CADD PACKAGE FOR ANALYSIS AND DESIGN OF UNDERGROUND RC TANKS

A DISSERTATION

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

MASTER OF ENGINEERING

in

CIVIL ENGINEERING
WITH SPECIALIZATION IN
BUILDING SCIENCE AND TECHNOLOGY

By

SURINDER KUMAR

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF ROORKEE
ROORKEE - 247 667 (INDIA)

JANUARY, 1996

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the dissertation entitled "**CADD PACKAGE FOR ANALYSIS AND DESIGN OF UNDERGROUND RC TANKS**" in partial fulfilment of the requirement for the award of the degree of **MASTER OF ENGINEERING** with specialisation in **BUILDING SCIENCE AND TECHNOLOGY**, University of Roorkee, Roorkee, is an authentic record of my own work carried out from Aug. 1995 to January 1996, under the guidance of **Dr. P.C. JAIN**, Professor, Department of Civil Engineering, University of Roorkee, Roorkee.

The matter embodied in this dissertation has not been submitted by me for any other degree or diploma.

Dated: Jan. 30 , 1996

(SURINDER KUMAR)

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

30.1.96

(Dr. P.C. JAIN)
Professor
Civil Engineering Department
University of Roorkee
Roorkee - 247 667 (India)

ACKNOWLEDGEMENT

It is with pervid sincerity that I owe my great debt and gratefulness to Dr. P.C. JAIN, Professor, Department of Civil Engineering, University of Roorkee, Roorkee for his invaluable suggestions, experts guidance, incersant encouragement and constructive criticism althrough the persuance of this work under his able and patient guidance without his perpetual interest and sound counsel, this report would not have been brought out in the defacto shape.

The assistance received through friends and fellow students, especially those from R.S. KATHAIT and NAVEEN AGARWAL are thankfully acknowledged.

Thanks are also due to NCF, Library and CAD Centre Staff especially Mr. A.K. GAUR, Mr. M.S. RAWAT and Mr. VINOD KUMAR for their kind cooperation and help.

Finally, I have no words to express thanks and gratitude to my parents who have been my inspiration, through out this study.

Date : Jan.30,1996
Place: Roorkee

(SURINDER KUMAR)

SYNOPSIS

CADD PACKAGE FOR ANALYSIS AND DESIGN OF UNDERGROUND R.C. TANKS

Computers are widely used in Civil Engineering designs as they can perform computational tasks of a magnitude far beyond the capability of any human. The problems of analysis and design of underground reinforced concrete tanks have been dealt in this dissertation. Primarily, the analysis and design of reinforced concrete underground tanks involve tedious calculations and numerous design charts and their interpolation. Any careless human error may result in fatal error. Therefore, a computer aided design would appear to be necessary.

Underground tanks are used in water purification, sewage treatment and for storage of water reserve for fire fighting etc. The sides have been designed for both the cases, when tank is empty with earth pressure acting from out side and tank full with no earthfill surrounding it.

A software 'RCTANK' is developed for design of various elements of underground tanks under different end conditions of wall with varying site conditions. Drafting of rectangular tank has also been done for sectional views. Static and dynamic pressures both can be dealt, with choice resting on user. Software offers great deal of flexibility in structural design and

complies with relevant codal provisons, i.e. IS: 456-1978, IS: 1893-1984, IS: 3370-Part-I, II and IV.

The package has been developed in FORTRAN 77 language using FORTRAN 77 and PLOT88 compilers for use on any IBM compatible computer. The package is made complete and effective by including drafting part which gives sectional views of elevation and plan of rectangular tank.

The working of the software package has been illustrated by solving few design problems.

LIST OF FIGURES

LIST OF TABLES

LIST OF NOTATIONS

A_{stv} = Area of steel in vertical direction

BFT = Bearing stress in soil

D = Diameter of tank

FH = Free board

GAMA,γ = Unit weight of soil

H = Height of tank

H1 = Depth of tank in soil

K_a = Coefficient of lateral active earth pressure

L = Length of tank

Spagi(i) = Spacing of horizontal reinforcement at inner face

Spago(i) = Spacing of horizontal reinforcement at outer face

Spagvi(i) = Spacing of vertical reinforcement at inner face

Spagvo(i) = Spacing of vertical reinforcement at outer face

T = Thickness of wall

W = Unit weight of water

WT = Water table position below ground level

ZSS = Code for square/Rectangular tank

ϕ = Angle of internal friction of soil

δ = Angle of friction between wall and earthfill

CONTENTS

CHAPTER - 1
INTRODUCTION

1.1 GENERAL

In an age of major technical advancement, there can only be few innovations with such far reaching potential effects as the development of digital computer. In span of less than 40 years the computer has emerged from laboratory to become an extremely powerful tool touching the everyday life.

Initially, the use of computer was limited to field of Science and Technology, but more or less, it is now going to help every part of human knowledge. As far as uses of computer in Civil Engineering works is concerned, they are now gaining maturity in developed countries but is still in its infancy in developing countries like India.

Use of computer in Civil Engineering works is mainly concerned with the analysis and design of structures, but its multidirectional capability like ability to store and to sort an immense amount of information and carrying out most complex computations, showing almost instantaneously numerical and graphical results, resulted its use in nearly every field of Civil Engineering.

The designs of reinforced concrete liquid retaining structures involve many tedious calculations and numerous design charts. Frequently some careless human errors, which may be fatal to the design, may be introduced in calculations or in interpolation of design charts.

Some time numerical results given by computer may be confusing to user so graphical representation of analysis and design (drafting) is also required.

In view of this computer aided design and drafting (CADD), software package would appear to be necessary. The capability to take different options using computers will also relieve design engineer from tiring work associated with routine calculations leaving him plenty of time to take other important decisions.

Design and drafting of underground RC tanks has been dealt with in this dissertation under various end conditions of tank wall and site conditions. Design has been done for extreme condition of tank empty and tank full cases.

1.2 R.C. TANKS : A Brief Introduction

1.2.1 General

RC tanks are used for storage of large volume of potable, sanitation and industrial water, petroleum products, industrial acids and as sewage oxidation and settling ponds. They are also used in small hydroelectric power plants as settling and forebay tanks.

Based on shape, underground tank can mainly be classified as circular and rectangular tanks having flat or sloping base slab. Circular tanks are more advantageous for large storage because for a given volume it has less surface area than that of rectangular tanks. Furthermore the cylinderical wall can be made thinner because it is mainly subjected to hoop tension only, whereas rectangular tank wall undergoes both tension and bending both in horizontal and vertical direction. Circular tanks are uneconomical for small storage, as cost of shuttering increases due to curved shuttering requirement, whereas analysis of large rectangular tank is more time consuming and it is difficult to make them impervious due to corners. Circular tanks can be made impervious easily.

1.2.2 Underground Tanks

Generally in multistoreyed buildings, complete storage of water can not be provided on roofs and due to non availability of land underground tanks are preferred. Wholly or partly, RC underground tanks are used on water purification or sewage treatment plants, settling and forebay tanks in case of small hydro-electric power plants, oil storage in petrol pumps etc.

The side of tank has to resist earth pressure acting from outside and water pressure from inside. The worst case arises when tank is empty and soil around it is charged with water. A worse case also occurs when tank is full and earth around it shrinks away from walls. This eventually, however is safeguarded at time of construction by filling the space around with well compacted granular material so that it acts as support, but as per IS: 3370 (Part-I)-1965, relief from external earth pressure should not be relied upon unless sure about it.

Tanks are tested in some cases for leakage through walls before filling earth around the walls. In such circumstances, the tanks are designed for full liquid pressure acting outward.

For earth pressure calculation, level of subsoil water table is taken into consideration, if it rises above the bottom of tank, lower part of fill remains submerged and upper part saturated. The submerged soil exerts pressure with density of earth reduced due to buoyancy plus full water pressure.

The base of underground tanks is usually made monolithic with wall for small storage whereas in case of large storage, joints at base are provided. At the junction of base slab with side walls, waterproof joint with copper strip embedded on both sides should be provided. If the subsoil water is likely to rise above base level, then there may be an uplift pressure on base tending to lift it when tank is empty. Then base slab is designed for uplift pressure with projection, for safety against uplift.

1.3 OBJECTIVE OF STUDY

In this dissertation work, a user interactive computer aided design and drafting (CADD) package 'RCTANK' has been developed on **Tata Elexi-3220** main frame system installed at new computational facility of University of Roorkee using FORTRAN language. Drafting of Rectangular tanks has been done using PLOT88.

This package has options for type of tank (circular or rectangular) with different end conditions. For design of circular tank, dissertation work of Anuj Kumar Jain [8] has been taken and combined with rectangular tank program so as to form a complete package for design of underground tanks.

This CADD package is developed to design tank with varying site conditions and different end conditions with different types of base slabs.

For rectangular tanks, various end conditions are as follows:-

1. Top free & bottom fixed
2. Top free & bottom hinged
3. Top and bottom hinged.

For top free, bottom fixed case if L/H ratio exceeds 3.0, then wall is designed like cantilever retaining wall. Subsequently after design, drawings (Drafting) are prepared by program files named 'DRAFT1.FOR' for sectional elevation and 'DRAFT2.FOR' for sectional plan of tank. For cantilever, retaining wall case, sectional elevation is prepared by program file 'DRAFT3.FOR'.

Circular tanks have been designed for following end conditions:

1. Top free bottom fixed
2. Hinged at base free at top

For top free bottom fixed case if diameter exceeds 12m,then it is also designed like cantilever retaining wall. Design of these tanks has been done as per Indian Standard code method using coefficients given in IS: 3370 (Part IV)-1969. The static and dynamic pressure both can be dealt, with choice resting on user. Software offers great degree of flexibility to user and has been compiled with relevant codal provisions i.e. IS: 456-1978, IS: 1883-1994 and IS: 3370 (Part I, II, IV).

Illustration of above software package has been made by solving few design problems.

1.4 ORGANISATION OF THESIS

The work carried out is divided in following seven chapters.

Chapter-1. deals with general introduction to underground tanks, necessity of CADD package and objective of present study.

Chapter-2. deals with analysis and structural design of RC underground tanks.

Chapter-3. deals with codal provisions regarding design of underground tanks. It also lists changes in first revision of IS: 3370 (Part I and Part II) draft.

Chapter-4. deals with various joints used in underground tanks.

Chapter-5. deals with design steps involved in rectangular and circular tanks.

Chapter-6. deals with software and various subroutines developed.

Chapter-7. gives output of some test problems including drawings.

Chapter-8. contains concluding remarks.

CHAPTER 2

ANALYSIS OF UNDERGROUND TANKS

2.1 GENERAL

Underground tanks in addition to self weight are subjected to following forces.

(i) Water pressure acting outward

(ii) Earth pressure acting inward

(iii) Weight of water acting downward

(iv) Uplift pressure

Tank walls are designed for two conditions

(1) Tank empty with full earth pressure.

(2) Tank full with no earth pressure

First condition arises when tank is empty and second condition arises when surrounding earth shrinks or tank is checked for leakage.

In case earthfill is well compacted with granular material then water pressure may be taken as half of the actual water pressure with no earth pressure. But in most of the cases underground tanks are checked for leakage so it is essential to design the tank for full water pressure. (Fig.2.1).

The base slab of tank should be checked for uplift pressure, the worst condition arises when tank is empty with water table rising above base slab. The projection of base slab is decided on the basis of the fact that weight of soil on projected slab plus self weight of tank should be more than uplift force on the base slab.

2.2 ANALYSIS OF CIRCULAR TANKS

2.2.1 Circular Tank with flexible Joint at base

For tanks with no earth pressure condition, water pressure acting outward tends to increase the diameter, linearly varying from top to bottom as shown in Fig.2.2. This causes hoop tension in walls, whereas for empty tank case hoop compression is developed.

Hoop Tension = wHD/2

Hoop Compression = $\gamma H_1 D/2$ Ka

Where w & γ = wt density of liquid & earth respectively

H & H_1 = height of tank & earthfill respectively.

D = diameter of tank

2.2.2 Circular Tank with rigid joint at base

When joint at base is rigid, no horizontal movement of the wall at base is possible. Deflected shape of wall is shown in Fig.2.3. Upper part of wall will have hoop tension while lower portion behave like cantilever.

Various methods of analysis are as follows

1) Reissner's method [2]

2) Carpenter's Simplified Method [2]

3) Approximate Method [11]

4) IS Code Method [5]

5) Analytical Method [16]

(1) Reissner's Method

As per Dr.Reissner pressure is counteracted by the combined ring and cantilever action i.e. pressure at any depth of wall is composed of p_r(Portion of load carried by rings) and p_c(remaining load resisted by cantilevers)

i.e $$P_x = P_r + P_c$$

A curve dividing the triangular load into two portions called **"load distribution line"** shown in Fig.2.3 indicates that at X = H load is totally resisted by cantilever action (p_c = p at X=H). In upper portion of wall p_c assumes negative value, shown by horizontal shading in fig. 2.3.

According to this theory all tanks with same value of 'K' have similar load distribution curves. Factor 'K' is defined by expression given below.

$$K = \frac{12H^4}{(D/2)^2T^2} = \frac{48\ H^4}{D^2T^2}$$

Where H is height, T is thickness and D is diameter of tank.

Depending upon the value of 'K' various load distribution curves, tables for restraint moment (M_f) and maximum ring tension or compression are given in Fig.2.5 and Table 2.1 & 2.2 for both uniform and triangular section.

(2) Carpenter's Simplified Method

Carpenter, simplified Dr.Reissner's method and gave the values of maximum cantilever bending moment and maximum hoop tension and its position in terms of following expressions.

(a) Position of maximum hoop tension L = KH

(b) Maximum hoop tension = T = (1-K)pD/2

(c) Restrain moment = $F\ p\ H^2$

where, $p = \omega H$. The values of coefficients K & F depends upon H/D and H/T Ratios and can be taken from Fig.2.6 or Table 2.3.

(3) Approximate Method

This method is followed when Reissner's or carpenter's tables are not available. In approximate method, it is assumed that cantilever action will take place for a height 'h'.

Where

h = H/3 or 1m [whichever is greater] for $6 \leq H^2/DT \leq 12$.

h = H/4 or 1m [whichever is greater] for $12 \leq H^2DT \leq 30$.

Fig.2.7(a) & (b). Above this height 'h' there is hoop action, maximum hoop tension per meter height = w(H-h)D/2

(4) IS Code Method

IS:3370(Part IV)-1967 gives design tables for moment and hoop tension in circular tanks for various conditions of joints and loading for Poisson's ratio $\mu=0.2$ for concrete. We have case of triangular loading with base rigid and base hinged. The Table (2.4) to Table (2.7) give coefficients for various H^2/DT ratio and base conditions.

The hoop tension and moment in wall can be directly calculated from these coefficients using following expressions.

Hoop tension = coefficient * wHD/2 N/m

Bending moment = coefficient * wH^3 N-m

Shear force at base = coefficient * wH^2 N-m.

(5) Analytical Method

At any section at depth 'x' below the top, the deformation y_r due to hoop stress will be equal to displacement y_c due to horizontal shear. The sum of loads transferred due to cantilever action and ring action is evidently equal to intensity of water pressure at that section.i.e.

$$p_c + p_r = w.x \qquad \text{(i)}$$

I = moment of Inertia at depth 'x'

T = thickness of wall

For compatibility $y_c = y_r = y$ (say)

Tensile strain due to ring action = p_r D/2TE

Change in radius due to $p_r = y_r = p_r D^2/4TE$

or $p_r = 4T y_r E/D^2 = 4TE y/D^2$

From simple theory of bending we have

$$B.M = EI \left(\frac{d^2 y_c}{dx^2}\right) \text{ and load intensity } p_c = EI \frac{d^4 y_c}{dx^4} = EI \frac{d^4 y}{dx^4}$$

From (i) $$w.x - p_r = EI \left[\frac{d^4 y}{dx^4}\right]$$

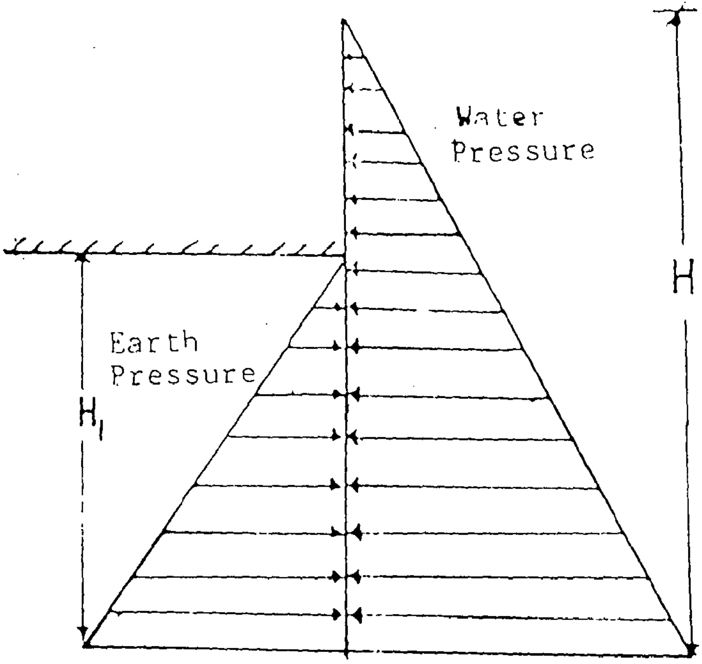
which on simplification gives (putting $T/ID^2 = \alpha^4$)

$$\frac{d^4 y}{dx^4} + 4\alpha^4 y = \frac{w\ x}{EI}$$

The solution of above differential equation is

$$y = w\ x /(4EI\ \alpha^4) + e^{\alpha x} (A \sin \alpha x + B \cos \alpha x) + e^{-\alpha x} (C \sin \alpha x + D \cos \alpha x)$$

The value of constant A, B, C and D can be evaluated by applying boundry conditions at ends of wall.Hence bending moment and hoop tension variation can be calculated.



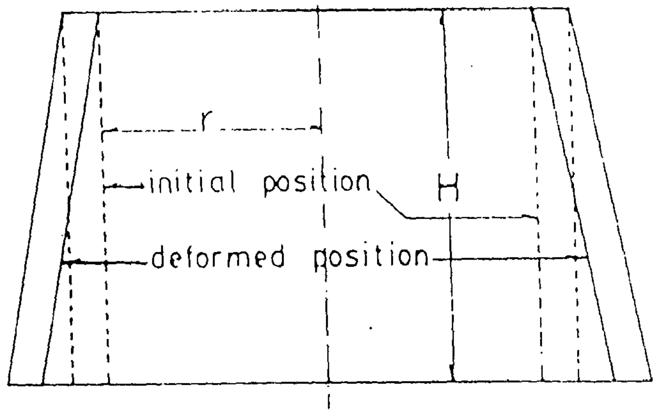
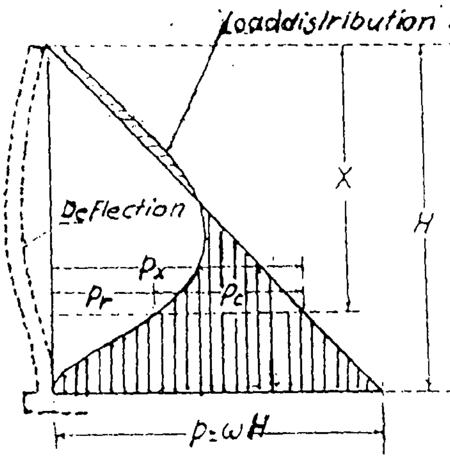


Fig.2.2 Deformation of circular tank having flexible joint at base.

Fig.2.1 Variation of earth & water pressure on tank wall.



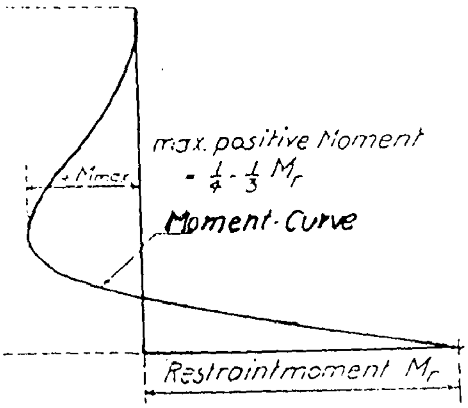


Fig. 2.3: Deflection of wall & variation of ring tension.

Fig.2.4 : Variation of bending moment

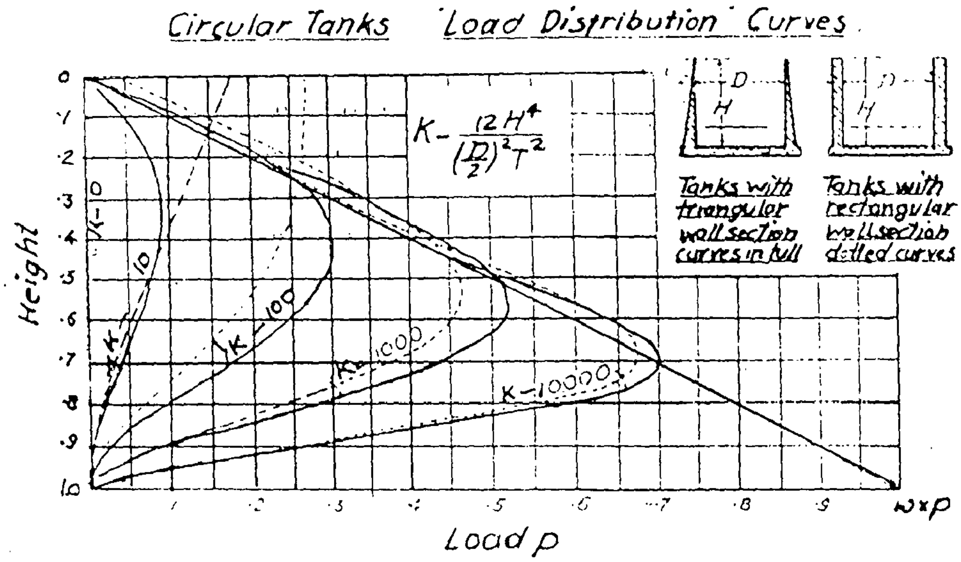


Fig.2.5 : Load distribution curves.

