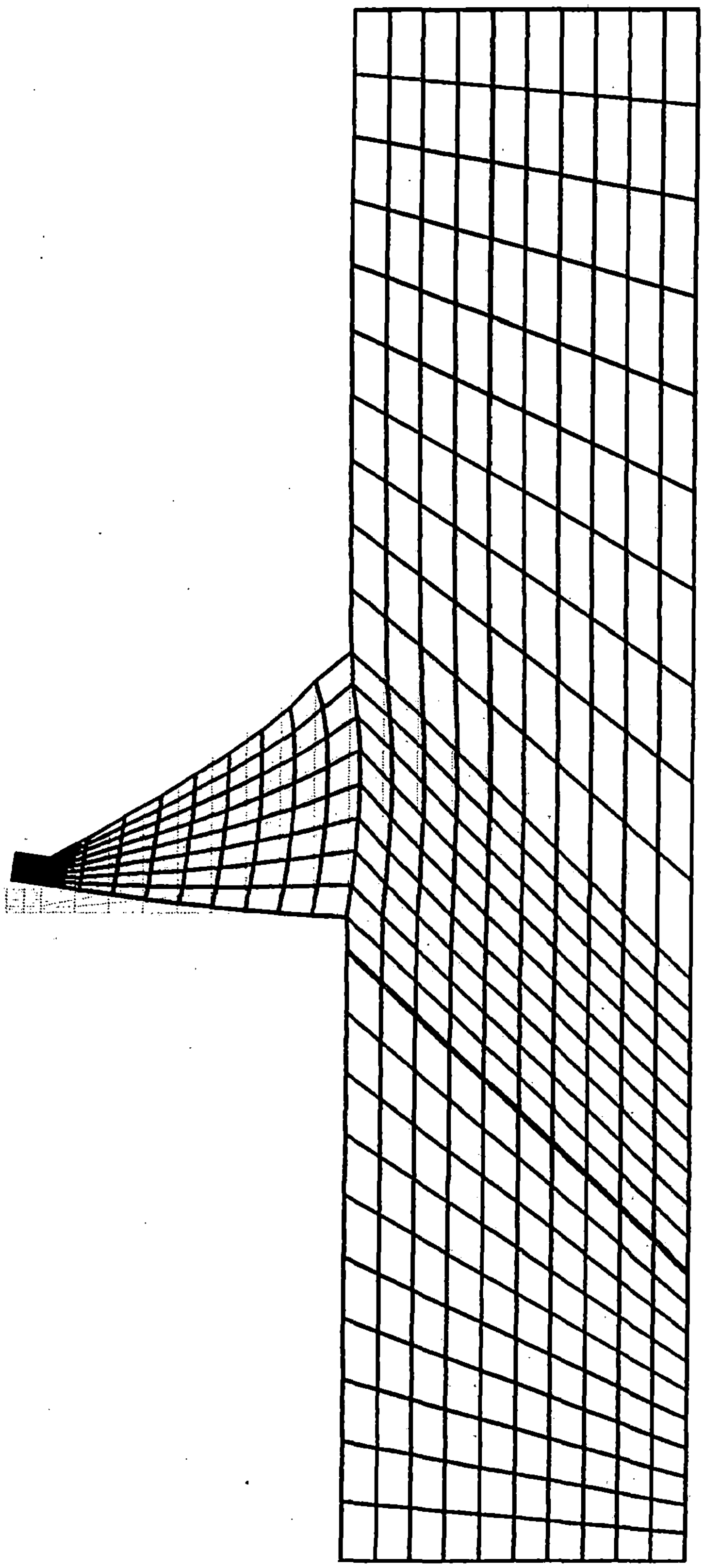


Figure 3.47 Deflected Shape of Dam of Part-3 Study (u/s Shear Zone)
Deflection magnified by 1500 times

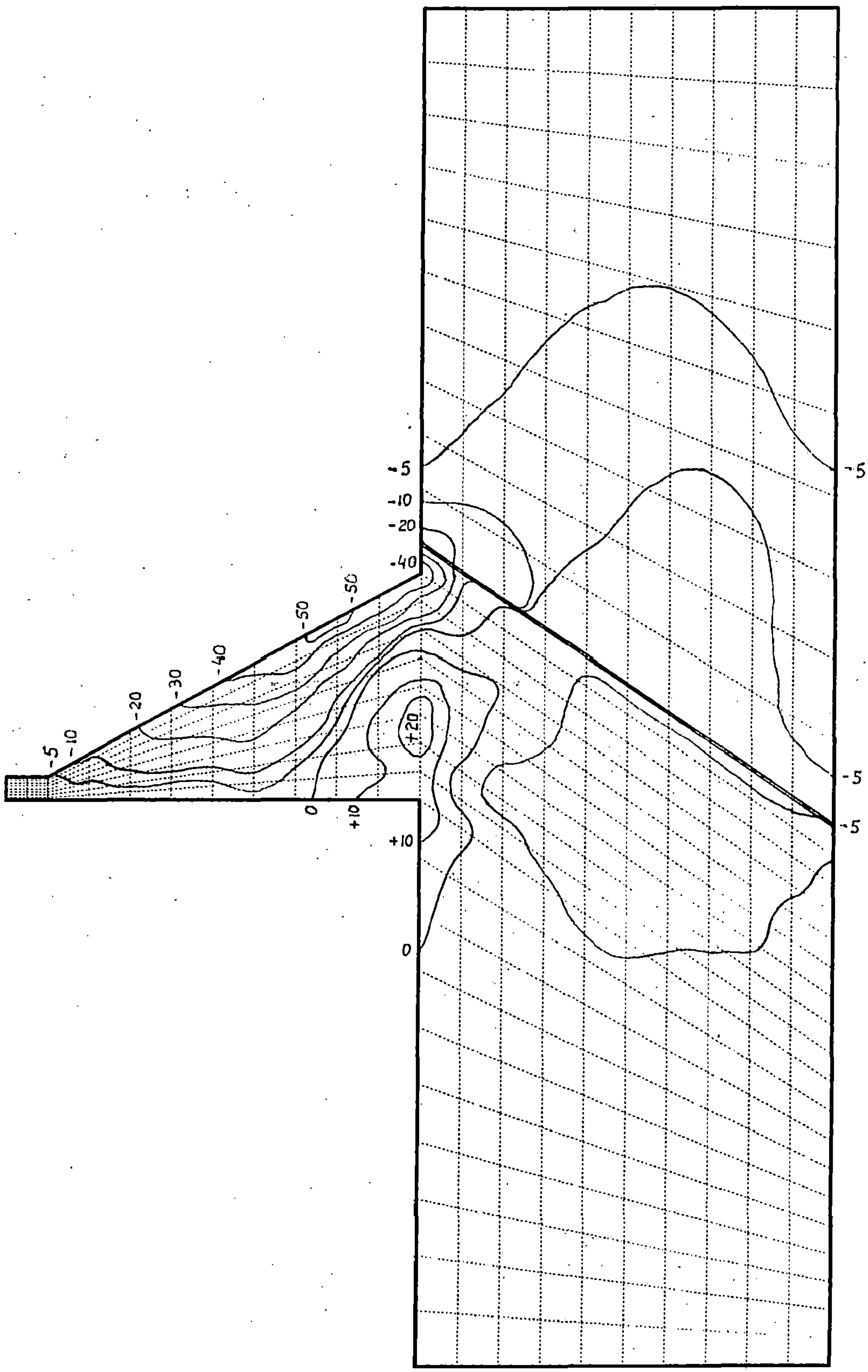


Figure 3.48 Contour of Horizontal Stress in Dam and Foundation of Part-3 Study (d/s Shear Zone)