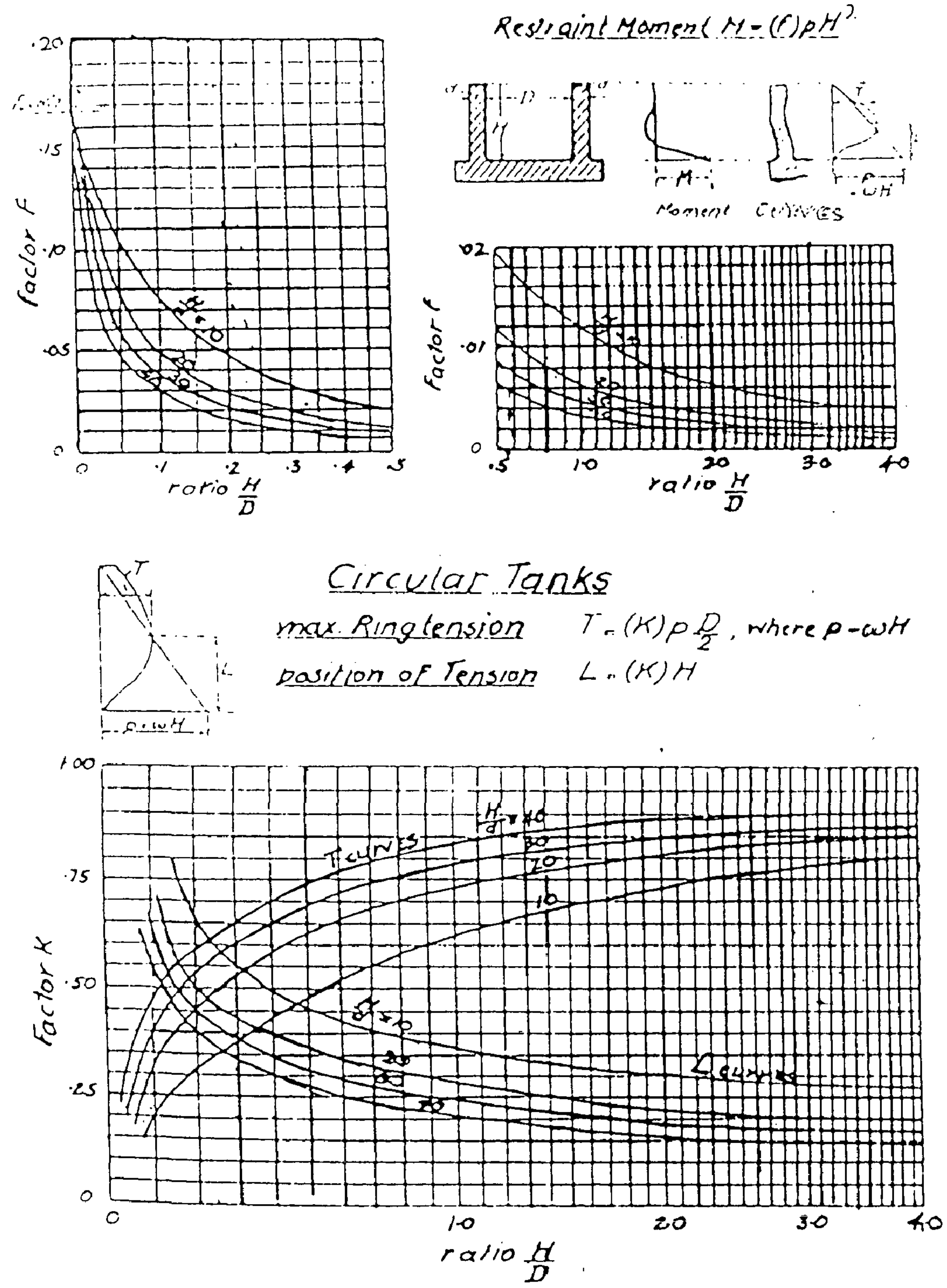


Fig.2.6 Carpenter's Coefficients

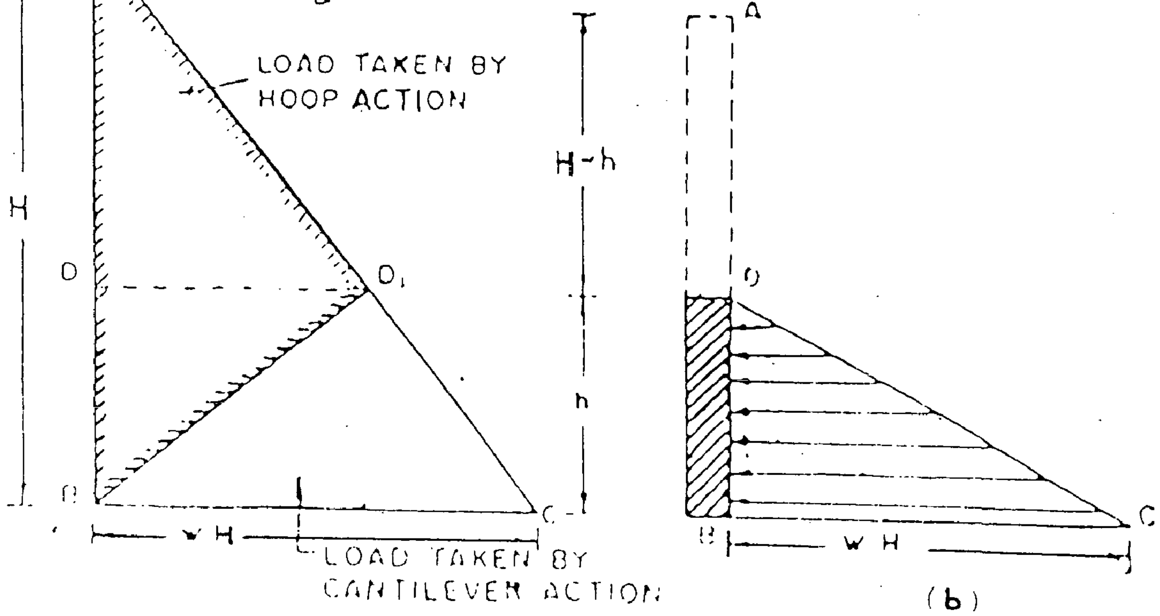


Fig 2.7 Approximate demarcation be-tween hoop & cantilever Action

TABLE 2.1 REISSNER'S VALUE OF RESTRAINT MOMENT M_f

($p = wH$)

K	Rectangular wall section	Triangular wall section
0	$0.167\ pH^2$	$0.167\ pH^2$
10	$0.110\ pH^2$	$0.140\ pH^2$
100	$0.0582\ pH^2$	$0.0707\ pH^2$
1000	$0.024\ pH^2$	$0.026\ pH^2$
10000	$0.0085\ pH^2$	$0.009\ pH^2$
∝	0	0

TABLE 2.2 REISSNER'S VALUE FOR RING TENSION

($p = wH$)

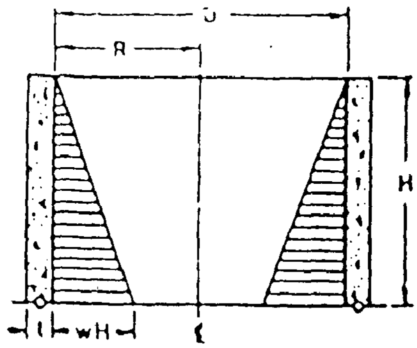
K	Rectangular wall section		Triangular wall section	
	Max. tension	Height from base	Max. tension	Height from base
0	0	—	—	—
10	$0.13\,p\left(\frac{D}{2}\right)$	1.0 H	$0.09\,p\left(\frac{D}{2}\right)$	0.65 H
100	$0.27\,p\left(\frac{D}{2}\right)$	1.0 H	$0.31\,p\left(\frac{D}{2}\right)$	0.58 H
1000	$0.47\,p\left(\frac{D}{2}\right)$	0.47 H	$0.52\,p\left(\frac{D}{2}\right)$	0.44 H
10000	$0.67\,p\left(\frac{D}{2}\right)$	0.31 H	$0.70\,p\left(\frac{D}{2}\right)$	0.30 H
∝	$1.0\,p\left(\frac{D}{2}\right)$	0	$1.0\,p\left(\frac{D}{2}\right)$	0

TABLE 2.3 CARPENTER'S VALUES OF COEFFICIENTS F AND K

Factor		F				K			
$\frac{H}{T}$		10	20	30	40	10	20	30	40
Values of H/D	0.2	0.046	0.028	0.022	0.015	—	0.50	0.45	0.40
	0.3	0.032	0.019	0.014	0.010	0.55	0.43	0.38	0.33
	0.4	0.024	0.014	0.010	0.007	0.50	0.39	0.35	0.30
	0.5	0.020	0.012	0.009	0.006	0.45	0.37	0.32	0.27
	1.0	0.012	0.006	0.005	0.003	0.37	0.30	0.24	0.21
	2.0	0.005	0.003	0.002	0.002	0.28	0.22	0.19	0.16
	4.0	0.003	0.002	0.002	0.001	0.27	0.20	0.17	0.14

TABLE 2.4 Coefficients for hoop tension in cylindrical wall hinged at base

T = Coefficient × wHR kg/m

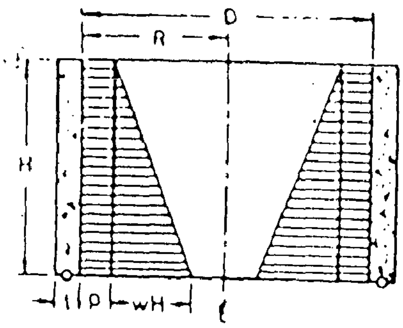


$\frac{H^2}{Dt}$	Coefficients at Point									
	0·0H	0·1H	0·2H	0·3H	0·4H	0·5H	0·6H	0·7H	0·8H	0·9H
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
0·4	+0·474	+0·440	+0·395	+0·352	+0·308	+0·264	+0·215	+0·165	+0·111	+0·057
0·8	+0·423	+0·402	+0·381	+0·358	+0·330	+0·297	+0·249	+0·202	+0·145	+0·076
1·2	+0·350	+0·355	+0·361	+0·362	+0·358	+0·342	+0·309	+0·256	+0·186	+0·098
1·6	+0·271	+0·303	+0·341	+0·369	+0·385	+0·385	+0·362	+0·314	+0·233	+0·124
2·0	+0·205	+0·260	+0·321	+0·373	+0·411	+0·434	+0·419	+0·369	+0·280	+0·151
3·0	+0·074	+0·179	+0·281	+0·375	+0·449	+0·506	+0·519	+0·479	+0·375	+0·210
4·0	+0·017	+0·137	+0·253	+0·367	+0·469	+0·545	+0·579	+0·553	+0·447	+0·256
5·0	−0·008	+0·114	+0·235	+0·356	+0·469	+0·562	+0·617	+0·606	+0·503	+0·294
6·0	−0·011	+0·103	+0·223	+0·343	+0·463	+0·566	+0·639	+0·643	+0·547	+0·327
8·0	−0·015	+0·096	+0·208	+0·324	+0·443	+0·564	+0·661	+0·697	+0·621	+0·386
10·0	−0·008	+0·095	+0·200	+0·311	+0·428	[illegible]	+0·666	+0·730	+0·678	+0·433
12·0	−0·002	+0·097	+0·197	+0·302	[illegible]	+0·541	+0·664	+0·750	+0·720	+0·477
14·0	0·000	+0·098	+0·197	+0·299	+0·408	+0·531	+0·659	+0·761	+0·752	+0·513
16·0	+0·002	+0·100	+0·198	+0·299	[illegible]	+0·521	+0·650	+0·764	+0·776	+0·536

Note 1 — w = Density of the liquid.
Note 2 — Positive sign indicates tension.

TABLE 2.5 Coefficients for bending moment in cylindrical wall hinged at base

Moment = Coefficient × ($wH^3 + pH^2$) kgm/m

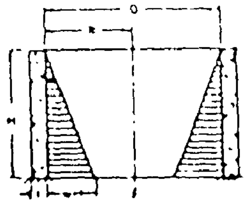


$\frac{H^2}{Dt}$	Coefficients at Point									
	0·1H	0·2H	0·3H	0·4H	0·5H	0·6H	0·7H	0·8H	0·9H	1·0H
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
0·4	+0·002 0	+0·007 2	+0·015 1	+0·023 0	+0·030 1	+0·034 8	+0·035 7	+0·031 2	+0·019 7	0
0·8	+0·001 9	+0·006 4	+0·013 3	+0·020 7	+0·027 1	+0·031 9	+0·032 9	+0·029 2	+0·018 7	0
1·2	+0·001 6	+0·005 8	+0·011 1	+0·017 7	+0·023 7	+0·028 0	+0·029 6	+0·026 3	+0·017 1	0
1·6	+0·001 2	+0·004 4	+0·009 1	+0·014 5	+0·019 5	+0·023 6	+0·025 5	+0·023 2	+0·015 5	0
2·0	+0·000 9	+0·003 3	+0·007 3	+0·011 4	+0·015 8	+0·019 9	+0·021 9	+0·020 5	+0·014 5	0
3·0	+0·000 4	+0·001 8	+0·004 0	+0·006 3	+0·009 2	+0·012 7	+0·015 2	+0·015 3	+0·011 1	0
4·0	+0·000 1	+0·000 7	+0·001 6	+0·003 3	+0·005 7	+0·008 3	+0·010 9	+0·011 8	+0·009 2	0
5·0	0·000 0	+0·000 1	+0·000 6	+0·001 6	+0·003 4	+0·005 7	+0·008 0	+0·009 4	+0·007 8	0
6·0	0·000 0	+0·000 0	+0·000 2	+0·000 8	+0·001 9	+0·003 9	+0·006 2	+0·007 8	+0·006 8	0
8·0	0·000 0	+0·000 0	−0·000 2	+0·000 0	+0·000 7	+0·002 0	+0·003 8	+0·005 7	+0·005 4	0
10·0	0·000 0	0·000 0	−0·000 2	−0·000 1	+0·000 2	+0·001 1	+0·002 5	+0·004 3	+0·004 5	0
12·0	0·000 0	0·000 0	−0·000 1	−0·000 2	0·000 0	+0·000 5	+0·001 7	+0·001 2	+0·003 9	0
14·0	0·000 0	0·000 0	−0·000 1	−0·000 1	−0·000 1	0·000 0	+0·001 2	+0·002 6	+0·003 3	0
16·0	0·000 0	0·000 0	0·000 0	−0·000 1	−0·000 2	−0·000 4	+0·000 8	+0·002 2	+0·002 9	0

Note 1 — w = Density of the liquid.
Note 2 — Positive sign indicates tension on the outside

TABLE 2.6 Coefficients for hoop tension in cylindrical wall fixed at base

T = Coefficient × wHR kg/m



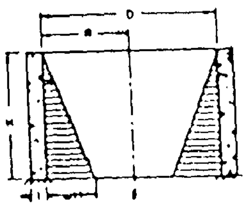
H^2/Dt	Coefficients at point									
	0·0H	0·1H	0·2H	0·3H	0·4H	0·5H	0·6H	0·7H	0·8H	0·9H
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
0·4	+0·149	+0·134	+0·120	+0·101	+0·082	+0·066	+0·049	+0·029	+0·014	+0·004
0·8	+0·263	+0·239	+0·215	+0·109	+0·160	+0·130	+0·096	+0·063	+0·034	+0·010
1·2	+0·283	+0·271	+0·254	+0·234	+0·209	+0·180	+0·142	+0·099	+0·054	+0·016
1·6	+0·265	+0·268	+0·268	+0·266	+0·250	+0·226	+0·185	+0·134	+0·075	+0·023
2·0	+0·234	+0·251	+0·273	+0·285	+0·285	+0·274	+0·232	+0·172	+0·104	+0·031
3·0	+0·134	+0·203	+0·267	+0·322	+0·357	+0·362	+0·330	+0·262	+0·157	+0·052
4·0	+0·067	+0·164	+0·256	+0·339	+0·403	+0·429	+0·409	+0·334	+0·210	+0·073
5·0	+0·025	+0·137	+0·245	+0·346	+0·428	+0·477	+0·469	+0·398	+0·259	+0·092
6·0	+0·018	+0·119	+0·234	+0·344	+0·441	+0·504	+0·514	+0·447	+0·301	+0·112
8·0	−0·001	+0·104	+0·218	+0·335	+0·443	+0·534	+0·575	+0·530	+0·381	+0·151
10·0	−0·001	+0·098	+0·208	+0·323	+0·437	+0·542	+0·608	+0·589	+0·440	+0·179
12·0	−0·005	+0·097	+0·202	+0·312	+0·429	+0·543	+0·628	+0·633	+0·494	+0·211
14·0	−0·002	+0·098	+0·200	+0·306	+0·420	+0·539	+0·639	+0·666	+0·541	+0·241
16·0	0·000	+0·099	+0·199	+0·304	+0·412	+0·531	+0·641	+0·687	+0·582	+0·265

Note 1 — w = Density of the liquid.

Note 2 — Positive sign indicates tension.

TABLE 2.7 Coefficients for bending moment in cylindrical wall fixed at base

Moment = Coefficient × wH^3 kgm/m



H^2/Dt	Coefficients at point									
	0·1H	0·2H	0·3H	0·4H	0·5H	0·6H	0·7H	0·8H	0·9H	1·0H
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
0·4	+0·0005	+0·0014	+0·0021	+0·0007	−0·0042	−0·0150	−0·0302	−0·0529	−0·0816	−0·1205
0·8	+0·0011	+0·0037	+0·0063	+0·0080	+0·0070	+0·0023	−0·0068	−0·0024	−0·0465	−0·0795
1·2	+0·0012	+0·0042	+0·0077	+0·0103	+0·0112	+0·0090	+0·0022	−0·0108	−0·0311	−0·0602
1·6	+0·0011	+0·0041	+0·0075	+0·0107	+0·0121	+0·0111	+0·0058	−0·0051	−0·0232	−0·0505
2·0	+0·0010	+0·0035	+0·0068	+0·0099	+0·0120	+0·0115	+0·0075	−0·0021	−0·0185	−0·0436
3·0	+0·0006	+0·0024	+0·0047	+0·0071	+0·0090	+0·0097	+0·0077	+0·0012	−0·0119	−0·0333
4·0	+0·0003	+0·0015	+0·0028	+0·0047	+0·0066	+0·0077	+0·0069	+0·0023	−0·0080	−0·0268
5·0	+0·0002	+0·0008	+0·0016	+0·0029	+0·0046	+0·0059	+0·0059	+0·0028	−0·0058	−0·0222
6·0	+0·0001	+0·0003	+0·0008	+0·0019	+0·0032	+0·0046	+0·0051	+0·0029	−0·0041	−0·0187
8·0	0·0000	+0·0001	+0·0002	+0·0008	+0·0016	+0·0028	+0·0038	+0·0029	−0·0022	−0·0146
10·0	0·0000	0·0000	+0·0001	+0·0004	+0·0007	+0·0019	+0·0029	+0·0028	−0·0012	−0·0122
12·0	0·0000	−0·0001	+0·0001	+0·0002	+0·0003	+0·0013	+0·0023	+0·0026	−0·0005	−0·0104
14·0	0·0000	0·0000	0·0000	0·0000	+0·0001	+0·0008	+0·0019	+0·0023	0·0001	−0·0090
16·0	0·0000	0·0000	−0·0001	−0·0002	−0·0001	+0·0004	+0·0013	+0·0019	+0·0001	−0·0079

Note 1 — w = Density of the liquid.

Note 2 — Positive sign indicates tension on the outside

2.3 ANALYSIS OF RECTANGULAR TANKS

The walls of a rectangular tank are subjected to bending moment both in the horizontal as well as in vertical direction. The magnitude of moment will depend upon several factors such as length, breadth & height of tank, and the condition of support of wall at top and bottom edges. If the length of wall is more in comparison to its height the moments will be mainly in the vertical direction i.e., the panel will bend as a cantilever. However, if height is large in comparison to length, the moment will mainly be in the horizontal direction and the panel will bend like a slab supported on edges. In addition to these moments, the walls are also subjected to direct pull exerted by water pressure.

Following are the method of analysis:

1. Approximate Method [11]
2. I.S. Code Method [5]

1. Approximate Method

Rectangular tanks under this head are classified as,

(a) Tank with ratio of length to breadth less than two

(b) Tanks with ratio of length to breadth greater than two.

(a) L/B Ratio less than 2

In this case tank walls are designed as continuous frame subjected to a triangular load. This behaviour or bending is considered to take place from top to a height h= H/4 or 1m above the base whichever is greater. For bottom height 'h', bending is assumed in vertical plane as cantilever, subjected to triangular load, having zero intensity at D and wH at the base, as shown in Fig. 2.8.

For horizontal bending the maximum force per unit height, at D is taken equal to $p=w(H-h)$ per metre run. The panels are assumed fixed at the side and fixing end moments are $pL^2/12$ & $pB^2/12$ for long and short span respectively. (Fig.2.9) Moment distribution can be carried out and moment M_f at corners are found out. Therefore moments at mid span are $\left(\frac{pL^2}{8} - M_f\right)$ & $\left(\frac{pB^2}{8} - M_f\right)$ for long and short wall respectively.

Bottom portion of height h of each panel is designed as cantilever like circular tank case.

Direct tension on long walls = $P_L = w(H-h)B/2$

Direct tension on short walls = $P_B = w(H-h)L/2$

(b) **L/B Ratio greater than 2**

In this case long wall is assumed to bend like cantilever vertically fixed at base and subjected to triangular load. The short wall is assumed to bend horizontally, supported on long wall, for the portion from top to the point D (Fig. 2.8) . The load intensity for such a bending is taken as $p = w(H-h)$. In short wall the bottom portion upto height $h = \frac{H}{4}$ or 1 m which ever is greater is designed as cantilever like previous case.

Thus, for long wall, maximum B.M. of the base, per unit length of wall is $\frac{wH^3}{6}$.

For short wall, the maximum bending moment at level D, at ends and centre may be taken as $w(H-h)B^2/16$ and maximum cantilever B.M. for short wall is equal to $wHh^2/6$. Direct tensions on long wall is given by $P_L = w(H-h)B/2$.

The long wall behave like cantilever, and hence they do not transfer any water load to short wall in the form of pull.

2. IS Code Method

IS Code IS:3370(Part IV) 1967 has provided different tables for moment & shear for different support condition.

Horizontal moment M_H = coefficient * wH^3
Vertical moment M_v = coefficient * wH^3
Shear force = S_f = coefficient * wH^2

Tables 2.8 to 2.10 show coefficients for fixed base condition. For earth pressure signs of coefficients are reversed and 'w' is replaced by 'γ'.

2.4 TANKS WITH FLAT BASE SLAB

If tanks wall are joined with base slab with a flexible joint then there is no moment in slab due to fixidity. But if slab is joined with rigid joint to wall then there design is like a circular & rectangular slab fixed at ends subjected to udl in case of circular & rectangular tank respectively.

2.5 TANKS WITH PYRAMIDICAL OR CONICAL FLOORS [14 & 16]

The slopes occurring in reservoir or swimming bath floors are small, do not effect the principle of design, but sludge or digester & sedimentation tanks having higher slopes often require a different procedure from that already given method [Art.3.4]. Design depends upon the type of soil.

2.5.1 Tanks in hard Dry Soil

In hard dry ground such as solid chalk the excavation may be trimmed to shape and will stand without support, the sloping slab being casted against the soil with nominal 150 mm thickness and minimum percentage of steel (0.3%) in both directions.

2.5.2 Tanks in soft wet Soil

In this case ground provides partial support so far this case water pressure is reduced by 50% and bottom is assumed to be suspended from upper portion (Fig. 2.10).

(a) Pyramidal bottom

(i) Meridional Tension (N)

This is the tension developed along the slope due to the weight of contents & concrete below the point where tension is calculated. Tension is maximum at junction & zero at bottom.(Fig.2.11(b)).

$N = W \operatorname{cosec} \alpha$

(ii) Bending Moment

Pyramidal bottom is subjected to bending moment due to bending of the slab spanning horizontally between the intersection of adjacent sloping faces. If we consider unit length of slab between level xx and yy (Fig. 2.11(a)), the span of the slab AB will be L and subjected to a normal load intensity P_n (including normal component of wt. of concrete). Since the strip is continuous on all the four sides, it forms a closed frame, developing negative moment at joint and positive moment at midspan. The pressure P_n will, however, increase and span decrease toward the bottom. So the section of the slab should be designed at mid height of pyramid. In addition to this, the strip will also be subjected to a direct pull equal to $P_nL/2$.

(b) Conical Bottom

(i) Meridional Tension

In conical bottom Tension is developed along the slope. [$N = W \operatorname{cosec} \alpha$] as in pyramidal bottom.

(ii) Hoop Tension

In conical bottom Hoop tension ($p_n r_n$) is developed which is maximum at junction & zero at bottom. For design purpose hoop tension is generally calculated at mid height of cone.

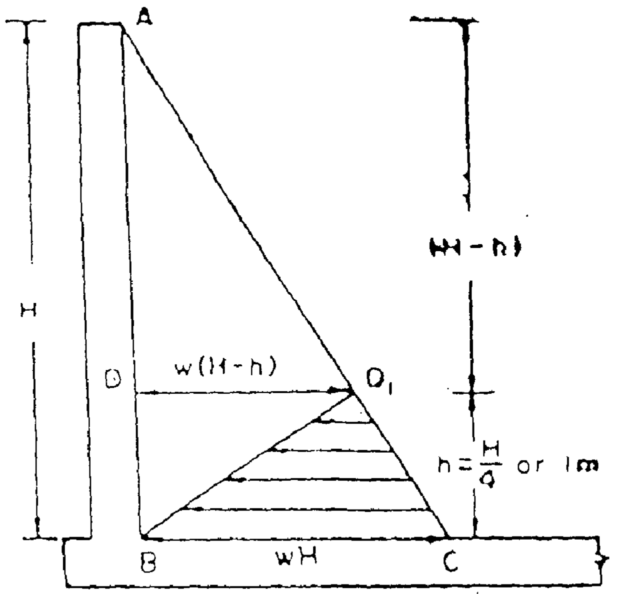


Fig. 2.8 Variation of loading on wall

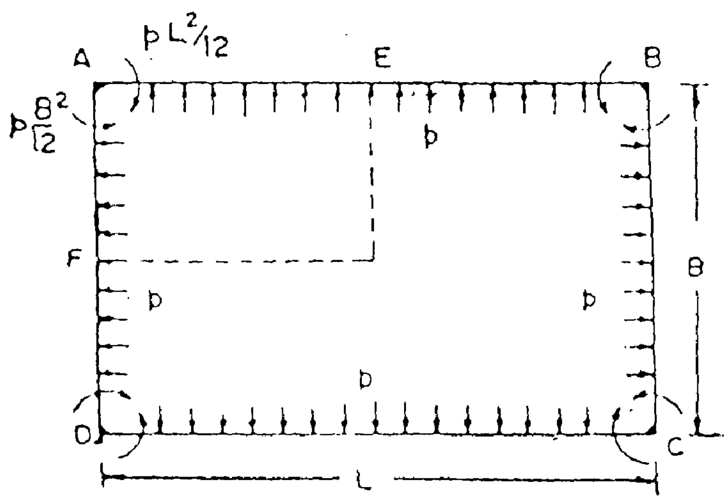


Fig. 2.9 Horizontal Forces

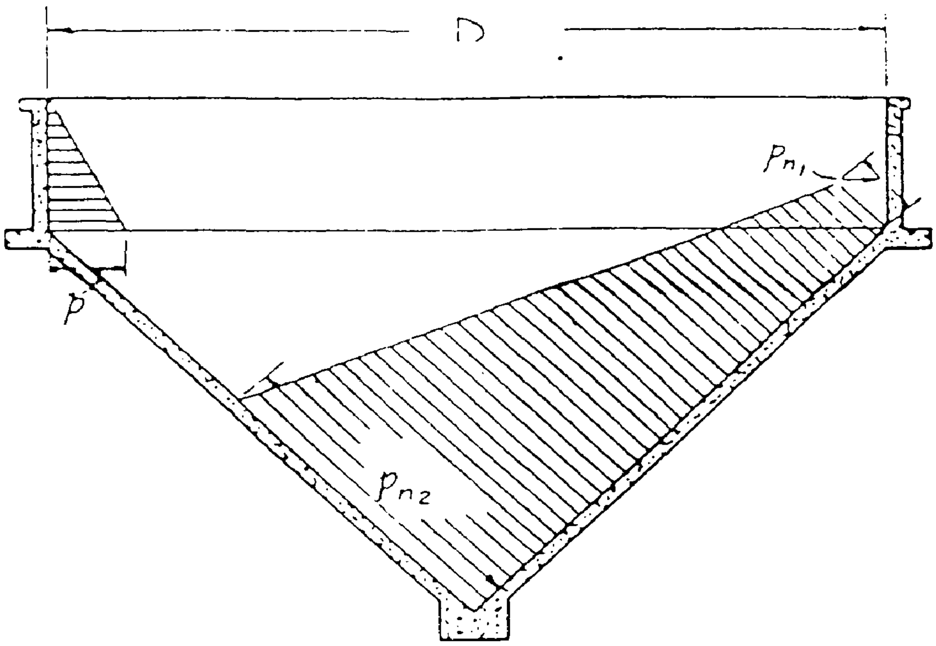


Fig.2.10 Pressure Variation on Sloping Portion

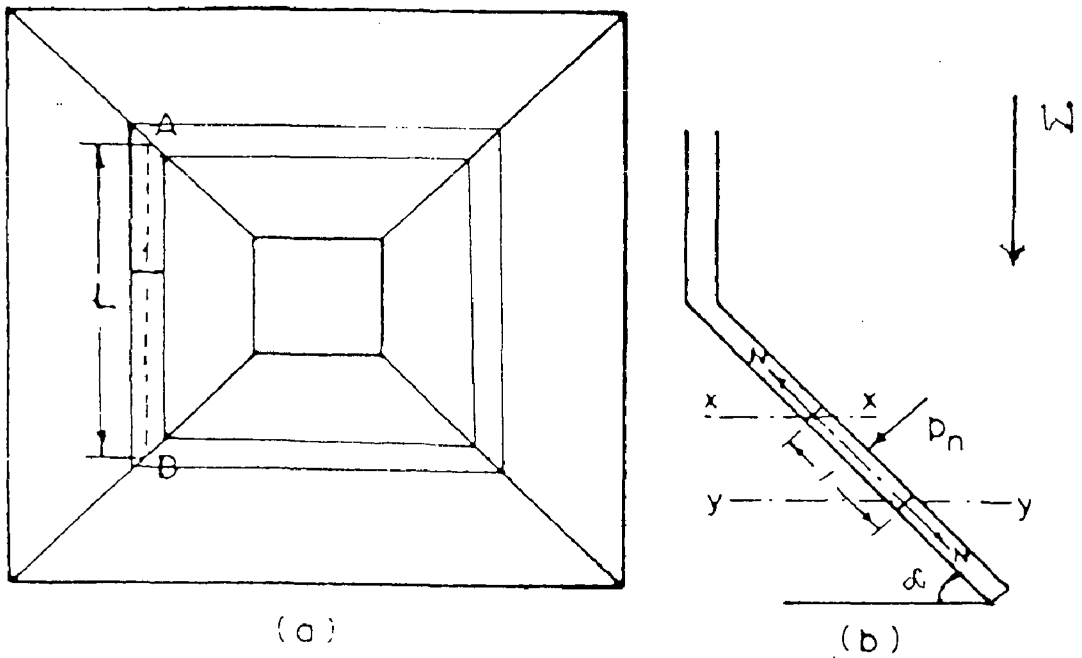


Fig.2.11 Pyramidal Bottom

TABLE 2.8 MOMENT COEFFICIENTS FOR INDIVIDUAL WALL PANEL, TOP FREE, BOTTOM AND VERTICAL EDGES FIXED

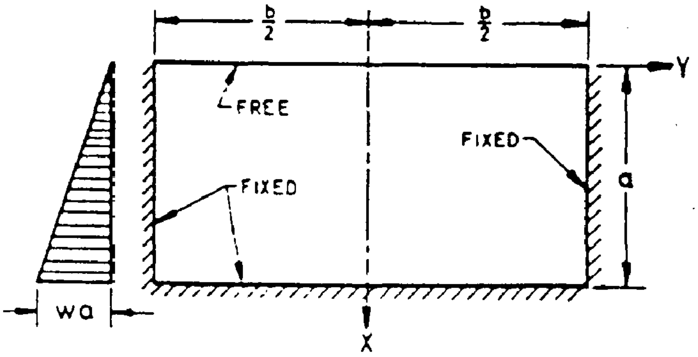
a = height of the wall

b = width of the wall

w = density of the liquid

Horizontal moment = $M_y \, wa^3$

Vertical moment = $M_x \, wa^3$



b/a	x/a	$y = 0$		$y = b/4$		$y = b/2$	
		M_x	M_y	M_x	M_y	M_x	M_y
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
3·00	0	0	+0·025	0	+0·014	0	−0·082
	1/4	+0·010	+0·019	+0·007	+0·013	−0·014	−0·071
	1/2	+0·005	+0·010	+0·008	+0·010	−0·011	−0·055
	3/4	−0·033	−0·004	−0·018	−0·000	−0·006	−0·028
	1	−0·126	−0·025	−0·092	−0·018	0	0
2·50	0	0	+0·027	0	+0·013	0	−0·074
	1/4	+0·012	+0·022	+0·007	+0·013	−0·013	−0·066
	1/2	+0·011	+0·014	+0·008	+0·010	−0·011	−0·053
	3/4	−0·021	−0·001	−0·010	−0·001	−0·005	−0·027
	1	−0·108	−0·022	−0·077	−0·015	0	0
2·00	0	0	+0·027	0	+0·009	0	−0·060
	1/4	+0·013	+0·023	+0·006	+0·010	−0·012	−0·059
	1/2	+0·015	+0·016	+0·010	+0·010	−0·100	−0·049
	3/4	−0·008	+0·003	−0·002	+0·003	−0·005	−0·027
	1	−0·086	−0·017	−0·059	−0·012	0	0

(Continued)

TABLE 2.8 **MOMENT COEFFICIENTS FOR INDIVIDUAL WALL PANEL, TOP FREE, BOTTOM AND VERTICAL EDGES FIXED**—*Contd*

b/a	x/a	$y = 0$		$y = b/4$		$y = b/2$	
		M_x	M_y	M_x	M_y	M_x	M_y
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1·75	0	0	+0·025	0	+0·007	0	−0·050
	1/4	+0·012	+0·022	+0·005	+0·008	−0·010	−0·052
	1/2	+0·016	+0·016	+0·010	+0·009	−0·009	−0·046
	3/4	−0·002	−0·005	+0·001	−0·004	−0·005	−0·027
	1	−0·074	−0·015	−0·050	−0·010	0	0
1·50	0	0	+0·021	0	+0·005	0	−0·040
	1/4	+0·008	+0·020	+0·004	+0·007	−0·009	−0·044
	1/2	+0·016	+0·016	+0·010	+0·008	−0·008	−0·042
	3/4	−0·003	−0·006	+0·003	−0·004	−0·005	−0·026
	1	−0·060	−0·012	−0·041	−0·008	0	0
1·25	0	0	+0·015	0	+0·003	0	−0·029
	1/4	+0·005	+0·015	+0·002	+0·005	−0·007	−0·034
	1/2	+0·014	+0·015	+0·008	+0·007	−0·007	−0·037
	3/4	+0·006	+0·007	+0·005	+0·005	−0·005	−0·024
	1	−0·047	−0·009	−0·031	−0·006	0	0
1·0	0	0	+0·009	0	+0·002	0	−0·018
	1/4	+0·002	+0·011	+0·000	+0·003	−0·005	−0·023
	1/2	+0·009	+0·013	+0·005	+0·005	−0·006	−0·029
	3/4	+0·008	−0·008	+0·005	+0·004	−0·004	−0·020
	1	−0·035	−0·007	−0·022	−0·005	0	0
0·75	0	0	+0·004	0	+0·001	0	−0·007
	1/4	+0·001	+0·008	+0·000	+0·002	−0·002	−0·011
	1/2	+0·005	+0·010	+0·002	+0·003	−0·003	−0·017
	3/4	+0·007	+0·007	+0·003	+0·003	−0·003	−0·013
	1	−0·024	−0·005	−0·015	−0·003	0	0
0·50	0	0	+0·001	0	+0·000	0	−0·002
	1/4	+0·000	+0·005	+0·000	+0·001	−0·001	−0·004
	1/2	+0·002	+0·006	+0·001	+0·001	−0·002	−0·009
	3/4	+0·004	+0·006	+0·001	+0·001	−0·001	−0·007
	1	−0·015	−0·003	−0·008	−0·002	0	0

TABLE 2.9 MOMENT COEFFICIENTS FOR INDIVIDUAL WALL PANEL, TOP FREE, BOTTOM HINGED, VERTICAL EDGES FIXED

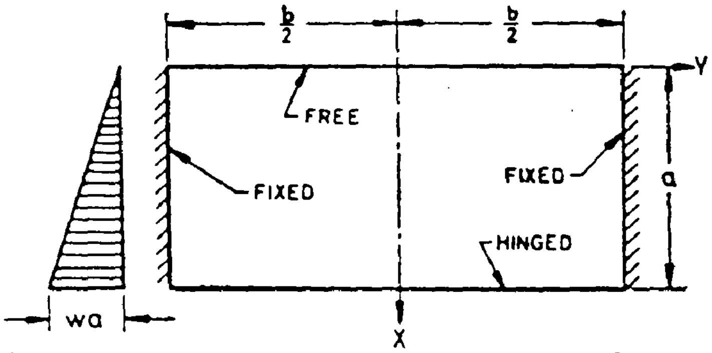
a = height of the wall

b = width of the wall

w = density of the liquid

Horizontal moment = $M_y\, wa^3$

Vertical moment = $M_x\, wa^3$



b/a	x/a	$y = 0$		$y = b/4$		$y = b/2$	
		M_x	M_y	M_x	M_y	M_x	M_y
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
3·00	0	0	+0·070	0	+0·027	0	−0·196
	1/4	+0·028	+0·061	+0·015	+0·028	−0·034	−0·170
	1/2	+0·049	+0·049	+0·032	+0·026	−0·027	−0·137
	3/4	+0·046	+0·030	+0·034	+0·018	−0·017	−0·087
2·50	0	0	+0·061	0	+0·019	0	−0·138
	1/4	+0·024	+0·053	+0·010	+0·022	−0·026	−0·132
	1/2	+0·042	+0·044	+0·025	+0·022	−0·023	−0·115
	3/4	+0·041	+0·027	+0·030	+0·016	−0·016	−0·078
2·00	0	0	+0·045	0	+0·011	0	−0·091
	1/4	+0·016	+0·042	+0·006	+0·014	−0·019	−0·04
	1/2	+0·033	+0·036	+0·020	+0·016	−0·018	−0·089
	3/4	+0·035	+0·024	+0·025	+0·014	−0·013	−0·065
1·75	0	0	+0·036	0	+0·008	0	−0·071
	1/4	+0·013	+0·035	+0·005	+0·011	−0·015	−0·076
	1/2	+0·028	+0·032	+0·017	+0·014	−0·015	−0·076
	3/4	+0·031	+0·022	+0·021	+0·012	−0·012	−0·059
1·50	0	0	+0·027	0	+0·005	0	−0·052
	1/4	+0·009	+0·028	+0·003	+0·008	−0·012	−0·059
	1/2	+0·022	+0·027	+0·012	+0·011	−0·013	−0·063
	3/4	+0·027	+0·020	+0·017	+0·011	−0·010	−0·052
1·25	0	0	+0·017	0	+0·003	0	−0·034
	1/4	+0·005	+0·020	+0·002	+0·005	−0·008	−0·042
	1/2	+0·017	+0·023	+0·009	+0·009	−0·010	−0·049
	3/4	+0·021	+0·017	+0·013	+0·009	−0·009	−0·044
1·00	0	0	+0·010	0	+0·002	0	−0·019
	1/4	+0·002	+0·013	+0·000	+0·003	−0·005	−0·025
	1/2	+0·010	+0·017	+0·005	+0·006	−0·007	−0·036
	3/4	+0·015	+0·015	+0·009	+0·007	−0·007	−0·036
0·75	0	0	+0·005	0	+0·001	0	−0·008
	1/4	+0·001	+0·008	+0·000	+0·002	−0·003	−0·013
	1/2	+0·005	+0·011	+0·002	+0·004	−0·004	−0·022
	3/4	+0·010	+0·012	+0·006	+0·004	−0·005	−0·026
0·50	0	0	+0·002	0	+0·000	0	−0·003
	1/4	+0·000	+0·004	+0·000	+0·001	−0·001	−0·005
	1/2	+0·002	+0·006	+0·001	+0·002	−0·002	−0·010
	3/4	+0·007	+0·008	+0·002	+0·002	−0·003	−0·014

TABLE 2.10 MOMENT COEFFICIENTS FOR INDIVIDUAL WALL PANEL, TOP AND BOTTOM HINGED, VERTICAL EDGES FIXED

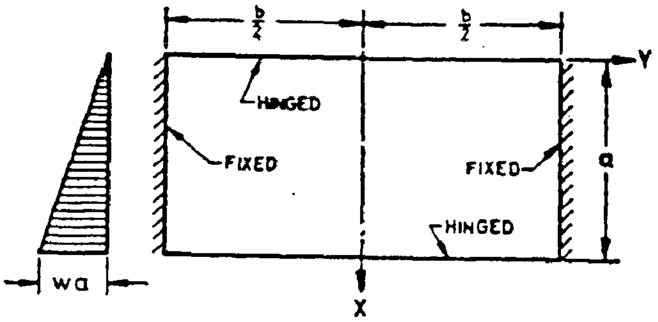
a = height of the wall

b = width of the wall

w = density of the liquid

Horizontal moment = $M_y wa^3$

Vertical moment = $M_x wa^3$



b/a	x/a	$y = 0$		$y = b/4$		$y = b/2$	
		M_x	M_y	M_x	M_y	M_x	M_y
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
3·00	1/4	+0·035	+0·010	+0·026	+0·011	−0·008	−0·039
	1/2	+0·057	+0·016	+0·044	+0·017	−0·013	−0·063
	3/4	+0·051	+0·013	+0·041	+0·014	−0·011	−0·055
2·50	1/4	+0·031	+0·011	+0·021	+0·010	−0·008	−0·038
	1/2	+0·052	+0·017	+0·036	+0·017	−0·012	−0·062
	3/4	+0·047	+0·015	+0·036	+0·014	−0·011	−0·055
2·00	1/4	+0·025	+0·013	+0·015	+0·009	−0·007	−0·037
	1/2	+0·042	+0·020	+0·028	+0·015	−0·012	−0·059
	3/4	+0·041	+0·016	+0·029	+0·013	−0·011	−0·053
1·75	1/4	+0·020	+0·013	+0·012	+0·008	−0·007	−0·035
	1/2	+0·036	+0·020	+0·023	+0·013	−0·011	−0·057
	3/4	+0·036	+0·017	+0·025	+0·012	−0·010	−0·051
1·50	1/4	+0·015	+0·013	+0·008	+0·007	−0·006	−0·032
	1/2	+0·028	+0·021	+0·016	+0·011	−0·010	−0·052
	3/4	+0·030	+0·017	+0·020	+0·011	−0·010	−0·048
1·25	1/4	+0·009	+0·012	+0·005	+0·005	−0·006	−0·028
	1/2	+0·019	+0·019	+0·011	+0·009	−0·009	−0·045
	3/4	+0·023	+0·017	+0·014	+0·009	−0·009	−0·043
1·00	1/4	+0·005	+0·009	+0·002	+0·003	−0·004	−0·020
	1/2	+0·011	+0·016	+0·006	+0·006	−0·007	−0·035
	3/4	+0·016	+0·014	+0·009	+0·007	−0·007	−0·035
0·75	1/4	+0·001	+0·006	+0·000	+0·002	−0·002	−0·012
	1/2	+0·005	+0·011	+0·002	+0·003	−0·004	−0·022
	3/4	+0·009	+0·011	+0·005	+0·005	−0·005	−0·025
0·50	1/4	+0·000	+0·003	0·000	+0·001	−0·001	−0·005
	1/2	+0·001	+0·005	+0·001	+0·001	−0·002	−0·010
	3/4	+0·004	+0·007	+0·002	+0·002	−0·003	−0·014

CHAPTER 3

CODAL PROVISIONS

3.1 IMPERVIOUSNESS OF CONCRETE

The concrete should be rich in cement content. Proportion of fine and coarse aggregate to cement should be such that it gives workable mix with high value of tensile strength. Low value of w/c ratio is adopted keeping in view the method to be used for compaction and type of aggregate. As per IS:3370 (Part 1)-1965 min. grade of concrete and min. cement content is M20 & 330 kg/m^3 respectively. Where as IS:3370 (Part 1) draft recommends M25 as min. grade and min. cement content as per IS:456-1978. Max. cement content is restricted to 530 kg/m^3.

3.2 CONTROL OF CRACKING

(a) Design of member while ignoring tensile resistance of concrete and calculated tensile stress on liquid retaining face does not exceed limits in IS:3370-Part II-1965. (Table 3.1).

(b) The expansion and contraction of concrete due to temperature variations or shrinkage and swelling of concrete, if restrained can cause cracking of R.C.C. member.

The risk of cracking due to contraction and expansion can be controlled by providing suitable joints at predetermined locations.

To guard against shrinkage cracks it is necessary to ensure that all parts of tank are kept damp during construction and curing, the tank should be filled with water as early as possible.

(c) In thick section there is likelihood of cracking as consequence of temperature rise during hydration of cement and subsequent cooling. In these cases a low heat evolution cement may be used. For effect of stresses caused due to drying shrinkage or differences in temperature, the following values of coefficient of expansion and coefficient of shrinkage may be adopted.

coefficient of expansion	11×10^{-6}
Coefficient of shrinkage	initial shrinkage - 450×10^{-6} of original length drying shrinkage 200×10^{-6} of original length

3.3 METHOD OF DESIGN

First revision of IS:3370 (Part II)-1965 includes limit state design in addition to working stress method with slight modification in it.

3.3.1 Working Stress Method [1,5]

(i) Permissible stress in concrete

(a) For Resistance to cracking :

For calculations relating to the resistance to cracking, the permissible stresses shall conform to the values specified in Table 3.1.

(b) For Strength Calculation :

In strength calculations,the permissible concrete stresses shall be in accordance with Table 3.2.

(ii) Permissible stress in steel

(a) For Resistance to cracking :

The tensile stresses in the steel will necessarily be limited by the requirement that the permissible tensile stress in the concrete is not exceeded, so that tensile stress in steel shall be equal to the product of modular ratio of steel and concrete, and corresponding permissible tensile stress in concrete.

(b) For Strength calculations

For strength calculations, the permissible stresses in steel shall conform to the values specified in Table 3.3.

3.3.2 Limit State Method [4,5]

(i) Limit State Requirements

Recommendation given in IS:456-1978 for limit state of collapse and serviceability are applicable but maximum crack width for direct tension and flexure shall not exceed 0.2 mm.

(ii) Limit State Design

(a) Design and detailing of reinforcement is same as specified in section 5 of IS:456-1978 except that steel grade in limited to Fe 415.

(b) **Crack width :** They may be deemed to be satisfactory if steel stress under service conditions does not exceed 115 N/mm^2 for mild steel and 130 N/mm^2 for HYSD bars.

(i) **Crack width assessment in mature concrete due to flexure**

Provided that strain in tensile reinforcement is limited to 0.8fy/Es and stress limited to 0.45fcu. The design surface crack width in flexure may be calculated from equation given below :

$$W = \frac{3\, a_{cr} \varepsilon_m}{1 + 2\left(\frac{a_{cr} - C_{min}}{D - X}\right)}$$

Where, W = surface crack width

nearest longitudinal bar.

ε_m = average strain at level where crack of considered

C_{min} = min. cover to tension steel.

D = overall depth of member

X = depth of N.A. (neutral axis)

$\varepsilon_m = \varepsilon_1 - \varepsilon_2$

ε_1 = strain at level considered

ε_2 = strain due to stiffening effect of concrete

Stiffening effect is assessed from following equation.

$$\varepsilon_2 = \frac{b_t (D - X)(a' - X)}{3\, E_s A_s (d - X)}$$ (design crack width of 0.2 mm.)

$$\varepsilon_2 = \frac{1.5\, b_t (D - X)(a' - X)}{3\, E_s A_s (d - X)}$$ (design crack width of 0.1mm)

Where, b_t = width of the section at the centroid of tensile steel.

D = overall depth of member

E_s = modulus of elasticity of steel.

A_s = area of tensile reinforcement.

a' = distance from the compression face to the point at which crack width is considered.

(ii) Crack Width Assessment in mature concrete due to Direct Tension :

$$w = 3\, a_{cr}\, \varepsilon_m$$

$$\varepsilon_2 = \frac{2\, b_t\, D}{3 E_s A_s} \text{ (limiting design crack width of 0.2 mm.)}$$

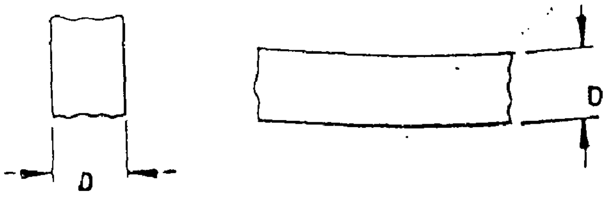
$$\varepsilon_2 = \frac{b_t\, D}{E_s A_s} \text{ (limiting design crack width of 0.1 mm.)}$$

3.4 MINIMUM REINFORCEMENT

As per IS : 3370 (Part II) 1965 minimum reinforcement in each of two direction at right angle shall have area of 0.3% of concrete section upto 100 mm, 0.2% for section of thickness above 450mm and for intermediate values it is interpolated. In the revised draft this has been changed and it states that minimum Reinforcement at right angle in each of two directions shall not be less than 0.35% of surface zone for HYSD and 0.64% for mildsteel. Surface zone are shown in Fig. 3.1.

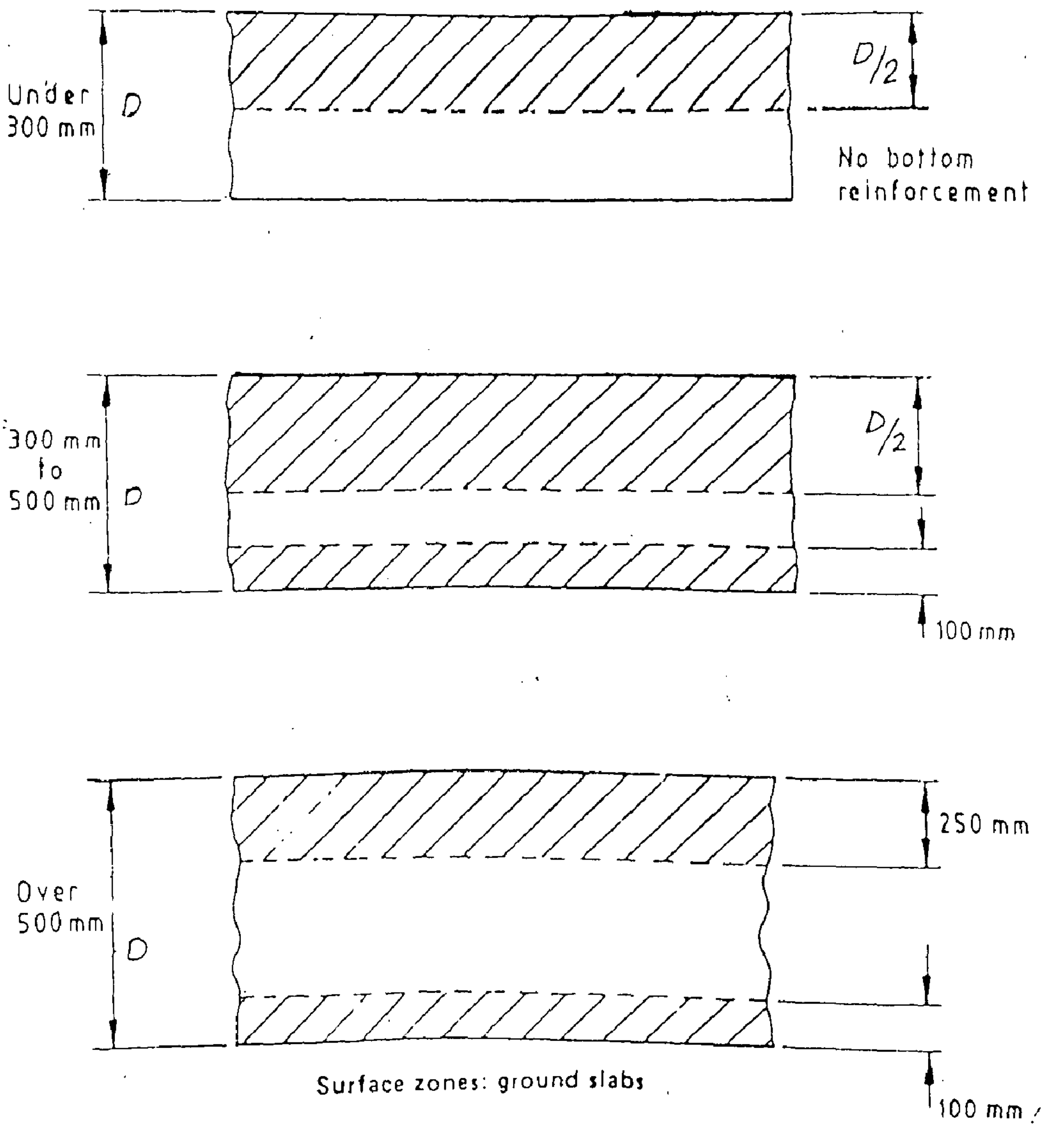
3.5 MINIMUM COVER

As per IS:3370-1965 Min. cover is 25 mm or dia of bar whichever is greater and for corrosive soil or water additional cover of 12 mm is provided. Where as revised draft recommends cover of 40 mm or dia of bar whichever is greater and 15 mm addition cover for corrosive soil or water.