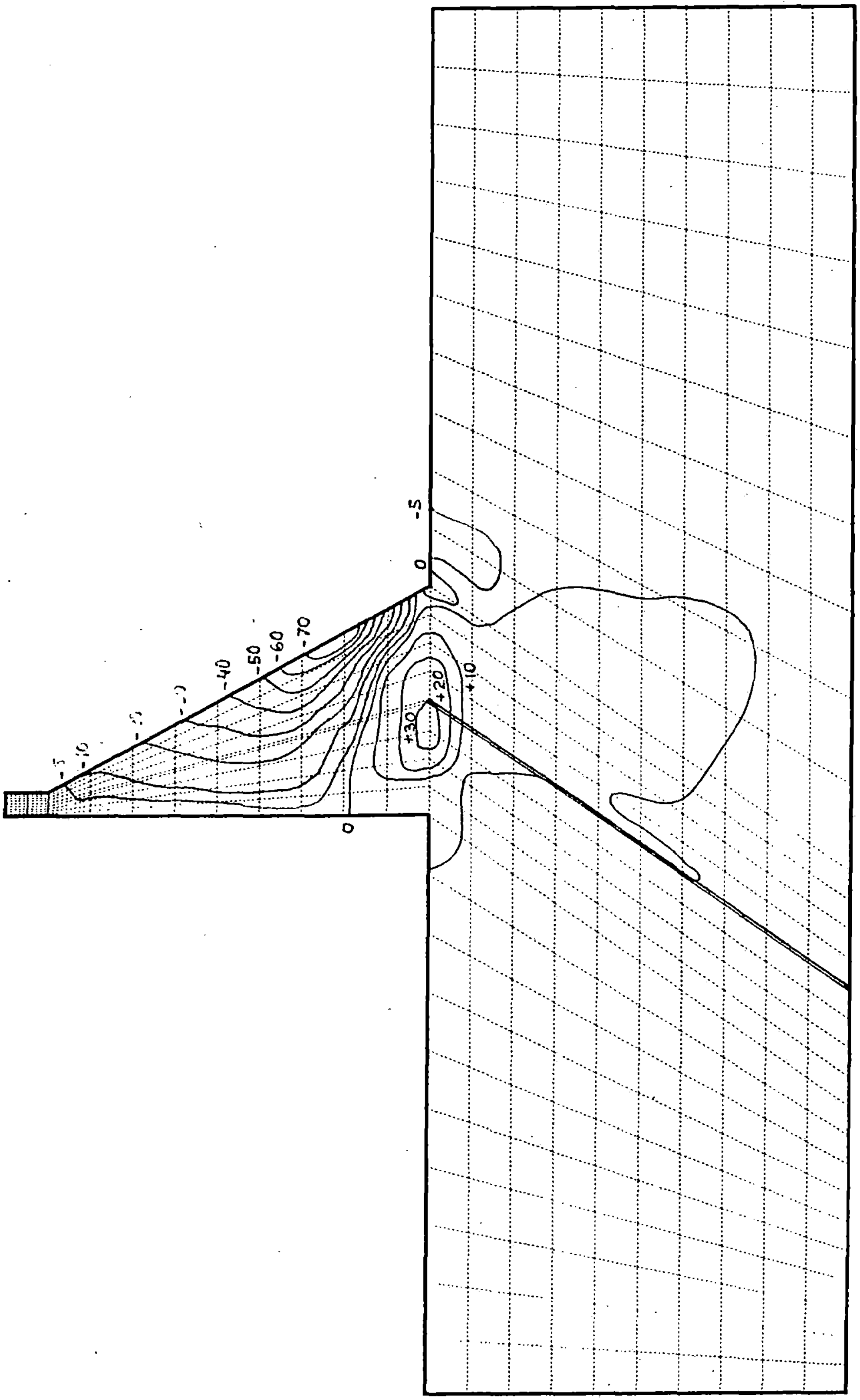


Figure 3.49 Contour of Horizontal Stress in Dam and Foundation of Part-3 Study (center Shear Zone)

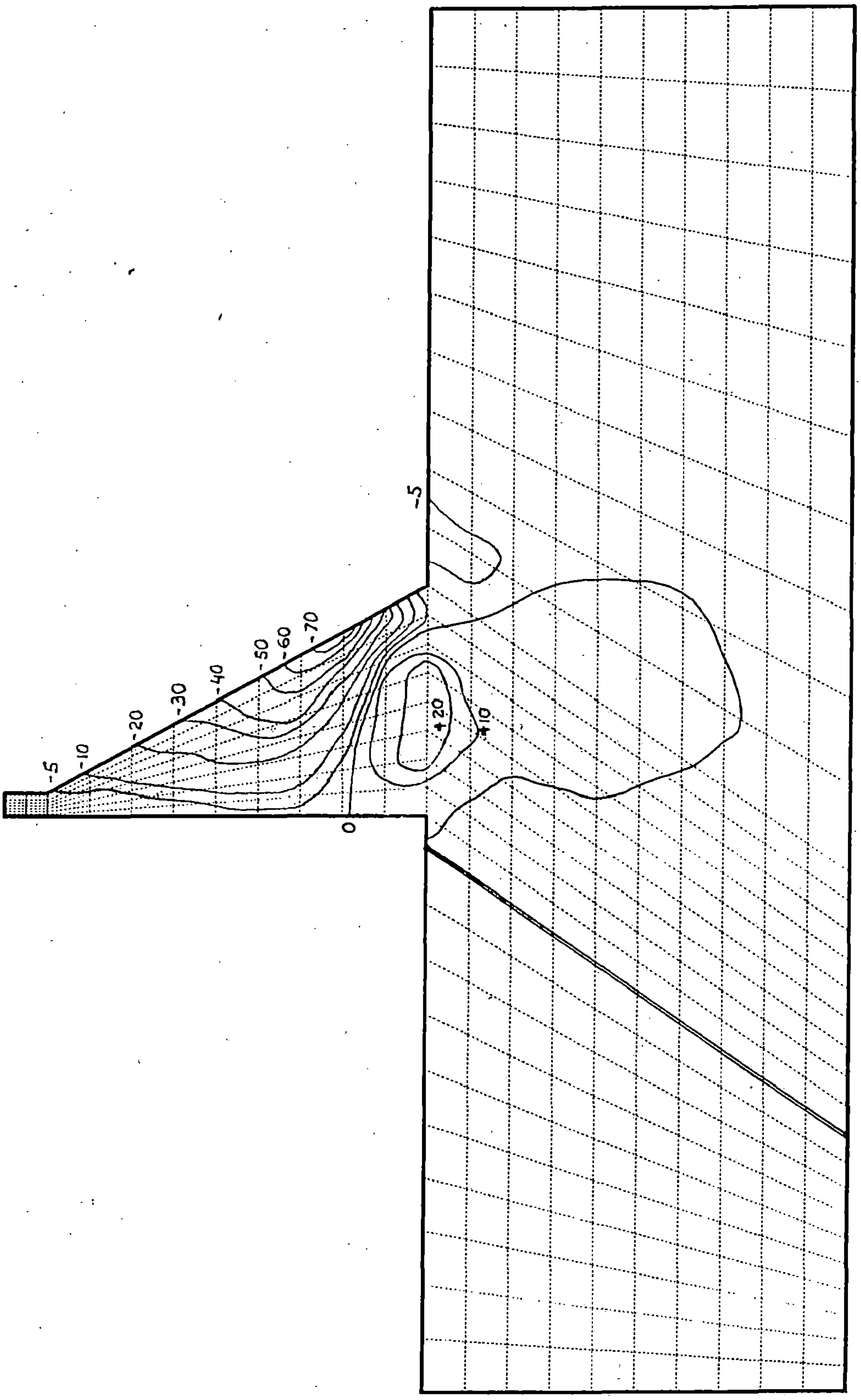


Figure 3.50 Contour of Horizontal Stress in Dam and Foundation of Part-3 Study (u/s Shear Zone)

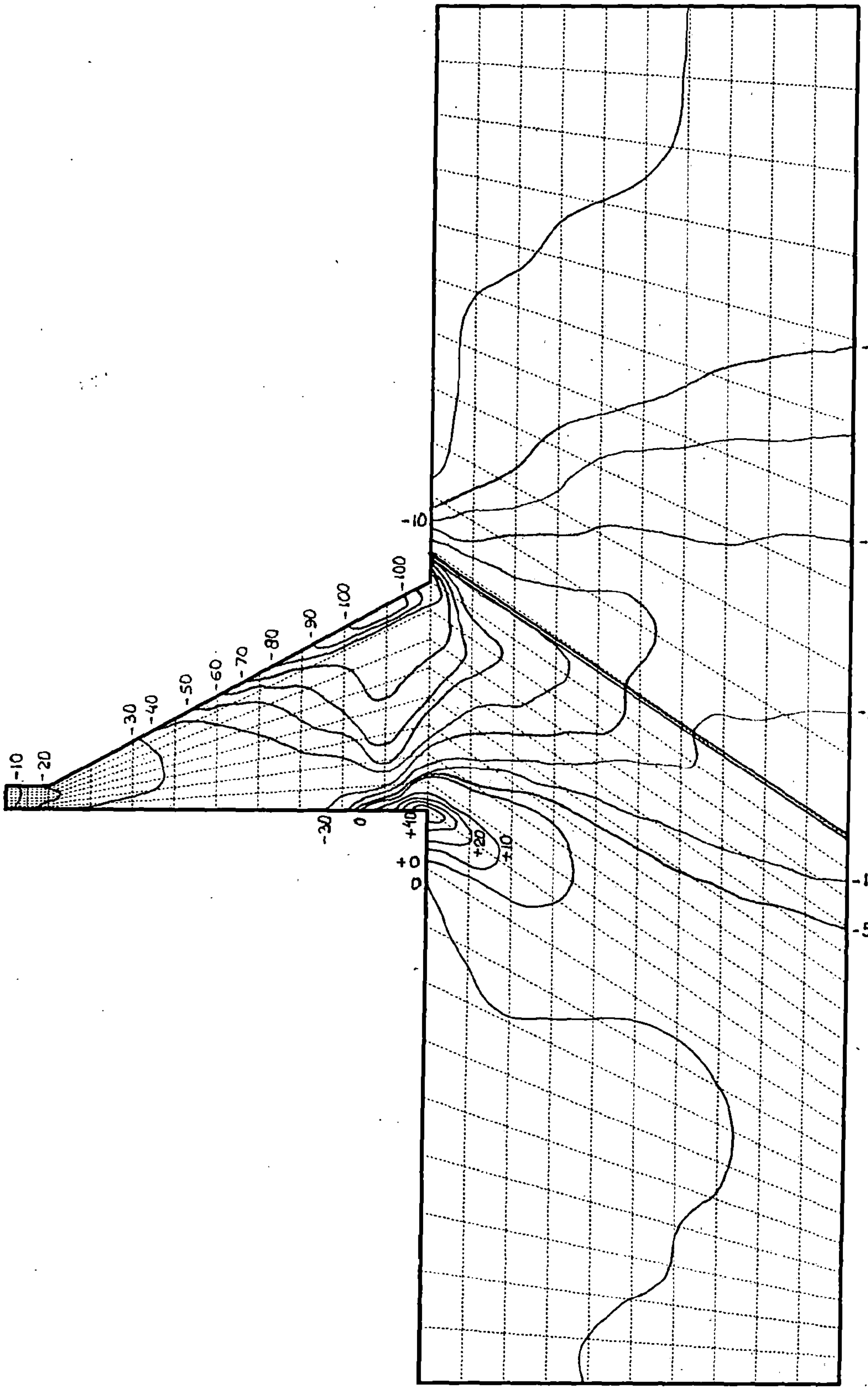


Figure 3.51 Contour of Vertical Stress in Dam and Foundation of Part-3 Study (d/s Shear Zone)