NOTE. For D 500 mm, assume each reinforcement face controls D/2 depth of concrete.
For D > 500 mm, assume each reinforcement face controls 250 mm depth of concrete, ignoring any central core beyond this surface depth.

Surface zones: walls and suspended slabs



Surface zones: ground slabs

Fig.3.1 : Surface Zones

Table - 3.1

Permissible concrete stresses in calculations relating to resistance to cracking.

Grade of concrete	Permissible stresses: Direct Tension (σ_{ct})	Permissible stresses: Tension due to bending (σ_{cbt})	Shear $= \frac{Q}{bjd}$
	N/mm	N/mm²	N/mm²
	1·1	1·5	1·5
M 20	1·2	1·7	1·7
M 25	1·3 (1.3)*	1·8(1.8)*	1·9(1.9)*
M 30	1·5(1.4)*	2·0(2.0)*	2·2(2.1)*
M 35	1·6	2·2	2·
M 40	1·7	2·4	2·7

* Values as per IS:3370 First Revision Draft.

TABLE 3.2 PERMISSIBLE CONCRETE STRESSES IN STRENGTH CALCULATIONS

Grade of Concrete	Permissible Concrete Stress, N/mm²: Direct	Compression Due to Bending	Shear	Bond (average) for plain mild steel bars in tension
(1)	(2)	(3)	(4)	(5)
M 25	6.0	8.5	As per Table 17 of IS 456:1978 For M 25 and M 30 Concrete	0.9
M 30	8.0	10.0		1.0

NOTES:

1) The bond stress given in column 5 shall be increased by 25 percent for bars in compression.
2) In the case of deformed bars conforming to IS:1786-1979 the bond stresses given above may be increased by 40 percent.
3) The anchorage (average) bond stresses for horizontal bars which are in sections in direct tension shall not exceed 0.7 times the above values.

Table 3.3 Permissible stresses in steel Reinforcement for Strength Calculation

Type of stress forcement	Permissible stresses in N/mm^2	
	Plain round mild steel bars conforming to grade I of IS:482 (Part 1)-1966	High yield strength deformed bars (HYSD) bars conforming to IS:1786-1966 or IS:1139-1966
1 Tensile stress in members under direct tension (σ_s)	115	150
2. Tensile stress in members in bending (σ_{st})		
(a) On liquid retaining face of members	115	150
(b) On face away from liquid for members less than 225 mm	115	150
(c) On face away from liquid for members 225 mm or more in thickness	125	190
3. Tensile stress in shear reinforcement (σ_{sv})		
(a) For members less than 225 mm thickness	115	150
(b) For members 225 or more in thickness	125	175
4. Compressive stress in columns subjected to direct load (σ_{sc})	125	175

CHAPTER 4

JOINTS IN WATER TANKS

As per IS:3370(Part I)-1965 Joints shall be categorized as below :

(a) **Movement Joints**

(b) **Construction Joints**

(c) **Temporary Joints**

4.1 MOVEMENT JOINTS

There are three categories of movement joints.

4.1.1 Contraction Joints :

A movement joint with a deliberate discontinuity but no initial gap between the concrete on either side of the Joint, being intended to accommodate contraction of the concrete. A distinction should be made between a partial contraction joint (Fig. 4.1) in which only concrete is interrupted and the steel running through and a complete contraction joint (Fig.4.2) in which both concrete and steel are interrupted. Its spacing should not exceed 7.5 m.

4.1.2 Expansion Joints :

A movement joint with complete discontinuity in both reinforcement and concrete, intended to accommodate either expansion or contraction of the structure (Fig.4.4). Its spacing should not exceed 30 m.

4.1.3 Sliding Joints :

A movement joint with complete discontinuity in both reinforcement and concrete at which special provision is made to facilitate relative movement in place of the joint.Fig.4.5 shows sliding joint between floor & wall in cylindrical tank.

4.2 CONSTRUCTION JOINTS

During construction of wall, height of lift is restricted generally to 2m. so to achieve subsequent continuity without movement, construction joints are provided (Fig.4.3).

4.3 TEMPORARY OPEN JOINTS

A gap temporarily left between the concrete of adjoining parts of a structure which after a suitable interval and before the structure is put into use , is filled with mortar or concrete completely as shown in Fig.4.6.

Plan showing location of expansion & contraction joint is shown in Fig.4.7.

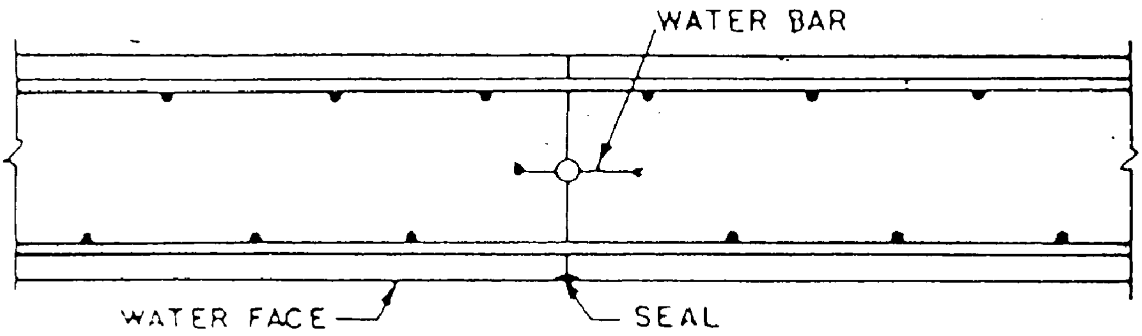


Fig. 4.1 Partial Contraction Joint

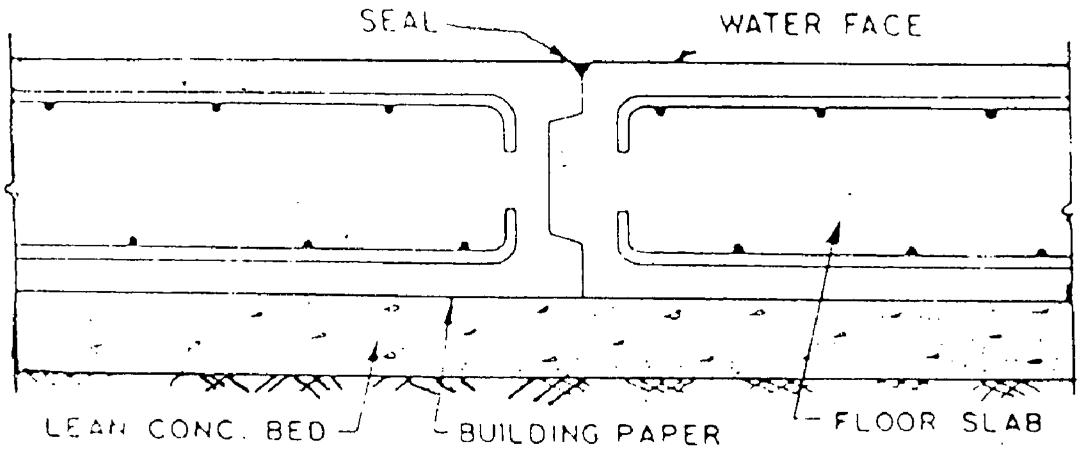


Fig. 4.2 Complete Contrattion Joint

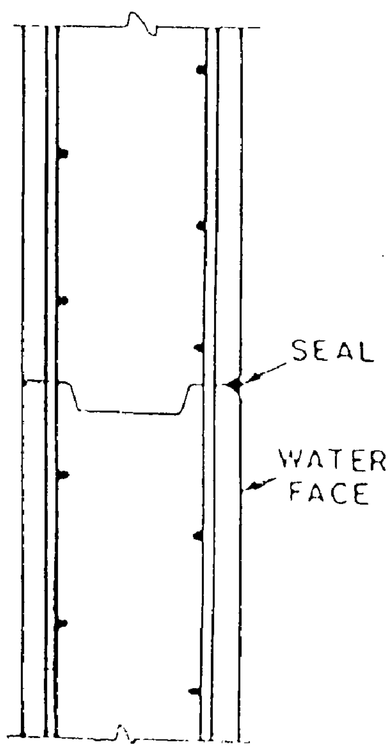


Fig. 4.3 Construction Joint

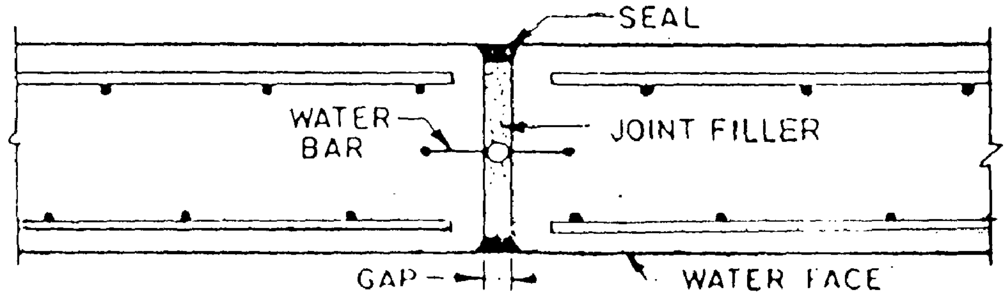


Fig.4.4 Expansion Joint

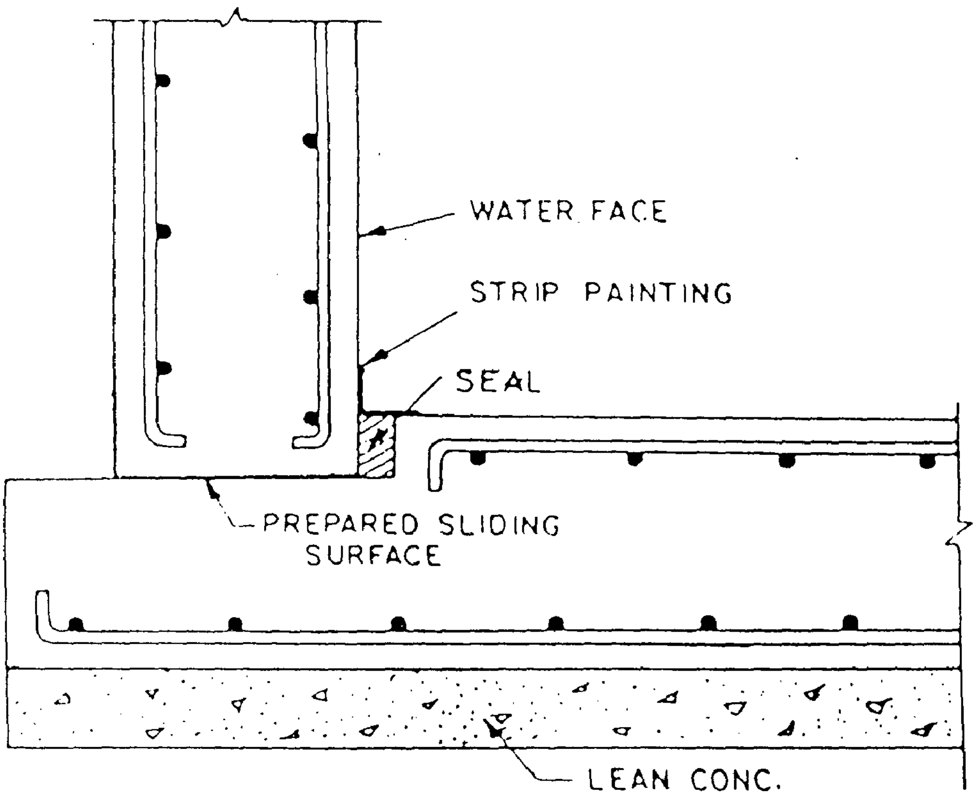


Fig. 4.5 Sliding Joint

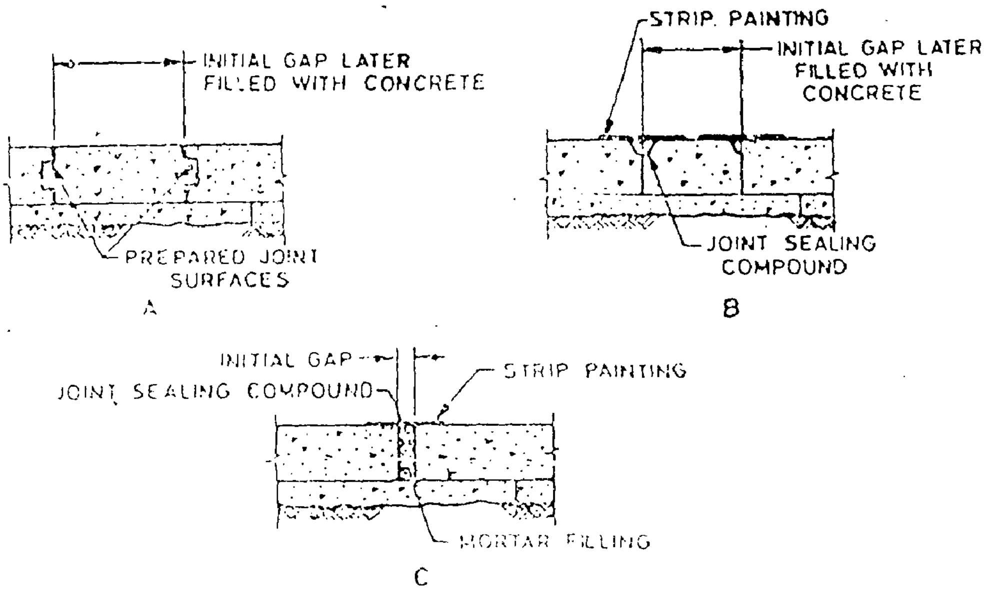


Fig. 4.6 Temporory Open Joints

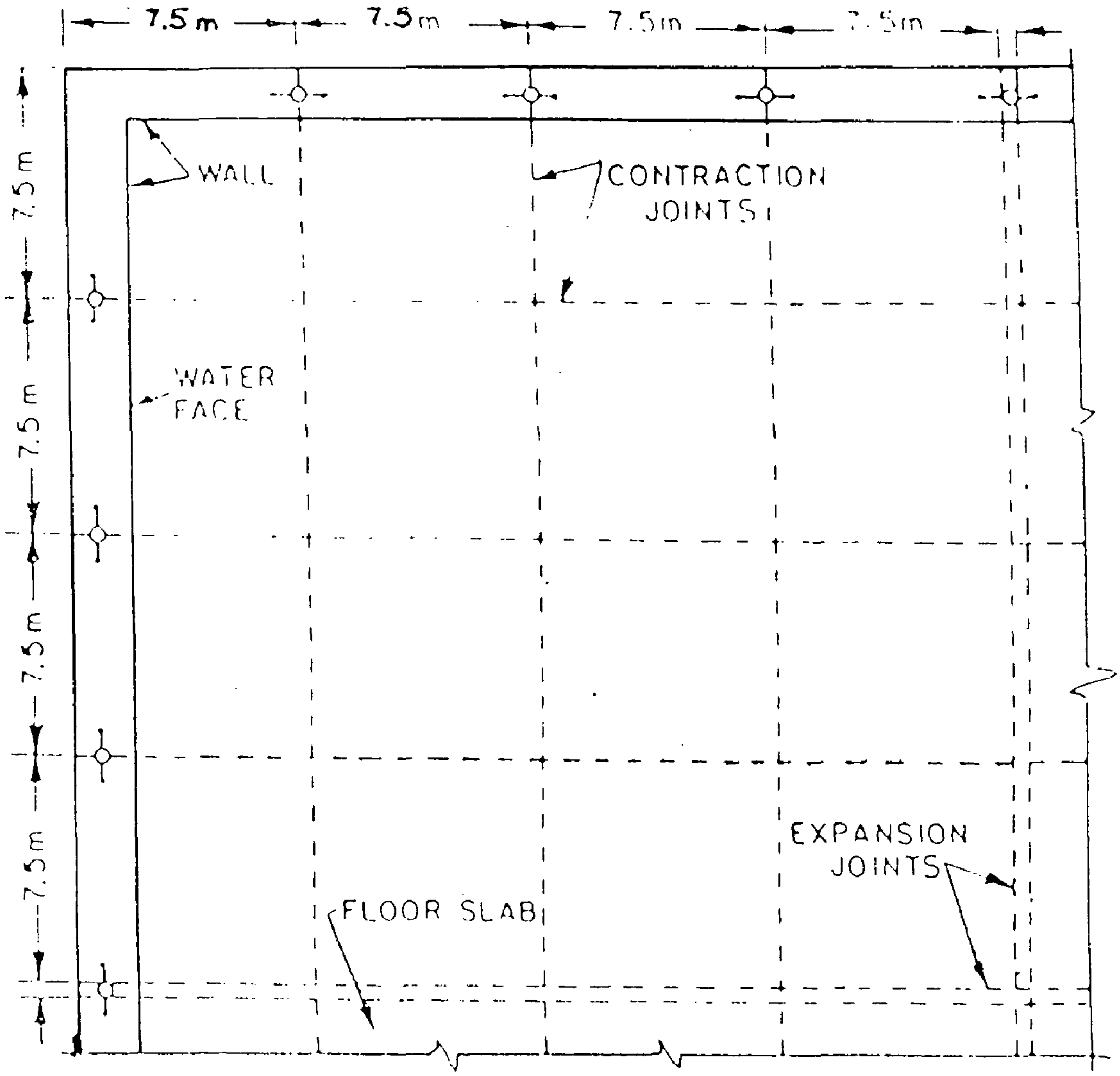


Fig. **4.7** Plan Showing Joints

DETAILS OF VARIOUS JOINTS IN TANKS

CHAPTER 5

DESIGN ASPECTS OF UNDERGROUND TANKS

The dimension of tank can be worked out from total capacity of tank required. The design of tank is done on the no crack basis. Various steps of design as per IS:3370 are given in following paragraphs.

5.1 DESIGN OF WALLS OF CIRCULAR TANK

(i) Computation of forces including seismic effect [6]

Case 1 : Empty tank with full earth pressure

Hoop compression = $C_f\ K_a\ \gamma\ H_1\ D/2$

Bending Moment = $C_f\ K_a\ \gamma\ H_1^3$

Shear force at base = $C_{fs}\ K_a\ \gamma\ H_1^2$

Where, C_f = coefficient for hoop compression & bending moment.

C_{fs} = coefficient for shear force at base.

γ = soil density

H_1 = height of soil

D = diameter of tank

K_a = coefficient of lateral acting earth pressure.

For dynamic case

$$K_a = \frac{(1 \pm \alpha_v)\cos^2(\phi - \lambda)}{\cos(\lambda)\ \cos(\delta + \lambda)} \left[\frac{1}{1 + \lambda \left\{ \dfrac{\sin(\phi + \delta)\ \sin(\phi - \lambda)}{\cos(\delta + \lambda)} \right\}^{1/2}} \right]^2 \qquad \text{(i)}$$

where, ϕ & δ = angle of internal friction of soil and angle of friction between wall and earthfill respectively

α_v = vertical seismic coeff. = 0.5 α_h

$\lambda = \tan^{-1} \frac{\alpha_h}{1 \pm \alpha_v}$

α_h = horizontal seismic coefficient = $\beta I \alpha_o$

I = Importance factor = 1.5 for tanks

α_o = basic horizontal seismic coefficient.

If earthfill is saturated, then

(a) The value of δ is taken as 1/2 of δ of dry backfill

(b) $\lambda = \tan^{-1} w_s^2 * \frac{\alpha_h}{1 \pm \alpha_v}$

w_s = saturated unit weight of soil in gm/cc

For **static case** to find K_a put $\alpha_h = \alpha_v = \lambda = 0$ in eq.(i)

Case-2 - Tank is full with no earth pressure
Dynamic Case

$$\text{Hoop tension} = c_f \; w \; H \; D/2 \left[1 + \alpha_h x 1.732 \tanh \left(\frac{1.732D}{2H} \right) \right]$$

$$\text{Bending moment} = c_f \; wH^3 \left[1 + \alpha_h x 1.732 \tanh \left(\frac{1.732D}{2H} \right) \right]$$

$$\text{Similarly shear force} = c_{fs} \; wH^2 \left[1 + \alpha_h x 1.732 \tanh \left(\frac{1.732D}{2H} \right) \right]$$

For **static case** put $\alpha_h = 0$

From these two cases choose the higher value as design force.

(ii) Thickness of Wall (T)

Thickness of wall (T) $= \sqrt{\dfrac{6M}{1000\ f_c}}$

where f_c = permissible stress in concrete in bending

Thickness should not be less than 150 mm or (30H + 50)mm whichever is greater.

(iii) Calculation of Steel

Area of steel for cantilever action (Ast) $= \dfrac{B.M}{\sigma_{st}\ Jd}$

Spacing of Steel $(s_v) = \dfrac{1000\ \pi\ \varnothing^2}{4\ A_{st}}$

where, $\varnothing$ = diameter of bar

Bars are extended beyond the critical section at least by development length $\left[L_d = \dfrac{\varnothing\ \sigma_{st}}{4\tau_{bd}}\right]$

σ_{st} = permissible tensile stress in steel

τ_{bd} = permissible bond stress.

Hoop reinforcement $(A_{sh}) = \dfrac{\text{Hoop Tension}}{\sigma_{st}}$

Actual area of hoop steel should be greater than required area for tensile stress in concrete given by.

$$\sigma'_t = \frac{\text{hoop tension}}{1000T + (m-1)A_{sh}} < \sigma_{ct}$$

σ'_t = tensile stress in concrete

σ_{ct} = permissible tensile stress in concrete

m = modular ratio

Shear stress (p_t) in wall is checked as

$$p_t = \frac{1000 * \pi * \o^2}{4 s_v}$$

Permissible shear stress $= k\tau_c > \frac{\text{Shear stress}}{1000\ d}$

Otherwise increase the thickness of wall. Usually shear is not critical.

(iv) Distribution Steel:

Distribution steel (0.3%) is provided where steel is less than minimum steel required.

5.2 DESIGN OF WALLS OF RECTANGULAR TANK

Various steps involved in design of rectangular tanks as per IS:3370 are as follows.

(i) Calculations of design forces

Various design forces like horizontal & vertical bending moment in both walls, and shear forces are calculated using various tables given in IS 3370 Part (IV) for tank full & empty cases. Signs of various coefficient are reversed for tank empty case. These forces are calculated similarily as calculated in circular tank in Art.5.1. For dynamic case 'D' is replaced by length of rectangular tank.

(ii) Calculation of thickness of walls

Walls of tanks are subjected to horizontal/vertical moment in addition to these direct tension.

Thickness of wall is governed by following equations.

$$\frac{\sigma_{cbt}'}{\sigma_{cbt}} + \frac{\sigma_{ct}'}{\sigma_{ct}} \leq 1 \qquad \text{[Tank full case]}$$

$$\frac{\sigma_{cbc}'}{\sigma_{cbc}} + \frac{\sigma_{cc}'}{\sigma_{cc}} \leq 1 \qquad \text{[Tank empty case]}$$

where

σ_{cbt}' and σ_{cbc}' = calculated tensile and compressive stress in bending in concrete respectively.

σ_{cbt} and σ_{cbc} = Permissible tensile and compressive stress in bending in concrete respectively.

σ_{ct}' and σ_{cc}' = calculated tensile and compressive direct stress in concrete respectively.

σ_{ct} and σ_{cc} = Permissible tensile and compressive direct stress in concrete respectively.

(iii) Reinforcement in Horizontal direction

Horizontal bending is coupled with direct tension due to water or earth pressure in walls at right angle to walls under consideration. Horizontal steel is provided for both hogging & sagging case as shown in Fig.5.1 & 5.2. Various steps for finding hogging and sagging steel are as follows

(i) Depth of N.A. = kd

where $k = \frac{mc}{mc+t}$ & $d = T$ - effective cover

Eccentricity of Tensile force (e_t) from center of section

$$e_t = \frac{\text{Bending moment}}{\text{Shear force}}$$

Eccentricity from the center of steel

$$e_{cs} = e_t - T/2 - \text{effective cover}$$

(ii) Distance of C.G of compressive zone from reinforcement

$$L = d - \frac{\text{depth of N.A.}}{3}$$

(iii) Area of steel (A_{sth}) $= \dfrac{SF\,(e_{cs} + L)}{\sigma_s\, L}$

σ_s = permissible stress in steel whose value depends upon condition that whether it is in contact with water or not.