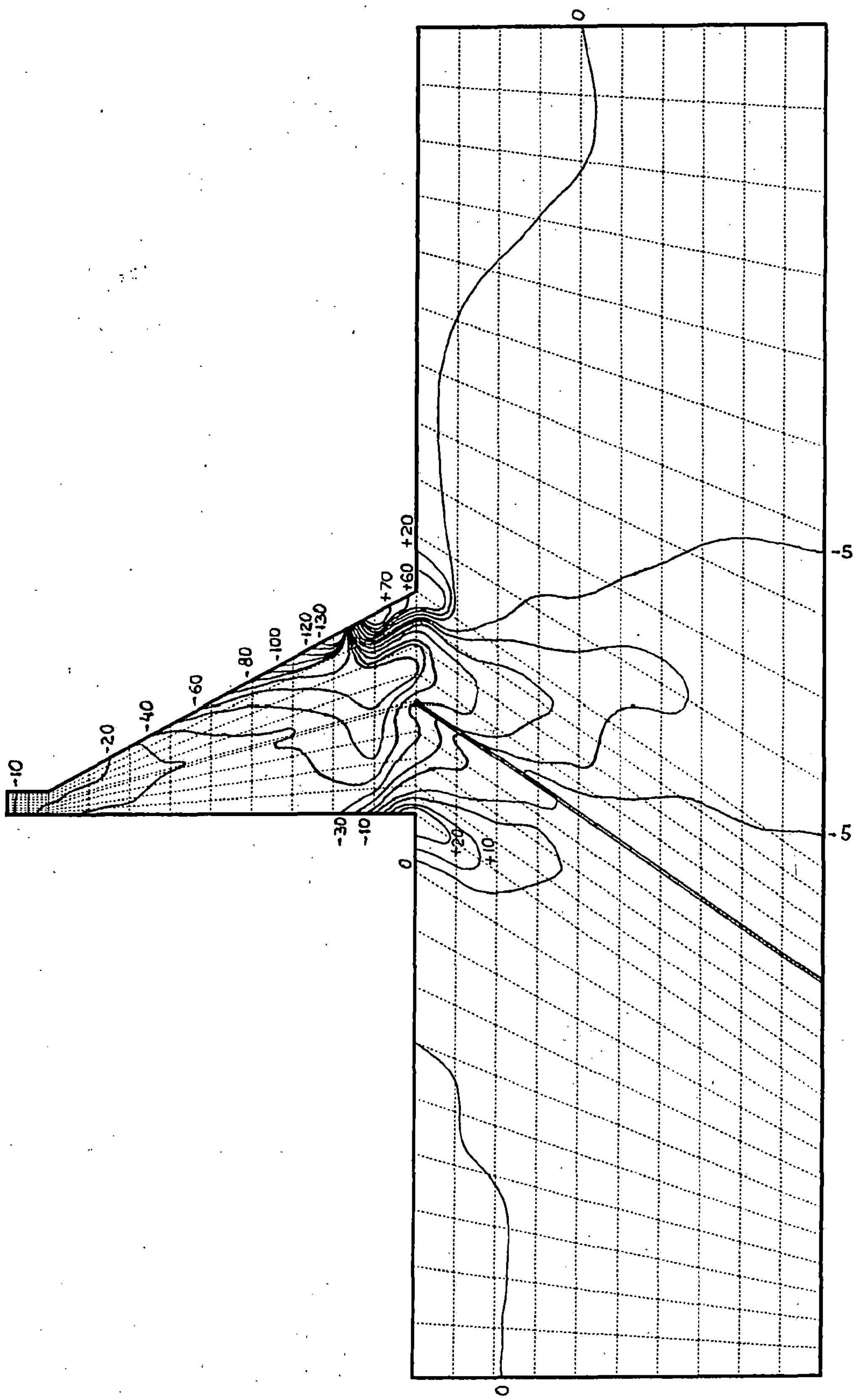


Figure 3.52 Contour of Vertical Stress in Dam and Foundation of Part-3 Study (center Shear Zone)