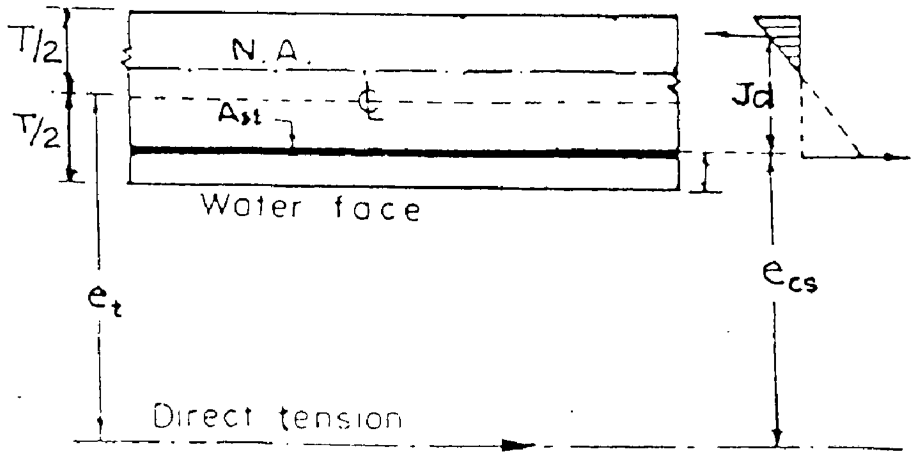


Fig. 5.1: Hogging Moment

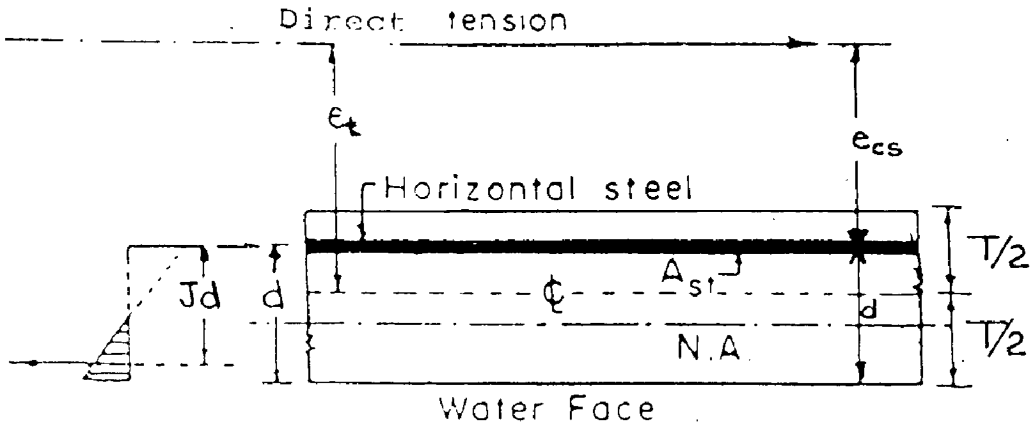


Fig. 5.2 : Sagging Moment

(iv) Reinforcement in Vertical Direction

Reinforcement in vertical direction for hogging and sagging moment is given by

$$A_{stv} = \frac{\text{B.M. in vertical direction}}{\sigma_S \, Jd}$$

During curtailment of bars development length criteria should be satisfied.

(v) Distribution Steel

Provide distribution steel equal to 0.3% in both direction if required.

5.3 DESIGN OF BASE SLAB

If both rectangular and circular tanks with flat or sloping base rests on hard rock and have flexible joint at base then base slab of nominal thickness (200 mm) with minimum (0.3%) steel is provided. But if rigid joint is provided then flat slab is designed like circular and rectangular slab fixed at ends.

5.3.1 Design of sloping base slab

(i) Pyramidal bottom :

Area of steel for meridional tension

$$A_S = \frac{\text{Meridional Tension}}{\text{Permissible tensile stress in steel}}$$

Steel spacing is increased toward the bottom.

Thickness of base slab $= \sqrt{\frac{6\ B.M}{1000\ f_c}}$

f_c = permissible stress in bending in concrete

This steel is provided about the periphery of Pyramidal bottom with increased spacing toward bottom.

(ii) Conical Bottom:

Conical bottom is designed like circular tank with flexible joint.

Max. hoop tension = wHD/2

H = height of cylindrical portion above junction with cone.

σ_s = Permissible stress in steel in direct tension.

Area of steel (A_{sh}) for hoop tension $= \frac{wHD}{2\sigma_s}$.

If σ_{ct} is permissible stress in concrete in direct tension then thickness (T) is governed by eqn. given below:

$$\sigma_{ct} \geq \frac{wHD/2}{1000T + (m-1)A_{sh}}$$

Projection of base slab (e) is governed by uplift pressure **when tank is empty.**

Uplift pressure (UP) = $w(H_1 - WT)$

Net uplift Pressure (NU) = UP - self weight of tank.

For circular tank gravity load $= \frac{\pi}{4}\left[(D+e)^2 - D^2\right]\gamma H_1$

For rectangular tank gravity load $= \left[(L+e)(B+e) - (LxB)\right]\gamma H_1$

$$\frac{\text{Gravity load}}{\text{uplift force}} \geq \text{FOS}$$

Factor of Safety as per IS:3370 (Part I) is **1.20**.

5.4 TANK DESIGN AS A CANTILEVER RETAINING WALL

If L/H ratio in rectangular tanks exceeds the value of 3.0 and diameter in circular tanks exceeds 12 m, then tanks are designed like cantilever retaining wall. The sides of tank are monolithic with base slab which act independently of the floor. The cantilever walls must be reinforced on both faces. The vertical main reinforcement on water face of wall is provided to resist B.M. caused when tank is full of liquid and no earth pressure is acting. Similarly, the reinforcement on faces of wall in contact with earth is provided to resist the bending moment, when tank is empty and back earth presence is fully active. Base slab is also designed for above two conditions. In the remaining portion of base slab, nominal thickness with nominal reinforcement is provided. In all cases, water table position is taken in account.

Retaining wall must be in equilibrium under given system of forces.

(1) Resisting moment must be more than the overturning moment. Total stablizing or resisting moment is at least 100% greater than total overturning moment.

$$FS = \frac{\text{Resisting moment}}{\text{Overturning moment}} \geq 2.0$$

2. Horizontal component of the lateral pressure tends to slide the wall along the base.

Force opposing sliding = $\mu \times \Sigma W$

$$FOS = \frac{\mu \times \Sigma W}{P} \geq 1.5$$

ΣW = Sum of vertical loads

μ = Coefficient of friction between base and soil

P = Total horizontal force tending to slide wall

3. Maximum and minimum pressures are given by

$$P_1 = \frac{\Sigma W}{b}\left\{1 + \left(\frac{6e}{b}\right)\right\}$$

$$P_2 = \frac{\Sigma W}{b}\left\{1 - \left(\frac{6e}{b}\right)\right\}$$

P_1 = Intensity of soil pressure at toe

P_2 = Intensity of soil pressure at heel

ΣW = Sum of vertical loads

P_1 should be not exceed bearing capacity of soil. P_2 should not be negative. So sum of all vertical forces and horizontal earth pressure should cut base of wall within middle third of the base.

The steps followed in design are :

1. The preliminary dimensions of tank stem, heel and toe slab are worked out.
2. The stability of tank is checked in tank empty and tank full cases and dimensions are accordingly decided.
3. Design of sides is carried out as cantilever wall, the reinforcement at both faces is provided according to B.M. calculated.
4. Design of toe slab is done in both cases of tank empty and tank full. The reinforcement is given according to resultant pressure diagram. Shear is checked at distance equal to effective depth of toe slab from the face of stem.
5. Heel is designed as cantilever slab fixed at back face of stem. The reinforcement is provided according to resultant pressure diagram. Critical section for shear is considered at stem face. The main reinforcement must be extended beyond the critical point by development length.

CHAPTER 6

SOFTWARE ASPECTS

6.1 GENERAL

The software package "RCTANK" has been developed for analysis, design and drafting of RC underground tanks in FORTRAN 77 language on **Tata Elexi-3220** main frame computer. It can also be run on personal computer. It mainly consists of two parts as follows :

1. Numerical Analysis and Design
2. Drafting

For numerical analysis and design of both rectangular and circular tank, a program COMBIN.FOR has been developed. This program provides a friendly environment to user. The program is developed on the basis of formulation presented in Chapter-5. The program is very general in nature. It can handle varying tank depth in soil for both rectangular and circular tanks. Circular tank design program has been taken from thesis work of ANUJ KUMAR JAIN and modified to adjust with the program for design of rectangular tank. This program can well be used for design of tank directly resting on ground also. The user gets facility of not referring to permissible stresses of materials as they are built in, according to choice of user for concrete grade and steel bars to be used.

Flow charts of program and its main subroutines have been presented in Fig.6.1 to 6.6 .

Rectangular tank walls have been designed for following end conditions:

1. Top free, bottom fixed.
2. Top free, bottom hinged
3. Top & bottom hinged

For first condition if L/H ratio exceeds the value 3, then walls are designed like cantilever retaining wall.

Similarly circular tank walls have been designed for following end conditions -

1. Hinged at base, free at top
2. Fixed at base, free at top
   (a) Small diameter tank
   (b) Large diameter tank

Large diameter tank (D > 12 m) is designed like cantilever retaining wall.

Second part of 'RCTANK' is the drafting of sectional elevation and plan of designed tank. Drafting of rectangular tank has been dealt in this dissertation work. It contains three program namely DRAFT1.FOR, DRAFT2.FOR and DRAFT3.FOR.

Based on these objectives, the functions of interactive program are given below :

1. Interpolation of coefficient for tension and moment according to types of tank and base conditions.
2. Computation of bending moment and tension in cylindrical tank and bending moment on horizontal and vertical direction for rectangular tank based on type of tank.
3. Design of wall based on codal provisions.
4. Design of base slab for slab end condition and water table position.
5. In case, diameter is greater than 12 m or L/H ratio is greater than 3, then design of tank wall like cantilever retaining wall is carried out.

6.2 SOFTWARE FOR ANALYSIS, DESIGN AND DRAFTING :

6.2.1 Input to Main Program

The input values which are asked interactively on screen mode in main program are -

* Name of output file
* Code for type of tank.
    1. Rectangular tank
    2. Circular tank

If code is 1; than following input values are asked.

* Capacity of tank in litres
* Depth of tank in soil
* Unit weight of material filled in tank in N/m^3
* Unit weight of soil
* Bearing capacity of soil
* Codes for square/rectangular tank
* Free board in metres
* Water table position below G.L.
* Codes for End conditions.

6.2.2 Description of Subroutines:

The subroutine which are used for analysis and design are listed below:

1. CINT	2. INTPOL
3. TEMPT	4. TFULL
5. STRESS	6. BIGN
7. THIC	8. SMAX
9. MINIBM	10 REINF
11. REINFV	12. HOOPREIN
13. MOMENT	14. HGSLAB
15. FBSLAB	16. CFSLAB
17. CANTTANK	18. CALCULN
19. CIRCULAR	

1. **CINT**

This subroutine is used for linear interpolation of coefficients for moments in horizontal and vertical direction depending on the value of Y (Y = L/H). The coefficients of corresponding locations are interpolated and transferred to main program through argument. This subroutine is required in rectangular tank only. Interpolated coefficients are printed out in output file.

2. **INTPOL**

This subroutine is used only for circular tank case for linear interpolation of coefficients of hoop tensions and moments in tank according to base condition. H^2/Dt ratio as evaluated in main program is inducted as an argument, correspondingly interpolation is done and interpolated coefficients are given out.

3. **TEMPT**

This subroutine is used in both rectangular and circular tank cases. This is also used for calculation of static and dynamic earth pressure for retaining wall case also. In circular tank case, this is used to calculate the hoop compression and moments in wall for tank empty case. This subroutine is called in subroutine CIRCULAR. For rectangular tank it calculates, horizontal and vertical B.M. at different points. In carrying out analysis option is given to user for analysis by static earth pressure or static and dynamic earth pressures both. The submergence of soil mass is also taken into account. Dynamic pressure analysis is done according to IS

: 1893-1984. Hoop tension and moments in circular tank case and horizontal and vertical B.M. in rectangular tank case are printed out in output file.

The input data, which is asked interactively in it, are as given below:

1. Value of angle of internal friction of soil (in degrees)
2. Value of angle of friction between wall and soil (in degrees)
3. Code for conditions under which tank is to be designed
   - i) Static Pressure
   - ii) Static and dynamic pressure
4. Seismic zone in which tank is located if dynamic pressure is to be included.

4. TFULL

This is also used in both types of tanks. For calculation of hoop tension and moments for circular tank and B.M. for rectangular tank in horizontal and vertical direction, for case when tank is full and no earth pressure is there. Here option is given to user, whether he wants to consider the relief from earth pressure or not. Accordingly forces are calculated and printed out in output file.

The input given in screen mode is :

1. Code for condition
   - a) half liquid pressure acting from inside
   - b) full liquid pressure acting from inside

5. STRESS

This subroutine is used for computing values of design constants i.e. modular ratio, neutral axis depth ratio, lever arm, moment constants, permissible stress in steel etc. These are computed out according to chosen type of concrete and steel. Permissible stresses are increased in dynamic case. All permissible stresses are in built in this subroutine.

6. BIGN

This subroutine is used only in rectangular tanks for calculating maximum absolute B.M. for both, tank full and tank empty cases.

7. THIC

In this subroutine, thickness of wall section of rectangular tank is calculated. If the maximum bending moment value calculated by subroutine BIGN lies below or at X/H = 0.5, then corresponding to this , thickness upto half of height from base, is provided. In rest of upper portion corresponding to maximum absolute bending moment acting in this portion, thickness is provided. User may change these, these are displayed on screen.

8. SMAX

This is used in rectangular tank for calculation of maximum positive B.M. at different X/H values by comparing the B.M. values at different points along length or width of wall. In this, maximum positive horizontal and vertical B.M. values are calculated.

9. **MINIBM**

This works like above subroutine but difference is that it calculates the maximum negative horizontal and vertical bending moment values.

10. **REINF**

This subroutine is used for calculation of area of steel and its spacing at outer and inner face in horizontal direction. In this, a message is displayed on screen. If spacing is either less than 100 mm or greater than 450 mm, then diameter is required to be changed. Diameter, area of horizontal steel and spacing are passed as argument to subroutine CALCULN where it is called. Minimum area of steel requirement criterion has also been introduced.

11. **REINFV**

This acts similarly as REINF but difference is that it calculates the steel in vertical direction at both faces.

12. **HOOPREIN**

This subroutine is used in circular tank to calculate reinforcement due to hoop tension. The minimum reinforcement according to codal provisions is calculated and if hoop reinforcement according to grade of concrete and steel is less than minimum, then at that level minimum hoop steel is provided. The option is available for user to give spacing as is needed. In the last part the tensile stress in section is checked and if greater than permissible, message is displayed to change the section. Results are written in output file.

13. MOMENT

This subroutine gives out the vertical reinforcement details at water face and away from water face. First of all, thickness of wall required for moment consideration is worked out. If assumed thickness is less then required, program gives error message and returns to main ·to calculate new moment according to H^2/DT ratio. The area of steel required for calculated moment is compared with minimum reinforcement. Spacing is worked out according to given diameter of bar. In bottom height development length for reinforcement is calculated and curtailment is done at this height. All results are given in output file.

14. HGSLAB

This subroutine is required for both circular and rectangular options hinged at base condition. In this, nominal thickness and reinforcement are provided and printed in output file.

15. FBSLAB

This subroutine is used to design the base slab fixed at end for uplift due to water table position for tank empty tank cases. Slab is designed using coefficients given in IS: 456-1978. This is used in rectangular tank case only.

16. CFSLAB

This is used to design the base slab of circular tank when base is fixed with wall. Slab is designed like circular slab for uplift due to water table position for tank empty cases. The input to this subroutine asked interactively on screen mode is :

1. Bearing capacity of soil
2. Bar diameter to be used in base slab.

17. CANTTANK

This is called when diameter is greater than 12 m for circular tank or when L/H ratio exceeds 3 for base fixed case for rectangular tank. First bearing capacity of soil is given. The preliminary dimensions of tank are set up and are checked for stability, if not satisfied the user is asked to revise the dimensions. These are checked in both tank empty and tank full conditions. After satisfying conditions, bending moments are calculated from resultant pressures. Tank wall is designed for these moments. Minimum reinforcement criterion is also kept in program. The input values asked in this subroutine are :

i) Bearing capacity of soil
ii) Base slab length, top projection, base slab depth, tank wall thickness after checking stability.
iii) Tank wall thickness decision
iv) Diameter of bars in tank wall and spacing
v) Diameter of bars in base slab, top face and bottom face and spacing.

18. CALCULN

This is the main subroutine used in rectangular tank. In this various subroutines called are given below :

TEMPT, TFULL, BIGN, THIC, SMAX, MINIMB, FSLAB, HGSLAB.

Input values required are -

* diameter of horizontal bars to be used at outer face
* diameter of horizontal bars to be used at inner face
* diameter of vertical bars to be provided at outer face
* diameter of vertical bars to be provided at inner face.

Various values of area of steel and spacing are printed out in output file in tabular form.

The flow chart of this subroutine has been shown in Fig. 6.2.

19. CIRCULAR

This is used in circular tank in which various subroutines are called. Various subroutines called are INTPOL, TEMPT, TFULL, STRESS, HOOPREIN, MOMENT, HGSLAB, CFSLAB, CANTTANK. Input values in this subroutine required are :

* Capacity of tank in litres
* Code for height specified / diameter specified
* Height or diameter of tank
* Depth of tank below G.L.
* Ground water level below G.L.

* Unit weight of liquid filled
* Unit weight of soil
* Base condition code, fixed or hinged.

Flow chart of this subroutine has been shown in Fig.6.3.

6.2.3 Drafting of Designed Section

Drafting of rectangular tank has been dealt in this section. For drafting three programs have been developed. Input of these programs in the file SHAKUN.DAT which is created when program COMBIN.FOR is run. DRAFT1.FOR is capable of generating three drawings of sectional elevation depending upon the end conditions.

Program DRAFT2.FOR generates the sectional plan of the tank. Program DRAFT3.FOR is for sectional elevation of tank wall when designed like cantilever retaining wall.

Input values given on screen for these files are :

* IOPORT and MODEL
* Window size
* Factor to enlarge or reduce the drawing
* Pen thickness for drawing

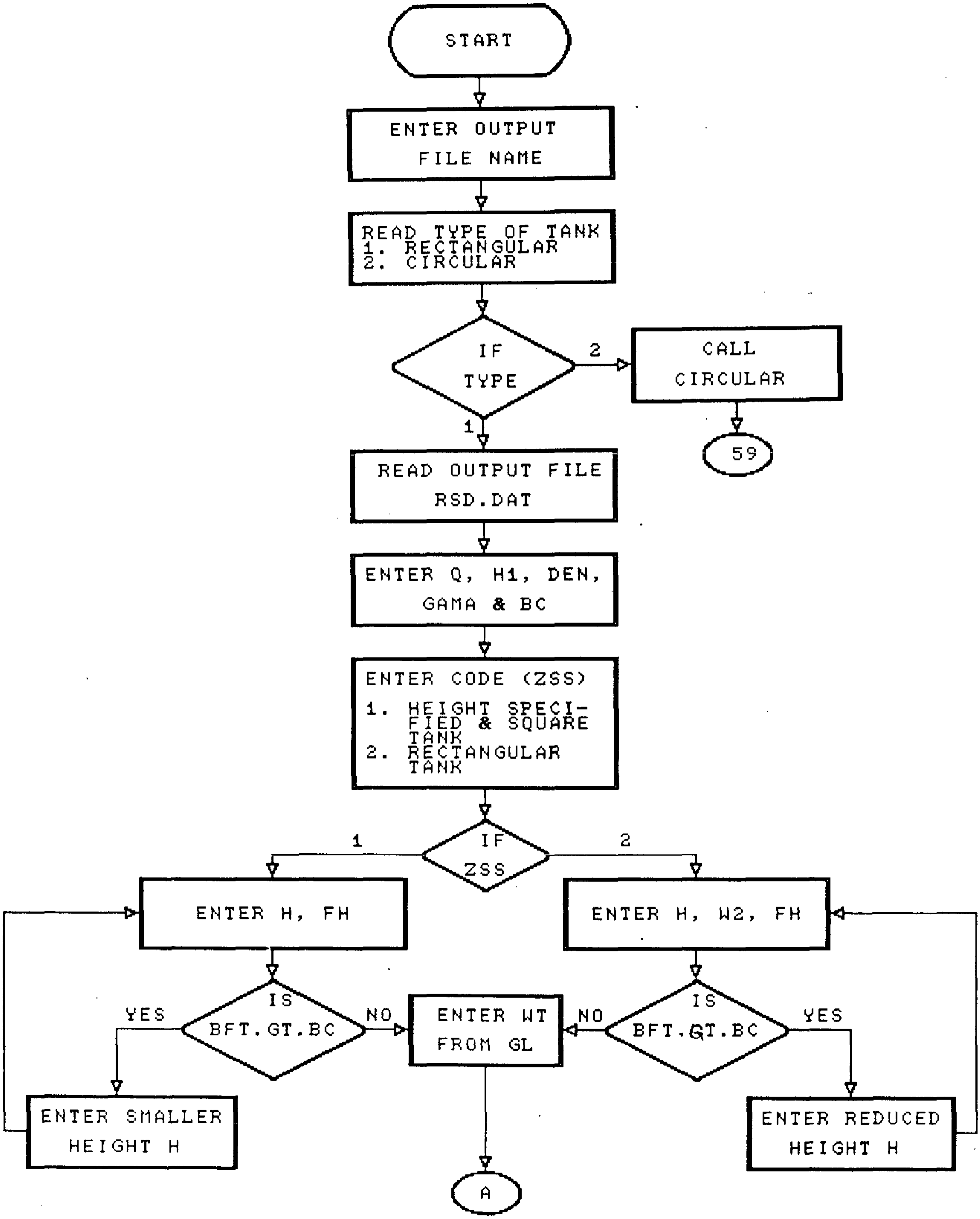
In these drawings colours have been used and give attractive coloured drawings when output is taken on coloured plotter. Various IOPORT & MODEL have been given in Table 6.1. Flow charts of DRAFT1.FOR and DRAFT2.FOR have been shown in Fig. 6.4 and Fig. 6.5 respectively.

6.3 USER INTERFACE

Software development and its successful use for design depends upon few important criteria which establish the desirable feature of process, Interactive program has the option for only desired restriction on design process, documentation ability to revise and case of redesign.

The interactive feature of software guides the user by providing additional information such as unit of system to be used.

The program has been written to be user friendly and hence it is very easy to use.


START
ENTER OUTPUT FILE NAME
READ TYPE OF TANK
1. RECTANGULAR
2. CIRCULAR
IF TYPE
2
CALL CIRCULAR
59
1
READ OUTPUT FILE RSD.DAT
ENTER Q, H1, DEN, GAMA & BC
ENTER CODE (ZSS)
1. HEIGHT SPECI-FIED & SQUARE TANK
2. RECTANGULAR TANK
IF ZSS
1
2
ENTER H, FH
ENTER H, W2, FH
IS BFT.GT.BC
YES
NO
ENTER WT FROM GL
NO
IS BFT.GT.BC
YES
ENTER SMALLER HEIGHT H
ENTER REDUCED HEIGHT H
A

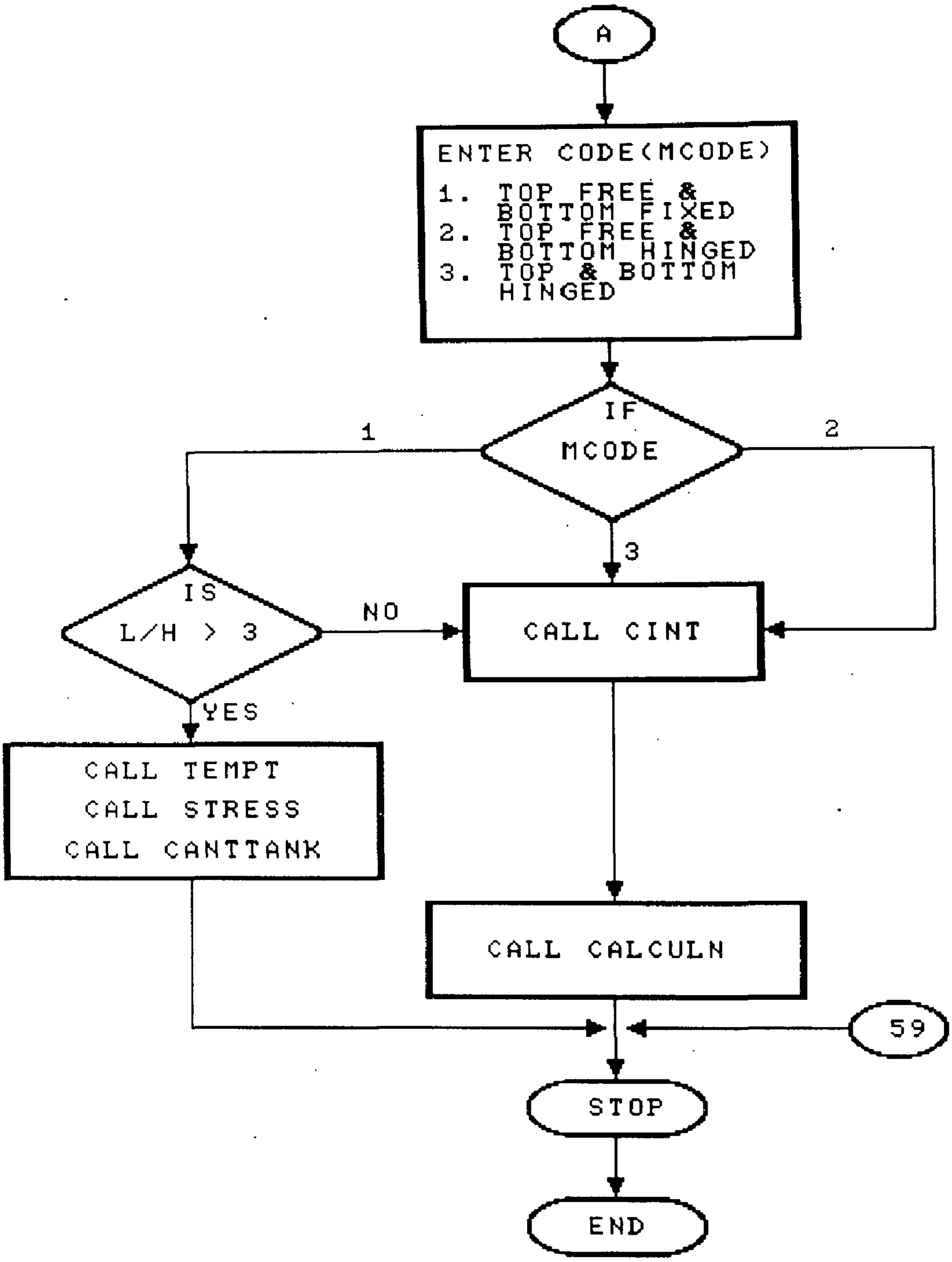
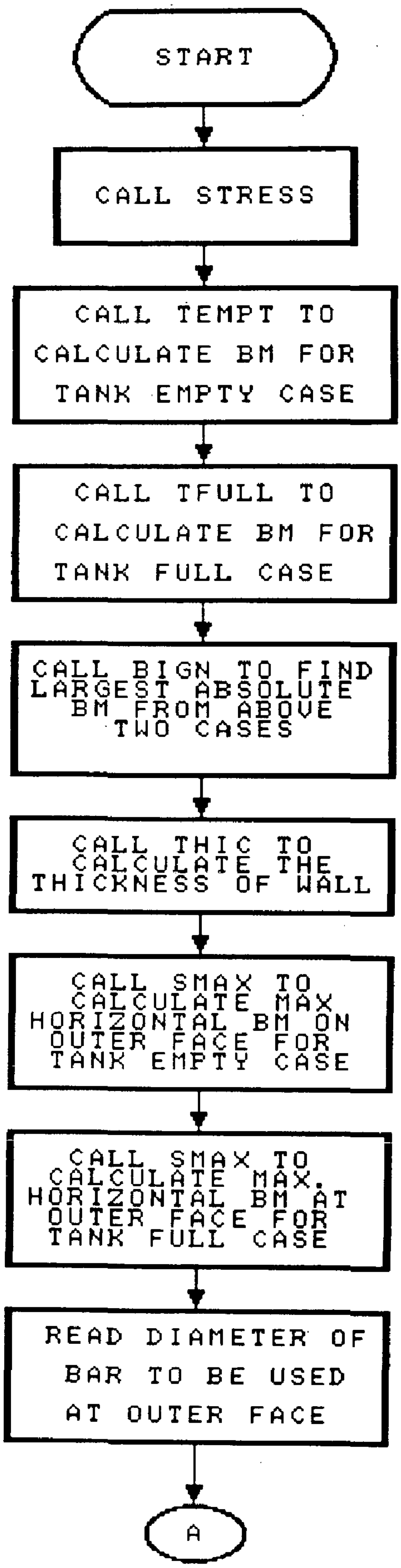
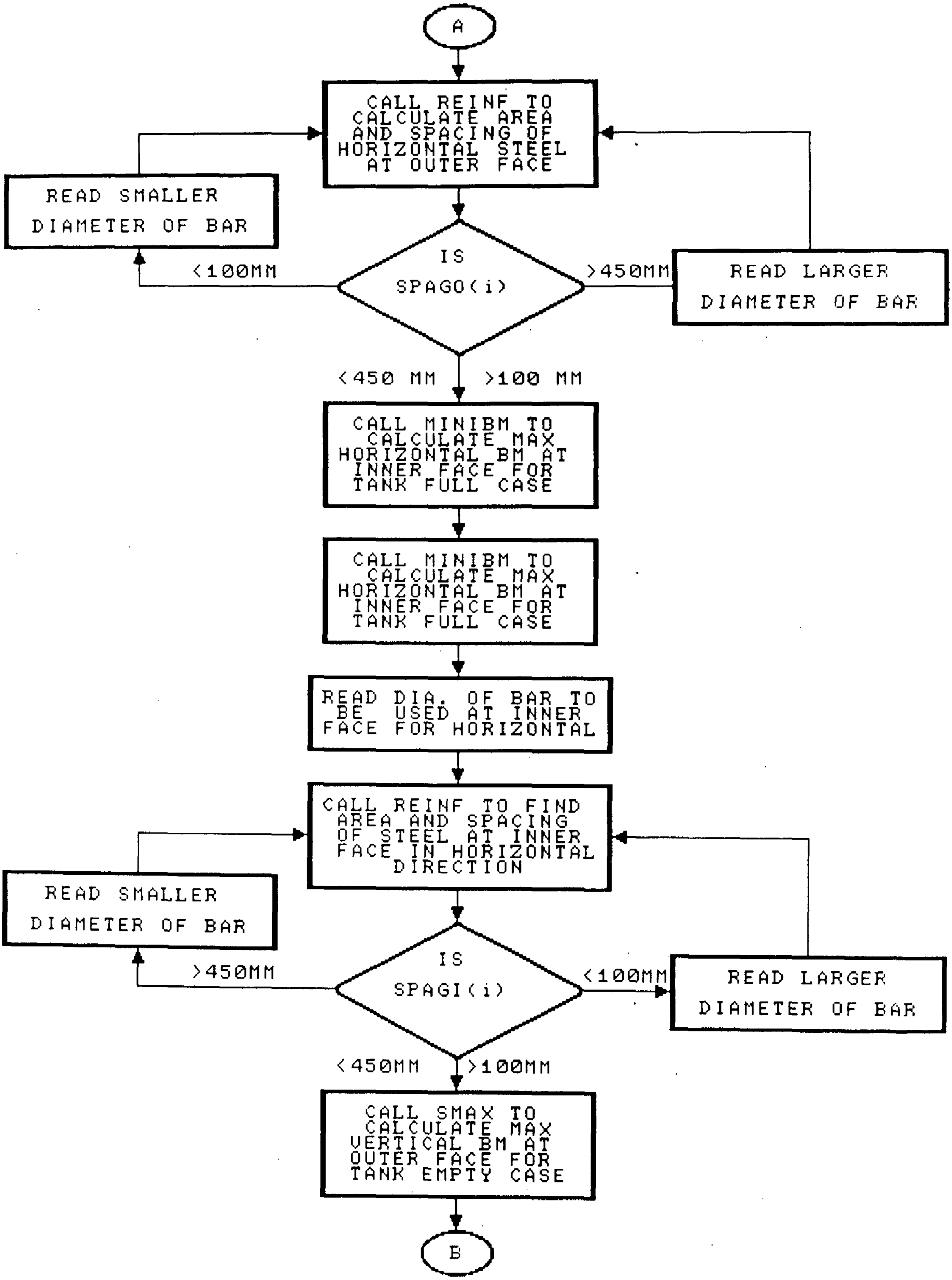
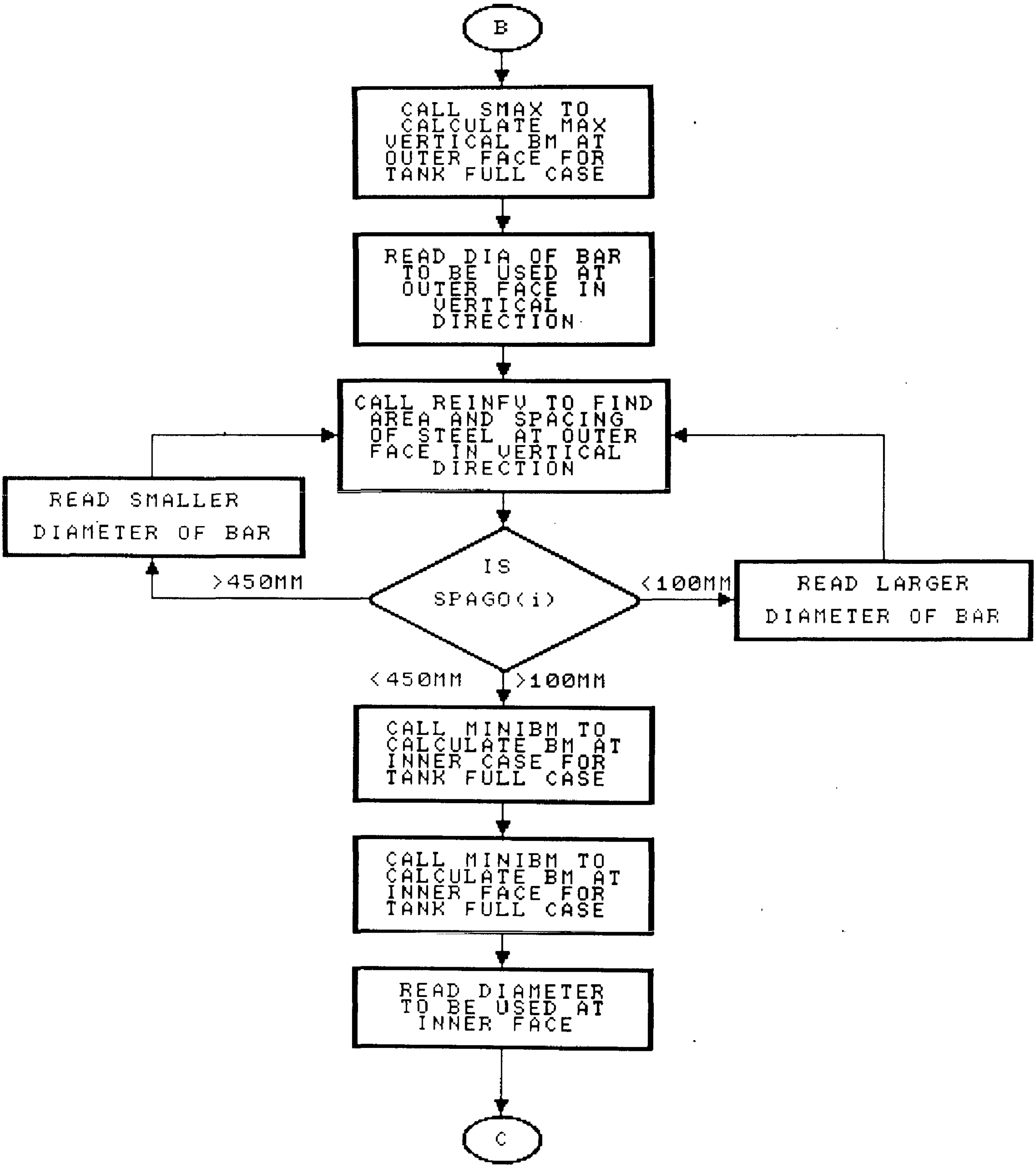


FIG.6.1 - FLOW CHART OF COMBIN.FOR


START
CALL STRESS
CALL TEMPT TO CALCULATE BM FOR TANK EMPTY CASE
CALL TFULL TO CALCULATE BM FOR TANK FULL CASE
CALL BIGN TO FIND LARGEST ABSOLUTE BM FROM ABOVE TWO CASES
CALL THIC TO CALCULATE THE THICKNESS OF WALL
CALL SMAX TO CALCULATE MAX HORIZONTAL BM ON OUTER FACE FOR TANK EMPTY CASE
CALL SMAX TO CALCULATE MAX. HORIZONTAL BM AT OUTER FACE FOR TANK FULL CASE
READ DIAMETER OF BAR TO BE USED AT OUTER FACE
A


A
CALL REINF TO CALCULATE AREA AND SPACING OF HORIZONTAL STEEL AT OUTER FACE
READ SMALLER DIAMETER OF BAR
IS SPAGO(i)
<100MM
>450MM
READ LARGER DIAMETER OF BAR
<450 MM
>100 MM
CALL MINIBM TO CALCULATE MAX HORIZONTAL BM AT INNER FACE FOR TANK FULL CASE
CALL MINIBM TO CALCULATE MAX HORIZONTAL BM AT INNER FACE FOR TANK FULL CASE
READ DIA. OF BAR TO BE USED AT INNER FACE FOR HORIZONTAL
CALL REINF TO FIND AREA AND SPACING OF STEEL AT INNER FACE IN HORIZONTAL DIRECTION
READ SMALLER DIAMETER OF BAR
IS SPAGI(i)
>450MM
<100MM
READ LARGER DIAMETER OF BAR
<450MM
>100MM
CALL SMAX TO CALCULATE MAX VERTICAL BM AT OUTER FACE FOR TANK EMPTY CASE
B


B
CALL SMAX TO CALCULATE MAX VERTICAL BM AT OUTER FACE FOR TANK FULL CASE
READ DIA OF BAR TO BE USED AT OUTER FACE IN VERTICAL DIRECTION
CALL REINFV TO FIND AREA AND SPACING OF STEEL AT OUTER FACE IN VERTICAL DIRECTION
READ SMALLER DIAMETER OF BAR
>450MM
IS SPAGO(i)
<100MM
READ LARGER DIAMETER OF BAR
<450MM
>100MM
CALL MINIBM TO CALCULATE BM AT INNER CASE FOR TANK FULL CASE
CALL MINIBM TO CALCULATE BM AT INNER FACE FOR TANK FULL CASE
READ DIAMETER TO BE USED AT INNER FACE
C

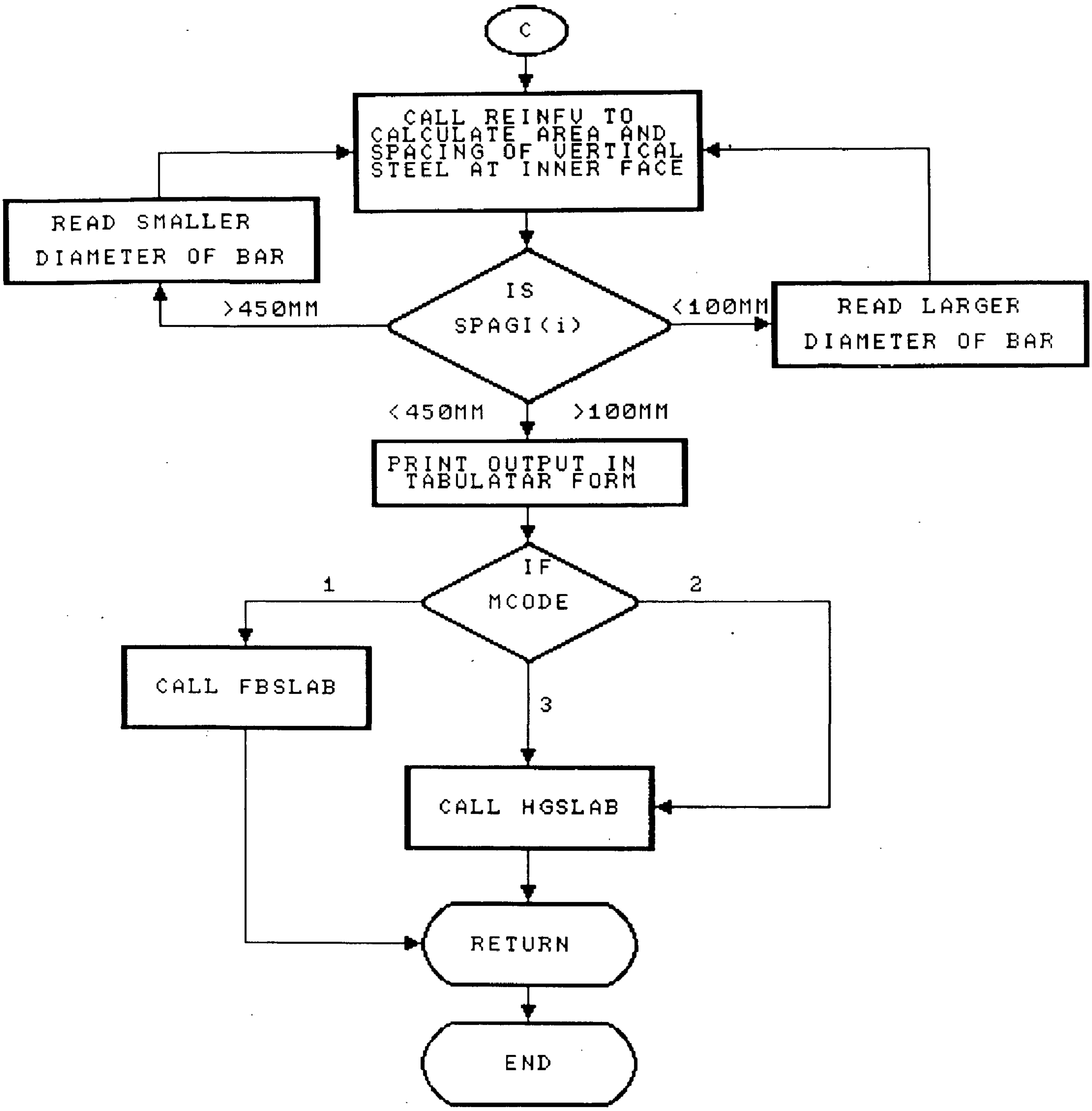
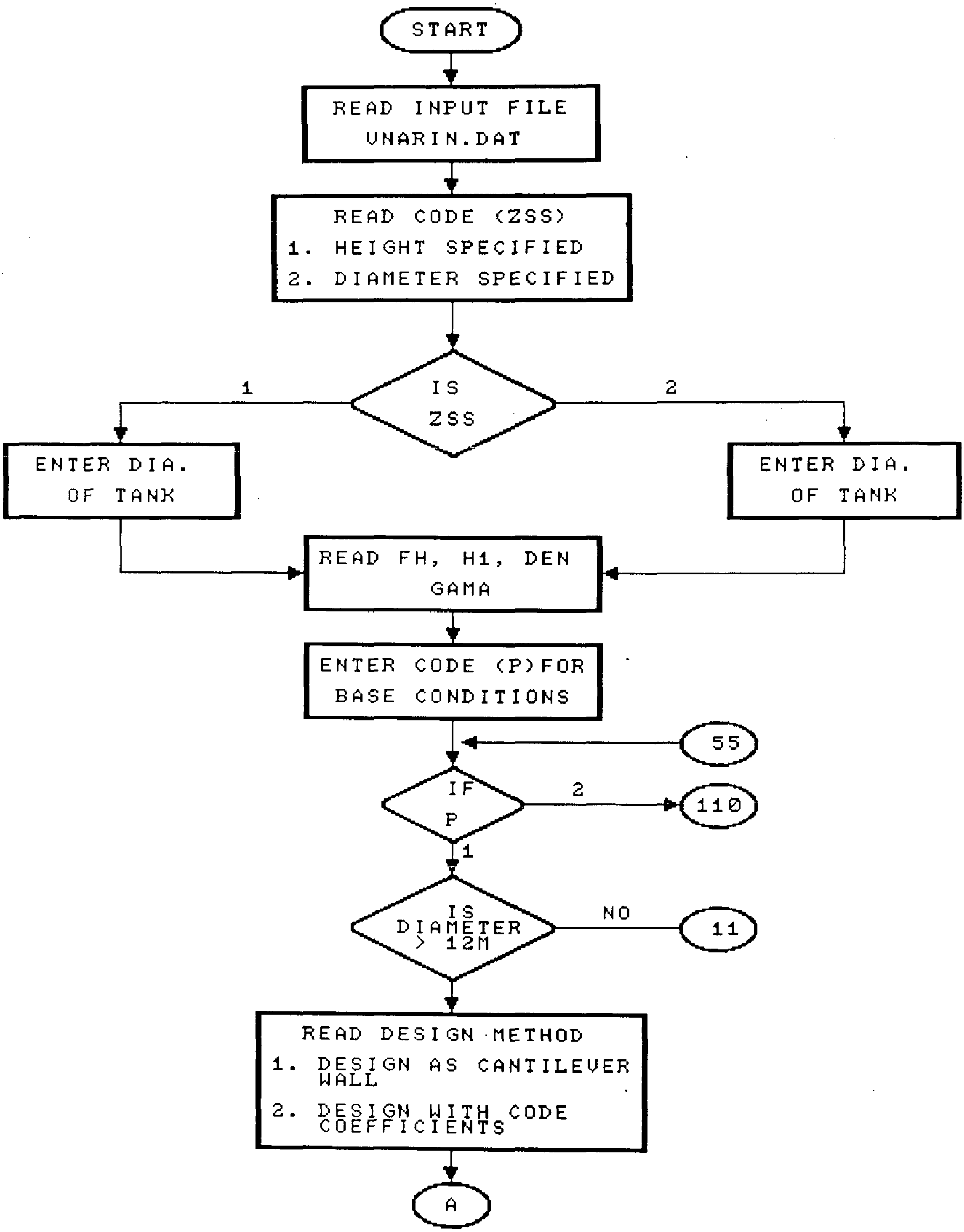
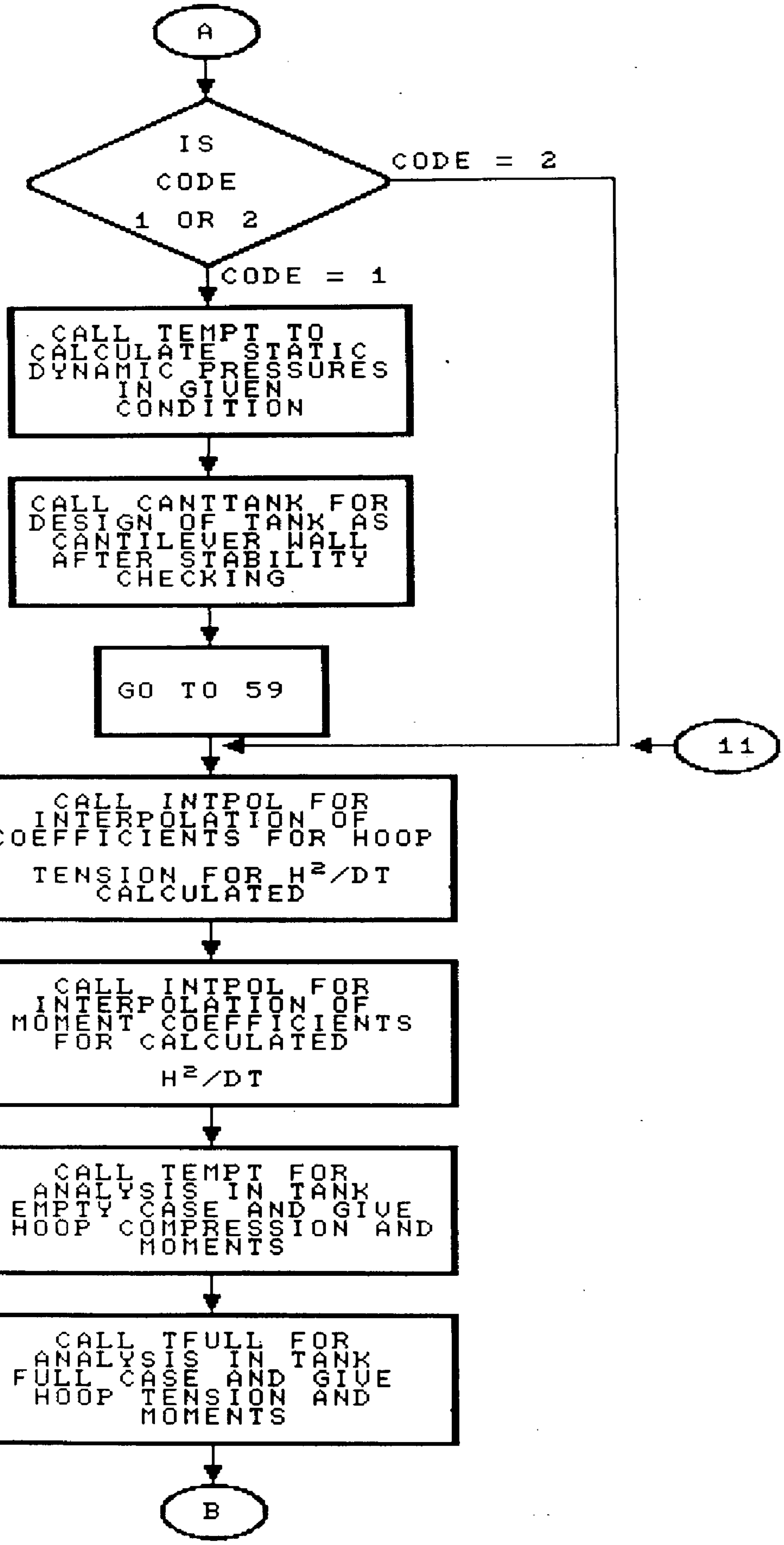
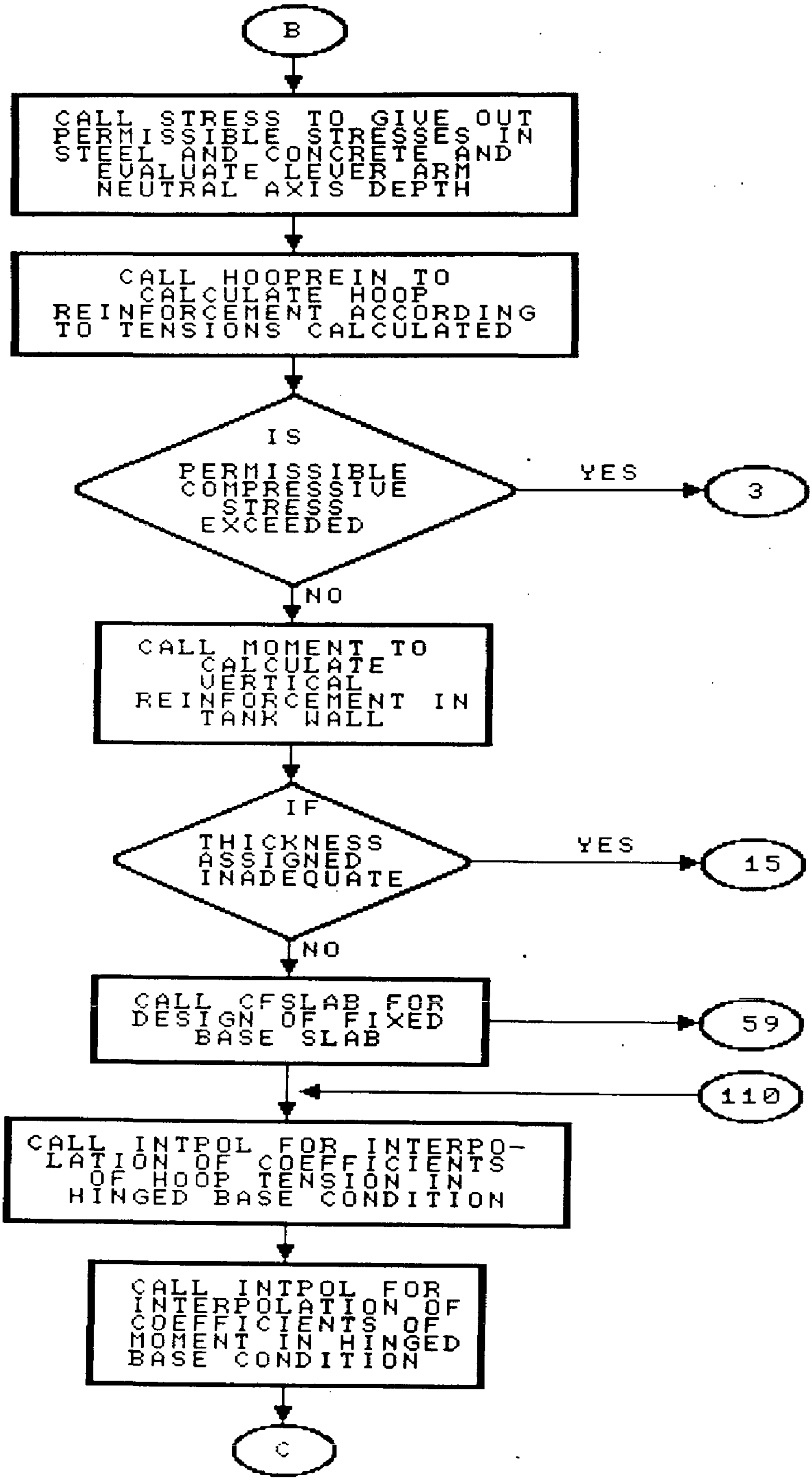