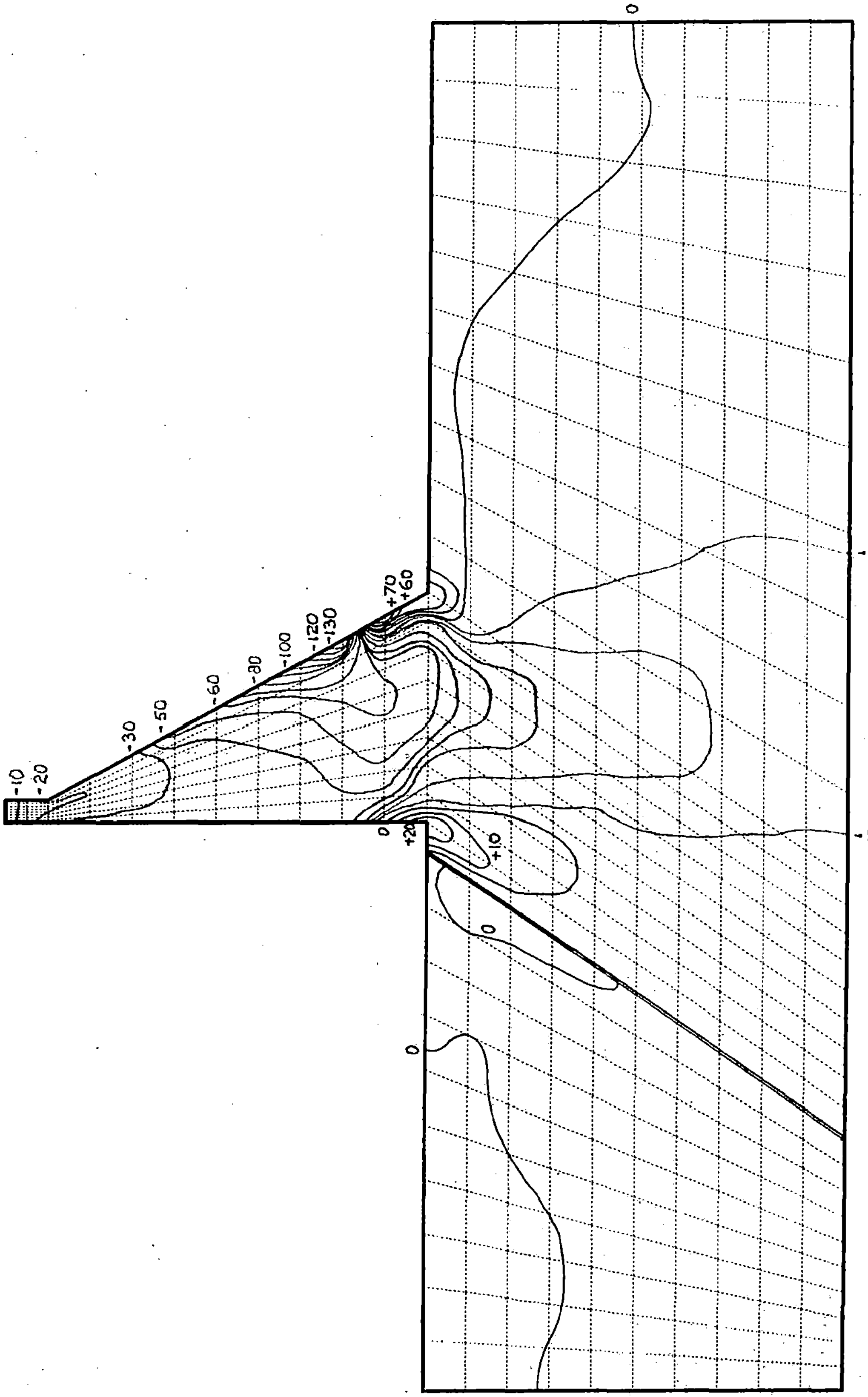


Figure 3.53 Contour of Vertical Stress in Dam and Foundation of Part-3 Study (u/s Shear Zone)

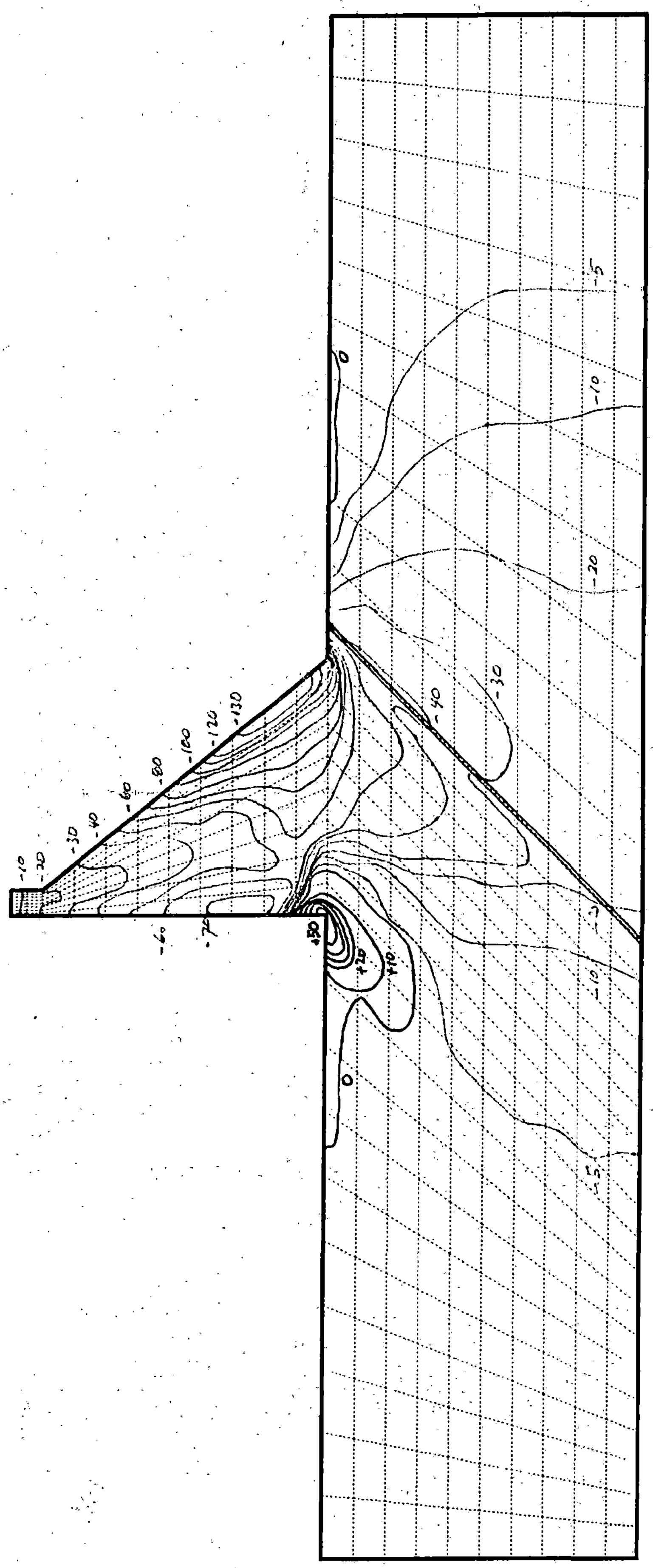


Figure 3.54 Contour of Major Principal Stress in Dam and Foundation of Part-3 Study (d/s Shear Zone)