FIG.6.2 - FLOW CHART OF SUBROUTINE CALCULN


START
READ INPUT FILE UNARIN.DAT
READ CODE (ZSS)
1. HEIGHT SPECIFIED
2. DIAMETER SPECIFIED
IS ZSS
1
2
ENTER DIA. OF TANK
ENTER DIA. OF TANK
READ FH, H1, DEN GAMA
ENTER CODE (P) FOR BASE CONDITIONS
55
IF P
2
110
1
IS DIAMETER > 12M
NO
11
READ DESIGN METHOD
1. DESIGN AS CANTILEVER WALL
2. DESIGN WITH CODE COEFFICIENTS
A


A
IS CODE 1 OR 2
CODE = 2
CODE = 1
CALL TEMPT TO CALCULATE STATIC DYNAMIC PRESSURES IN GIVEN CONDITION
CALL CANTTANK FOR DESIGN OF TANK AS CANTILEVER WALL AFTER STABILITY CHECKING
GO TO 59
11
CALL INTPOL FOR INTERPOLATION OF COEFFICIENTS FOR HOOP TENSION FOR H²/DT CALCULATED
CALL INTPOL FOR INTERPOLATION OF MOMENT COEFFICIENTS FOR CALCULATED H²/DT
CALL TEMPT FOR ANALYSIS IN TANK EMPTY CASE AND GIVE HOOP COMPRESSION AND MOMENTS
CALL TFULL FOR ANALYSIS IN TANK FULL CASE AND GIVE HOOP TENSION AND MOMENTS
B


B
CALL STRESS TO GIVE OUT PERMISSIBLE STRESSES IN STEEL AND CONCRETE AND EVALUATE LEVER ARM NEUTRAL AXIS DEPTH
CALL HOOPREIN TO CALCULATE HOOP REINFORCEMENT ACCORDING TO TENSIONS CALCULATED
IS PERMISSIBLE COMPRESSIVE STRESS EXCEEDED
YES
3
NO
CALL MOMENT TO CALCULATE VERTICAL REINFORCEMENT IN TANK WALL
IF THICKNESS ASSIGNED INADEQUATE
YES
15
NO
CALL CFSLAB FOR DESIGN OF FIXED BASE SLAB
59
110
CALL INTPOL FOR INTERPOLATION OF COEFFICIENTS OF HOOP TENSION IN HINGED BASE CONDITION
CALL INTPOL FOR INTERPOLATION OF COEFFICIENTS OF MOMENT IN HINGED BASE CONDITION
C

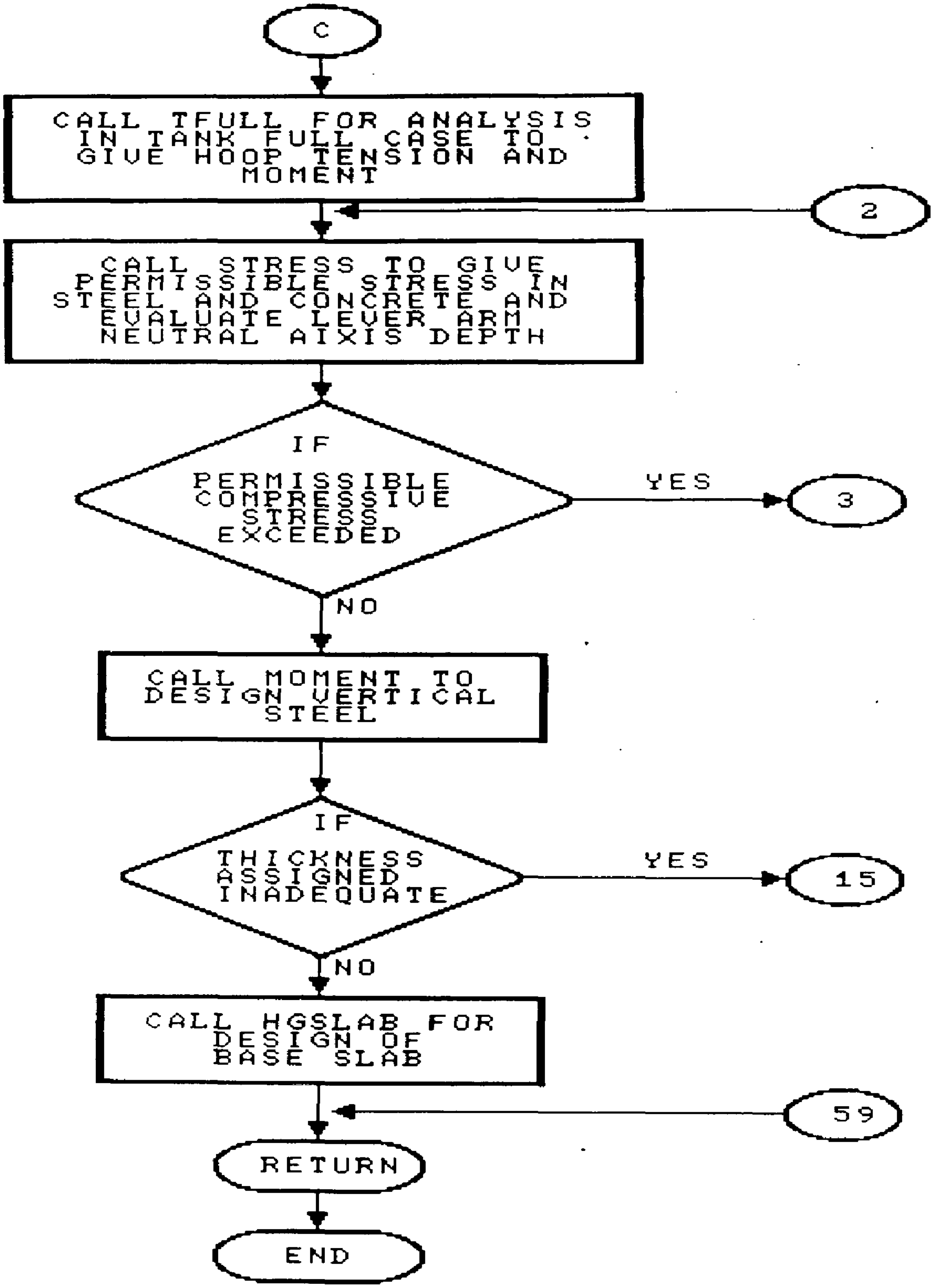


FIG.6.3 – FLOW CHART OF SUBROUTINE CIRCULAR

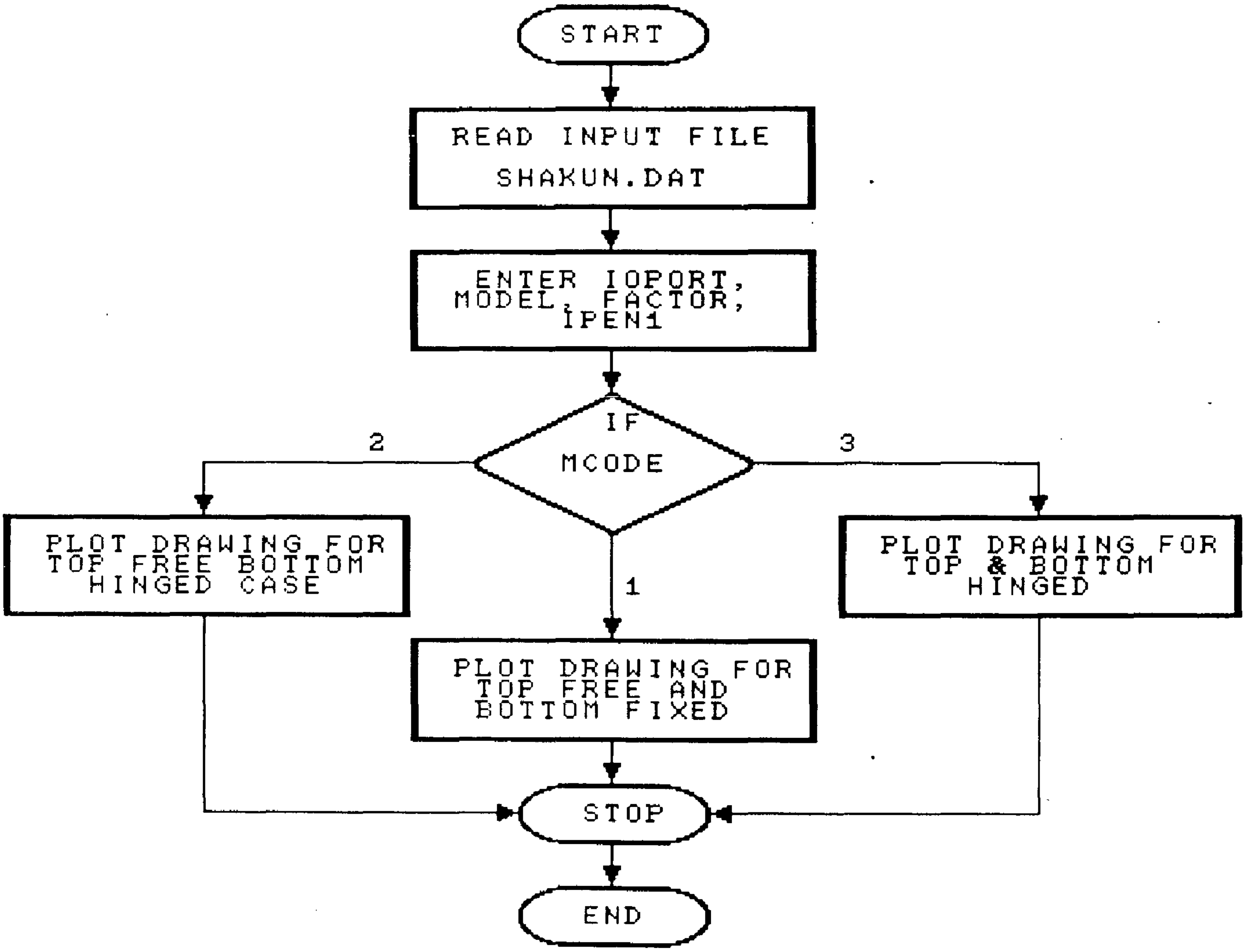


FIG.6.4 - FLOW CHART OF DRAFT1.FOR

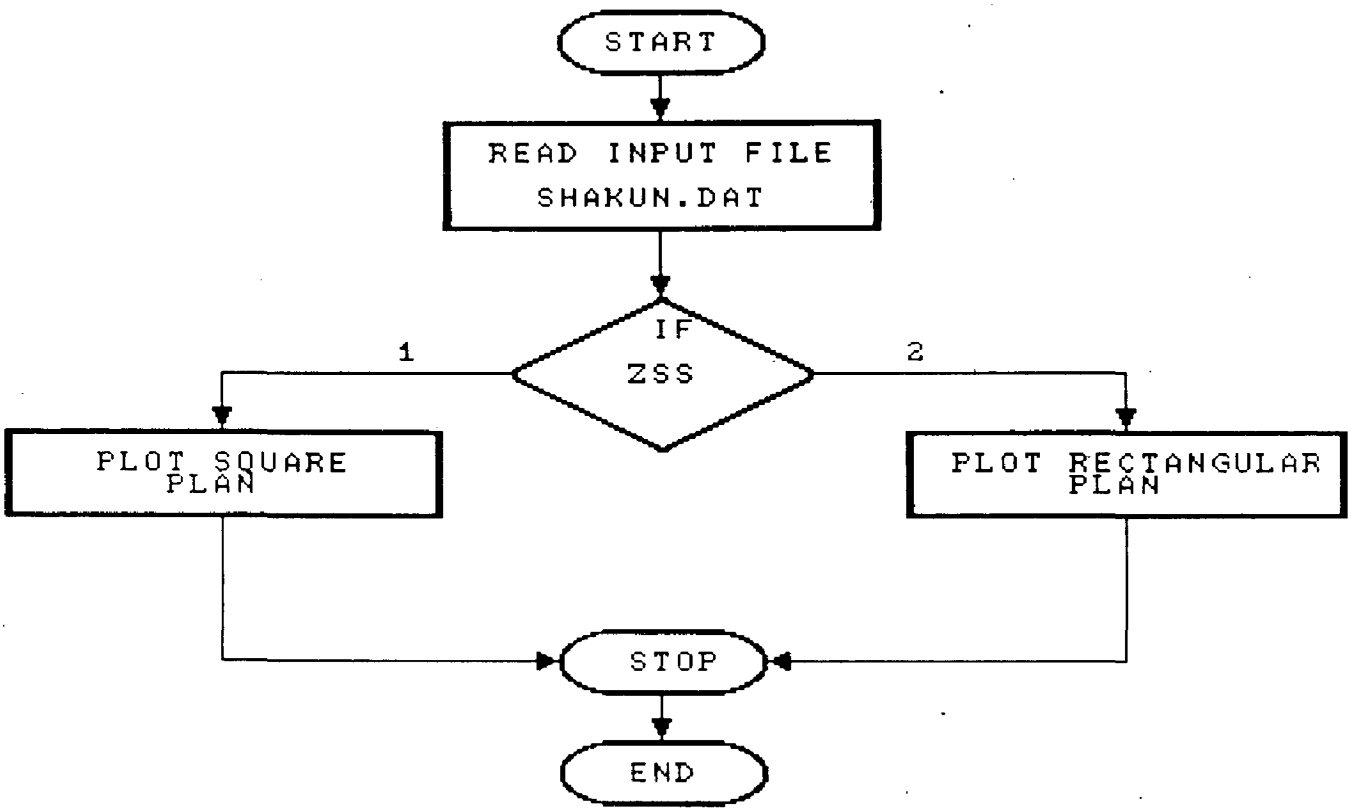


FIG.6.5 - FLOW CHART OF DRAFT2.FOR

Table -6.1: List of Devices Supported by Plot88

Device Name	Codes MODEL	Codes IOPORT	Default Window Size	Pixel Density X	Pixel Density Y
IBM Color Graphix Monitor CGA &.EGA	99	99	8.25"x6"	77	33
Hercules Grahpics & Monochrom Monitor (through Magic Key)	99	99	-	-	-
Tektronix 4025	90	4800/4850	8.5"x8.75"	75	75
Epson Fx-80	0	0	11"x8"	72	60
	1	0	"	72	120
	2	0	"	72	120
	3	0	"	72	240
	4	0	"	72	80
	5	0	"	72	72
	6	0	"	72	90
Epson Fx-100	10	0	11"x13.6"	72	60
	11	0	"	72	120
	12	0	"	72	120
	13	0	"	72	240
	14	0	"	72	80
	15	0	"	72	72
	16	0	"	72	90
Epson Mx-80	0,1,2,3	0	11"x8"		
IBM Printer	0,1,2,3	0	11"x8"		
Epson Mx-100	10 to 13	0	11"x13.6"		
HI-DMP-51 Plotter	51	9600/9650	32.7"x21.5"	1000	1000
HI-DMP-52 Plotter	52	9600/9650	34.0"x21.5"	200	200
HP-7470A Plotter	20	9600/9650	10.7"x 7.5"	1016	1016
HP-7475A Plotter	30	9600/9650	A 10.15x 7.8	1016	1016
			B 16.3x10.15	1016	1016
			A4 10.81x7.56	1016	1016
			A3 15.82x10.81	1016	1016
HP-7440A Drafting Plotter	80	9600/9650	32.2"x23.15	1016	1016
HP-7585B Drafting Plotter	85	9600/9650	46.6"x34.6"	508	508

CHAPTER 7

TEST EXAMPLES

The CADD package 'RCTANK' developed for analysis, design and drafting of underground reinforced concrete tanks has been tested in variety of conditions, which are being presented in this chapter. The test examples involve problems with different base conditions and water table position, to which program responds efficiently. Eight problems have been presented here In first four problems, capacity of tank is 200 KL and in remaining four problems, capacity of tank is 100KL. In these problems all end conditions have been used to illustrate the functioning of software. Test problems 4 & 8 are the cases when L/H ratio exceeds 3 and their design like cantilever retaining wall is carried out. In these test problems different depths of tanks in soil and water table positions has been used. Grade of concrete and steel have also been varied. Drawings of these test problems have been drawn using coloured plotter.

In test problem No. 5 and 6, uniform thickness has been taken to illustrate its functioning.

TEST PROBLEM NO.1

~~~~ **RECTANGULAR** ~~~~
~~~~ **UNDERGROUND TANK** ~~~~

DEPTH OF TANK IN SOIL= 5.00M
CAPACITY OF TANK IN LITRES = 200000.000
MATERIAL UNIT WEIGHT FILLED IN TANK= 9810.00N/M3
SOIL UNIT WEIGHT =16000.00N/M3
BEARING CAPACITY OF SOIL =125.00KN/M2
FREEBOARD TO TANK= .1M
LENGTH OF TANK = 6.900M
BREADTH OF TANK = 6.000M
HEIGHT OF TANK = 5.000M
WATER TABLE POSITION FROM G.L.= 1.00M

TOP FREE & BOTTOM FIXED CASE

COEFFICIENTS FOR BENDING MOMENT

.0000	.0000	.0000	.0000	.0181	.0040	-.0347
.2500	.0066	.0030	-.0080	.0176	.0060	-.0392
.5000	.0150	.0090	-.0075	.0155	.0075	-.0396
.7500	.0013	.0040	-.0050	.0002	.0003	-.0250
1.0000	-.0538	-.0362	.0000	-.0106	-.0070	.0000

CONCRETE GRADE USED =M25
HYSD BARS USED
ANGLE OF INTERNAL FRICTION OF SOIL (DEG)= 30.00
ANGLE OF FRICTION BETWEEN SOIL AND WALL (DEG)= 10.00
SEISMIC ZONE NO.FOR TANK LOCATION = 4
SUBMERGENCE ,STATIC AND DYNAMIC PRESSURE

TANK EMPTY CASE

x/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.00	.000E+00	.000E+00	.000E+00	-.927E+04	-.207E+04	.178E+05
.25	-.336E+04	-.156E+04	.411E+04	-.900E+04	-.309E+04	.201E+05
.50	-.769E+04	-.462E+04	.385E+04	-.794E+04	-.385E+04	.203E+05
.75	-.675E+03	-.203E+04	.256E+04	-.123E+03	-.164E+03	.128E+05
1.00	.275E+05	.185E+05	.000E+00	.540E+04	.360E+04	.000E+00

TANK FULL CASE

X/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.00	.000E+00	.000E+00	.000E+00	.251E+05	.560E+04	-.481E+05
.25	.909E+04	.421E+04	-.111E+05	.244E+05	.837E+04	-.543E+05
.50	.208E+05	.125E+05	-.104E+05	.215E+05	.104E+05	-.549E+05
.75	.183E+04	.549E+04	-.693E+04	.333E+03	.443E+03	-.347E+05
1.00	-.745E+05	-.502E+05	.000E+00	-.146E+05	-.975E+04	.000E+00

LARGEST BM(N-m)= 74486.630 AT x/H=1.000

THICKNESS OF WALL FROM TOP TO 2.50M= 470.00mm
THICKNESS OF WALL FROM 2.5M TO BOTTOM JUNCTION = 550 mm

***** HORIZONTAL REINFORCEMENT *****

DIAMETRE OF HORIZONTAL STEEL BAR AT OUTER FACE=16.00mm
DIAMETRE OF HORIZONTAL STEEL BAR AT INNER FACE=16.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0 TO	1.9	940	954	210	210
1.9 TO	3.1	940	964	210	205
3.1 TO	5.0	1100	1100	180	180

***** VERTICAL REINFORCEMENT *****

DIAMETER OF VERTICAL STEEL BAR AT OUTER FACE=16.00mm

DIAMETER OF VERTICAL STEEL BAR AT INNER FACE=16.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0 TO	1.9	940	940	210	210
1.9 TO	3.1	940	940	210	210
3.1 TO	5.0	1100	1100	180	180

BASE SLAB DETAILS

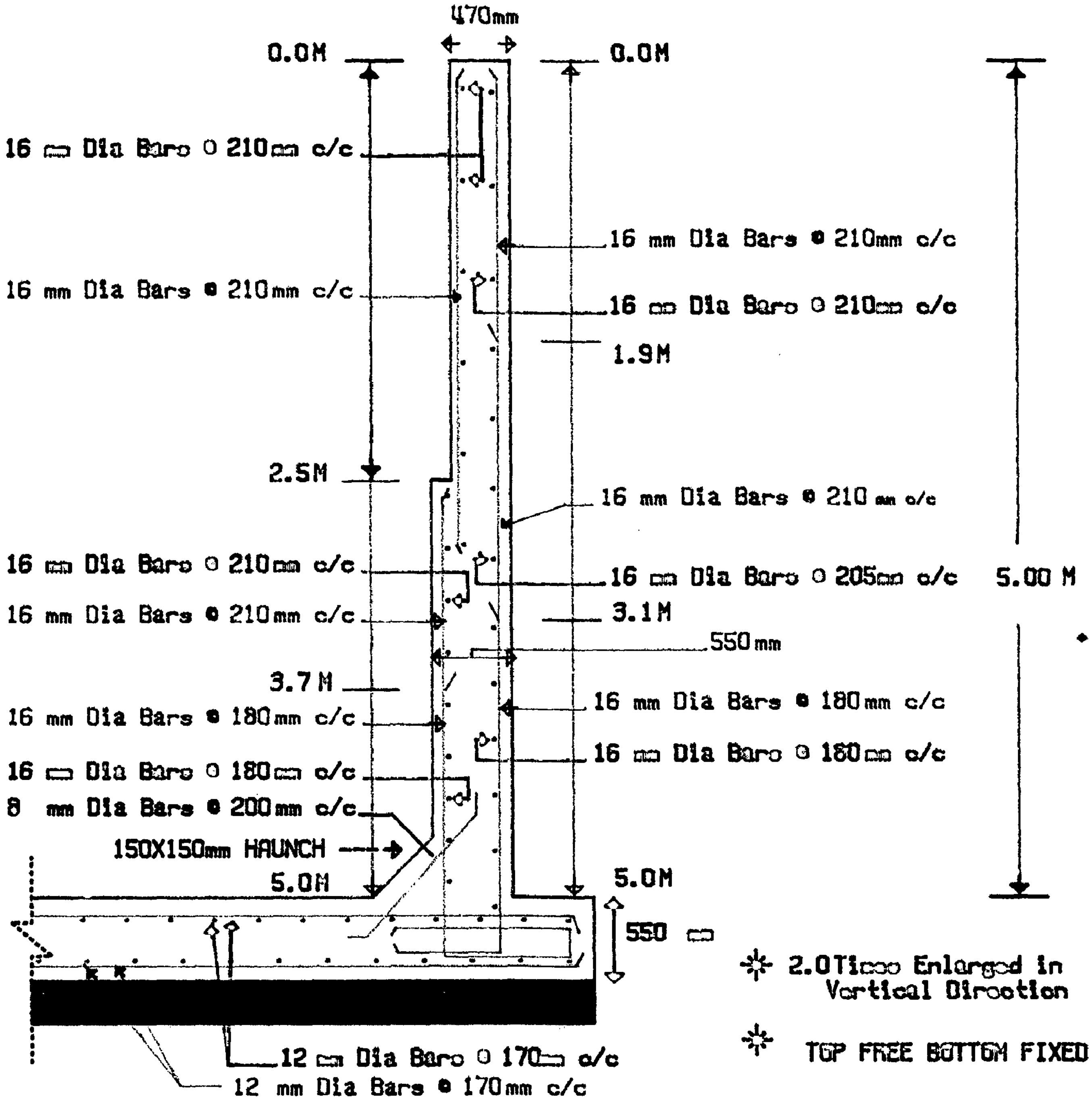
DIAMETER OF STEEL BAR USED IN BASE SLAB=12.00mm