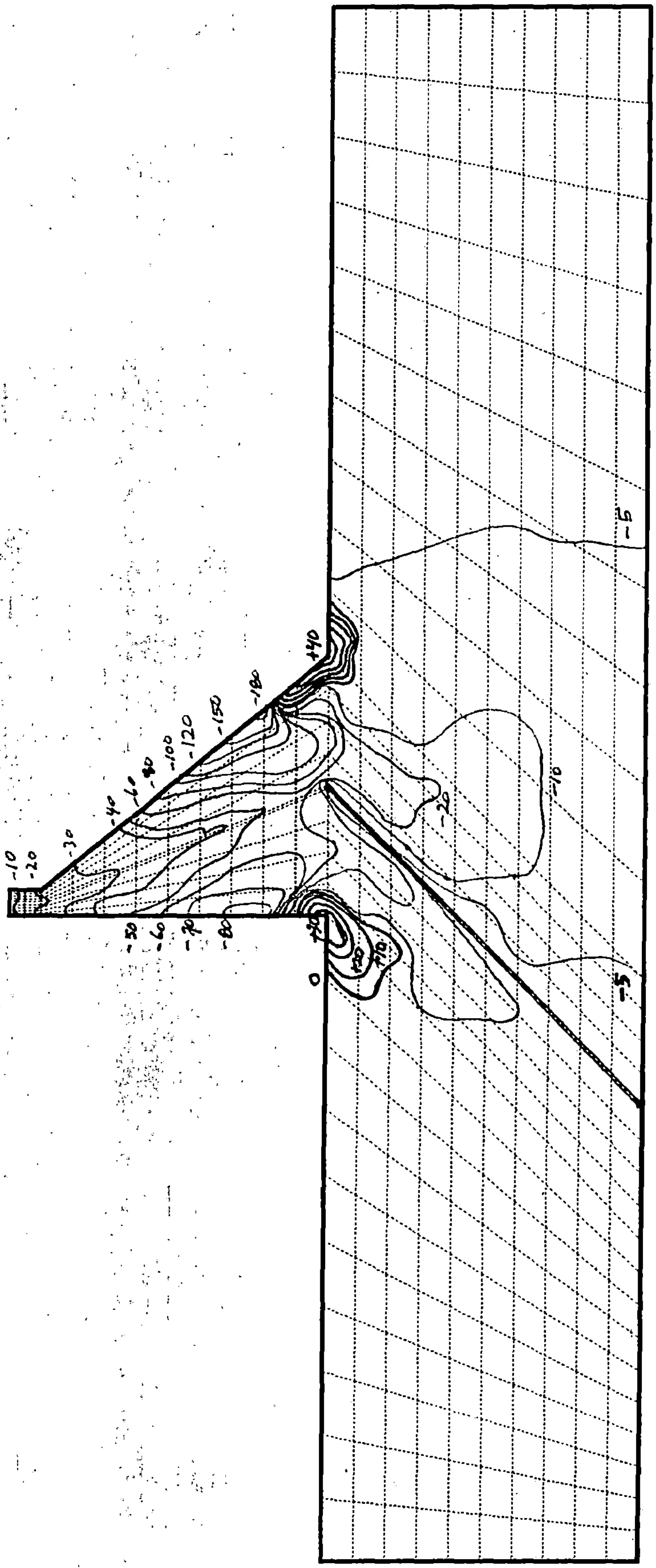


Figure 3.55 Contour of Major Principal Stress in Dam and Foundation of Part-3 Study (center Shear Zone)

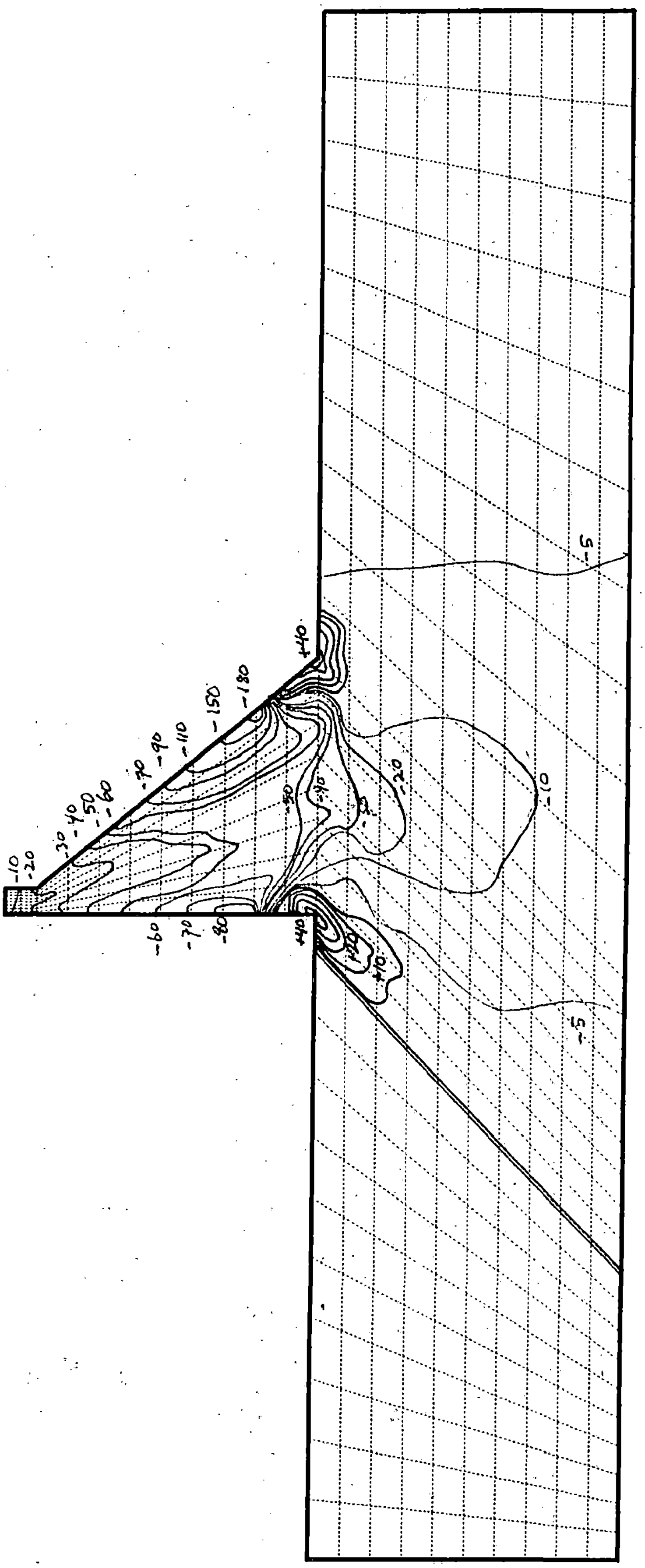


Figure 3.56 **Contour of Major Principal Stress in Dam and Foundation of Part-3 Study (u/s Shear Zone)**

Chapter - 4

CONCLUSIONS

In this study, a concrete gravity dam section 100 m high has been analyzed by using 2D-FEM programmed. The dam foundation system has been analyzed in different conditions. In the analysis, dam is assumed to be founded on weak rock of varying elastic modulus ranging from 0.2 to 0.8 times that of concrete. Different extents of foundation varying from 1H to 3H (H is height of dam section) have been considered. The Poisson's ratio of rock has been considered as 0.3 and 0.2. The dam foundation system has been analyzed both with full uplift and modified uplift (with drainage). The dam section has been analyzed with an inclined shear zone in foundation at different locations such as downstream, upstream and center of base of dam section. This study has been carried out in three parts and in each case, deformations and stresses (horizontal, vertical, shear, and principal stresses) at critical locations have been worked out and compared. The conclusion derived from this analysis are summarized below.

- Part-1 Study

  In this part of study, the dam section is analyzed with varying rock modulus, Poisson's ratio, and foundation extent by considering external loads of water pressure and full uplift pressure. The results of analysis show the effect of these parameters on deformations and stresses. The general conclusions are:

  1. Elastic modulus of foundation and foundation extent have a bearing on the deformations and stresses in dam foundation system.
  2. Boundary conditions of lateral sides (lateral extent 1.5H or more) are found to have little effect on stresses and deformations in dam foundation system.
  3. The value of Poisson's ratio of foundation are found to have little effect on stresses and deformations in dam foundation system.
  4. Modulus of foundation more than 0.5 times that of concrete is found to affect the values of stresses and deformations in dam foundation system marginally. Therefore, the foundation rock having a minimum elastic modulus of 0.5 times of concrete is suitable for the dam 100 m high.

5. Foundation extent 1.5H u/s, 1.5 d/s and 1H depth is considered adequate for analysis with rollers on the sides.

- Part-2 Study

In this part study, the dam section is analyzed with external loads of water pressure and modified uplift (with drainage). The result shows that:

1. Stress concentration in dam and foundation are observed around the heel and toe of dam. Tensile stress is concentrate at heel and compressive stress at toe. In foundation, stress concentration is seen below the dam base.
2. By increasing the foundation extent in depth and sides, the stresses get reduced but displacements marginally increase.
3. The comparison of displacements and stresses with full uplift and modified uplift are shown in Tables 3.30 and 3.31. It shows that displacement of heel and crest has marginally reduced and settlement of toe has increased with modified uplift. The stresses at toe (compressive) have increased and tensile stresses at heel have substantially reduced in case of modified uplift. Shear stresses have also increased in case of modified uplift.

- Part-3 Study

In this part study, a dam section is analyzed for stresses and deformations with a shear zone at different locations in foundation with loads and foundation extent as in part-2. Analysis of results shows that:

1. The deflection of crest and settlement of toe increase with the shear zone at downstream location. The vertical and principal stresses at heel (tensile) and toe (compressive) also increased about 70 to 100%.
2. Tensile stresses are found both at heel and toe in case a shear zone is located below the center of dam-base or in upstream of dam section.
3. Stress concentration in dam are not only found in heel and toe but also inside the dam and downstream face. In foundation, stress concentration is seen below the dam base.

Suggestion for Further Studies.

1. Dam may be analyzed for others forces also.
2. The dam section maybe analyzed with other stratification to get an insight into the behavior of the dam.
3. The study may be carried out with different heights of dam to specify the minimum rock modulus.

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