PROVIDE 75mm THICK CONCRETE LAYER OF GRADE M10 ON WELL RAMMED GROUND ON THAT

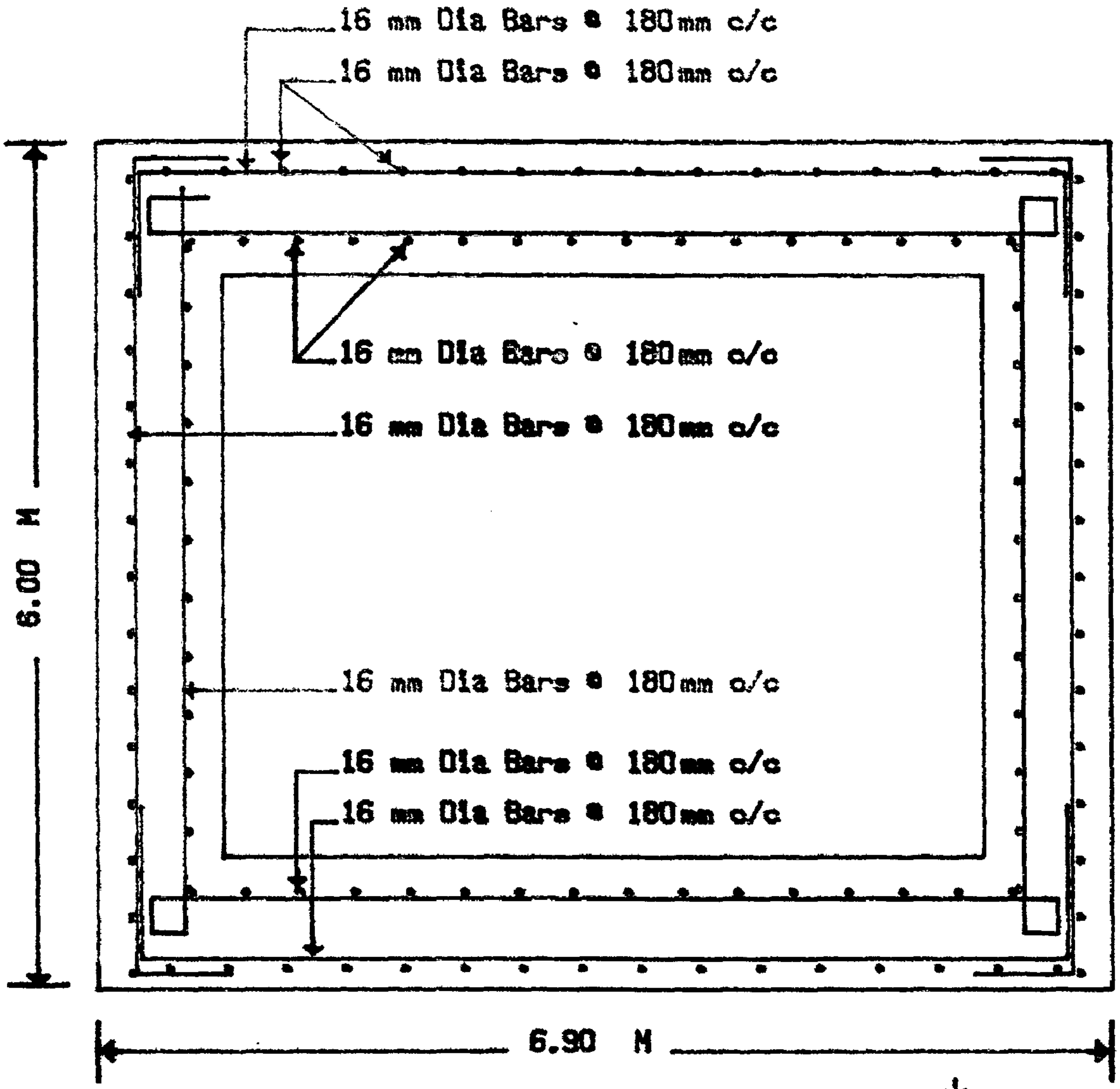
PUT A BITUMEN OR EQUIVALENT MATERIAL LAYER.THEN ON THIS PROVIDE BASE SLAB. IF WIDTH OF TANK IS SMALL THEN THICKNESS EQUAL TO THICKNESS OF WALL IS PROVIDED IN WHOLE BASE SLAB ELSE EXTEND ATLEAST BY 1M IN BASE SLAB AND IN REST OF THE PORTION PROVIDE THICKNESS OF BASE SLAB =250.00mm. PROVIDE HAUNCH OF 150x150 mm AT WALL- SLAB JUNCTION WITH 8mm BARS @ 200mm c/c.

PROVIDE 12.0mm DIA BARS AT UPPER FACE OF BASE SLAB @ 170mm c/c WITH EFFECTIVE COVER OF 20mm IN BOTH DIRECTION AT RIGHT ANGLE.

PROVIDE12.0mm DIA BARS AT LOWER FACE OF BASE SLAB @ 170mm c/c WITH EFFECTIVE COVER OF 20mm IN BOTH DIRECTION AT RIGHT ANGLE.



SECTIONAL ELEVATION



SECTIONAL PLAN

* NOT TO SCALE

TEST PROBLEM NO.2

~~~~ RECTANGULAR ~~~~
~~~~ UNDERGROUND TANK ~~~~

DEPTH OF TANK IN SOIL= 4.00M
CAPACITY OF TANK IN LITRES = 200000.000
MATERIAL UNIT WEIGHT FILLED IN TANK= 9810.00N/M3
SOIL UNIT WEIGHT =16000.00N/M3
BEARING CAPACITY OF SOIL =125.00KN/M2
FREEBOARD TO TANK= .1M
LENGTH OF TANK = 6.400M
BREADTH OF TANK = 6.400M
HEIGHT OF TANK = 5.000M
WATER TABLE POSITION FROM G.L.= 1.00M

TOP FREE & BOTTOM HINGED CASE

COEFFICIENTS FOR BENDING MOMENT.

.0000	.0000	.0000	.0000	.0182	.0032	-.0362
.2500	.0055	.0021	-.0085	.0210	.0054	-.0440
.5000	.0176	.0094	-.0104	.0235	.0092	-.0507
.7500	.0217	.0135	-.0091	.0174	.0092	-.0450

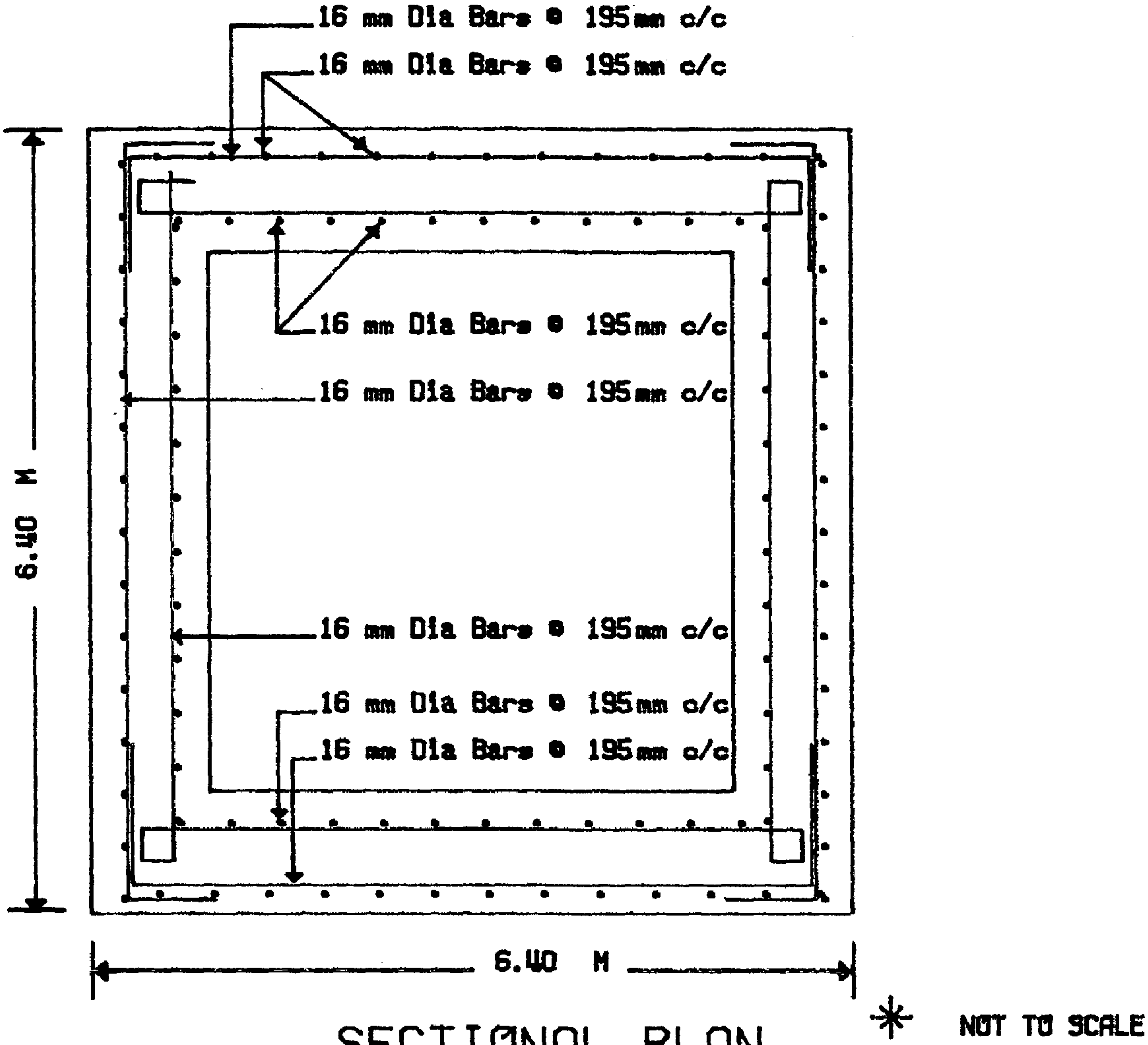
CONCRETE GRADE USED =M25
HYSD BARS USED
ANGLE OF INTERNAL FRICTION OF SOIL (DEG)= 30.00
ANGLE OF FRICTION BETWEEN SOIL AND WALL (DEG)= 10.00
SUBMERGENCE AND STATIC PRESSURE CONSIDERED

TANK EMPTY CASE

x/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.00	.000E+00	.000E+00	.000E+00	-.102E+05	-.182E+04	.203E+05
.25	-.308E+04	-.119E+04	.476E+04	-.118E+05	-.301E+04	.247E+05
.50	-.989E+04	-.526E+04	.582E+04	-.132E+05	-.519E+04	.285E+05
.75	-.122E+05	-.757E+04	.512E+04	-.975E+04	-.519E+04	.253E+05

TANK FULL CASE

X/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.00	.000E+00	.000E+00	.000E+00	.223E+05	.397E+04	-.443E+05
.25	.672E+04	.260E+04	-.104E+05	.257E+05	.657E+04	-.540E+05
.50	.216E+05	.115E+05	-.127E+05	.288E+05	.113E+05	-.621E+05
.75	.266E+05	.165E+05	-.112E+05	.213E+05	.113E+05	-.551E+05



SECTIONAL PLAN

TEST PROBLEM NO.3

~~~~ RECTANGULAR ~~~~
~~~~ UNDERGROUND TANK ~~~~

DEPTH OF TANK IN SOIL= 5.00M
CAPACITY OF TANK IN LITRES = 200000.000
MATERIAL UNIT WEIGHT FILLED IN TANK= 9810.00N/M3
SOIL UNIT WEIGHT =16000.00N/M3
BEARING CAPACITY OF SOIL =125.00KN/M2
FREEBOARD TO TANK= .1M
LENGTH OF TANK = 6.900M
BREADTH OF TANK = 6.000M
HEIGHT OF TANK = 5.000M
WATER TABLE POSITION FROM G.L.= 1.00M

TOP HINGED & BOTTOM HINGED CASE

COEFFICIENTS FOR BENDING MOMENT

.2500	.0121	.0066	-.0060	.0125	.0060	-.0301
.5000	.0169	.0094	-.0074	.0159	.0080	-.0382
.7500	.0266	.0171	-.0095	.0170	.0100	-.0456

CONCRETE GRADE USED =M25
HYSD BARS USED
ANGLE OF INTERNAL FRICTION OF SOIL (DEG)= 30.00
ANGLE OF FRICTION BETWEEN SOIL AND WALL (DEG)= 10.00
SEISMIC ZONE NO.FOR TANK LOCATION = 4
SUBMERGENCE ,STATIC AND DYNAMIC PRESSURE

TANK EMPTY CASE

x/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.25	-.620E+04	-.336E+04	.307E+04	-.640E+04	-.309E+04	.154E+05
.50	-.866E+04	-.483E+04	.381E+04	-.812E+04	-.407E+04	.196E+05
.75	-.136E+05	-.876E+04	.487E+04	-.870E+04	-.514E+04	.233E+05

TANK FULL CASE

X/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.25	.168E+05	.909E+04	-.831E+04	.173E+05	.837E+04	-.417E+05
.50	.234E+05	.131E+05	-.103E+05	.220E+05	.110E+05	-.530E+05
.75	.369E+05	.237E+05	-.132E+05	.236E+05	.139E+05	-.632E+05

LARGEST BM(N-m)= 63180.620 AT x/H= .750

THICKNESS OF WALL FROM TOP TO 2.50M= 470.00mm
THICKNESS OF WALL FROM DEPTH (= 2.50M) TO BOTTOM JUNCTION= 510.00mm

HORIZONTAL REINFORCEMENT

DIAMETRE OF HORIZONTAL STEEL BAR AT OUTER FACE=16.00mm

DIAMETRE OF HORIZONTAL STEEL BAR AT INNER FACE=16.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0	1.9	940	940	210	210
1.9	3.1	940	940	210	210
3.1	5.0	1020	1020	195	195

VERTICAL REINFORCEMENT

DIAMETER OF VERTICAL STEEL BAR AT OUTER FACE=16.00mm

DIAMETER OF VERTICAL STEEL BAR AT INNER FACE=16.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0	1.9	940	940	210	210
1.9	3.1	940	940	210	210
3.1	5.0	1020	1020	195	195

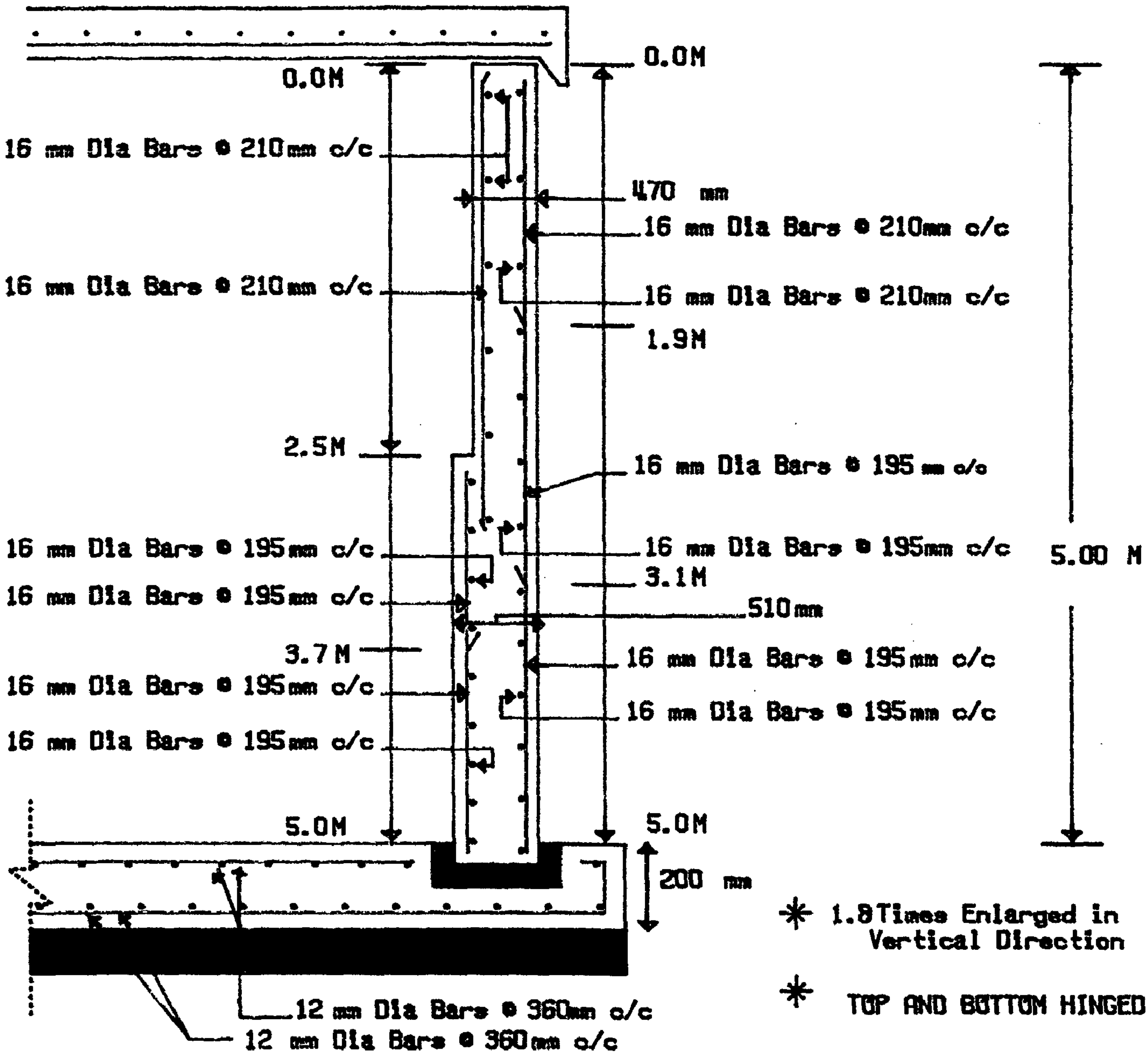
BASE SLAB DETAILS

DIAMETER OF STEEL BAR USED IN BASE SLAB=12.00mm

PROVIDE 75mm THICK CONCRETE LAYER OF GRADE M10 ON WELL RAMMED GROUND ON THAT PUT A BITUMEN OR EQUIVALENT MATERIAL LAYER. THEN ON THIS PROVIDE BASE SLAB.

THICKNESS OF BASE SLAB=200.00mm

PROVIDE 12.0mm DIA BARS @ 360.00mm c/c BOTHWAYS AT TOP AND BOTTOM FACE OF BASE SLAB IN BOTH DIRECTIONS AT RIGHT ANGLE



SECTIONAL ELEVATION

TEST PROBLEM NO. 4

~~~~ RECTANGULAR ~~~~
~~~~ UNDERGROUND TANK ~~~~

DEPTH OF TANK IN SOIL= 4.00M
CAPACITY OF TANK IN LITRES = 200000.000
MATERIAL UNIT WEIGHT FILLED IN TANK= 9810.00N/M3
SOIL UNIT WEIGHT =16000.00N/M3
BEARING CAPACITY OF SOIL =125.00KN/M2
FREEBOARD TO TANK= .1M
LENGTH OF TANK = 12.900M
BREADTH OF TANK = 4.000M
HEIGHT OF TANK = 4.000M
WATER TABLE POSITION FROM G.L.= 6.00M
ANGLE OF INTERNAL FRICTION OF SOIL (DEG)= 30.00
ANGLE OF FRICTION BETWEEN SOIL AND WALL (DEG)= 10.00
SEISMIC ZONE NO.FOR TANK LOCATION = 3
STATIC AND DYNAMIC PRESSURE CONSIDERED
CONCRETE GRADE USED =M25
HYSD BARS USED

****
DESIGN OF TANK AS CANTILIVER
****

STEM WALL DETAILS

THICKNESS(M)= .30
REDUCED TO 20CM AT TOP

WATER FACE REINFORCEMENT (FROM TOP) IN STEM

REINFORCEMENT FROM	TO (M)	BARDIA (MM)	SPACING C/C (MM)
.00	2.10	20.00	240.00
2.10	4.00	20.00	120.00

EARTH FACE REINFORCEMENT (FROM TOP) IN STEM

REINFORCEMENT FROM	TO (M)	BARDIA (MM)	SPACING C/C (MM)
.00	2.10	16.00	320.00
2.10	4.00	16.00	160.00

DISTRIBUTION REINFORCEMENT ON EACH FACE

BARDIA	SPACING
12.00	300.00

BASE SLAB DETAILS

THICKNESS OF BASE SLAB= .30
TOE SLAB LENGTH= 1.00
HEEL SLAB LENGTH= 2.50

HEEL REINFORCEMENT DETAILS

TOP FACE

BARDIA	SPACING
20.00	175.00

BOTTOM FACE

BARDIA	SPACING
20.00	330.00

DISTRIBUTION REINFORCEMENT ON EACH FACE

BARDIA	SPACING
12.00	300.00

TOE REINFORCEMENT DETAILS

TOP FACE

BARDIA	SPACING
20.00	175.00

BOTTOM FACE

BARDIA	SPACING
20.00	120.00

DISTRIBUTION BARS ON EACH FACE

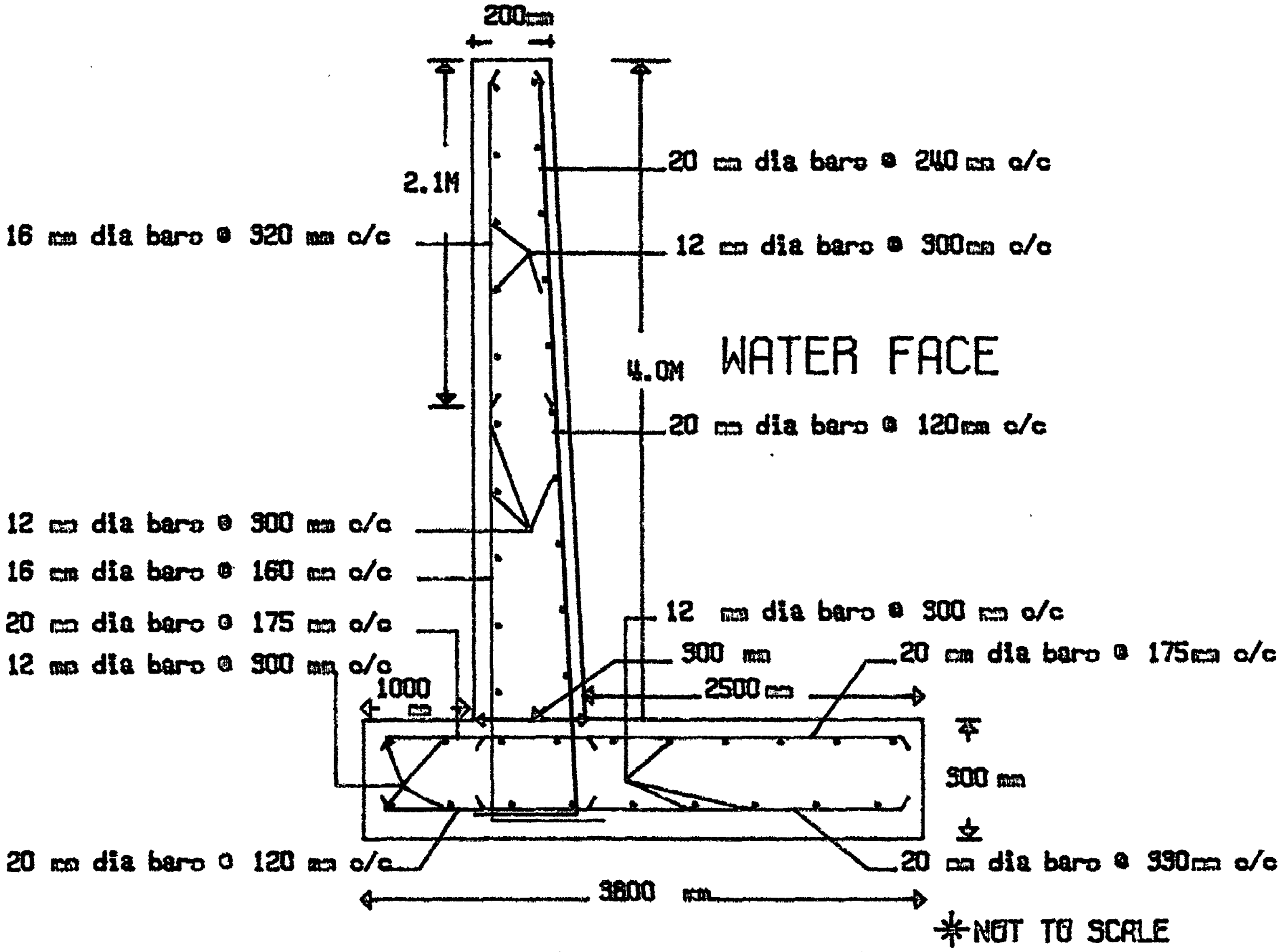
BARDIA	SPACING
12.00	300.00

PROVIDE CONSTRUCTION JOINT AT BASE.
DIAMETER OF STEEL BAR USED IN BASE SLAB=12.00mm

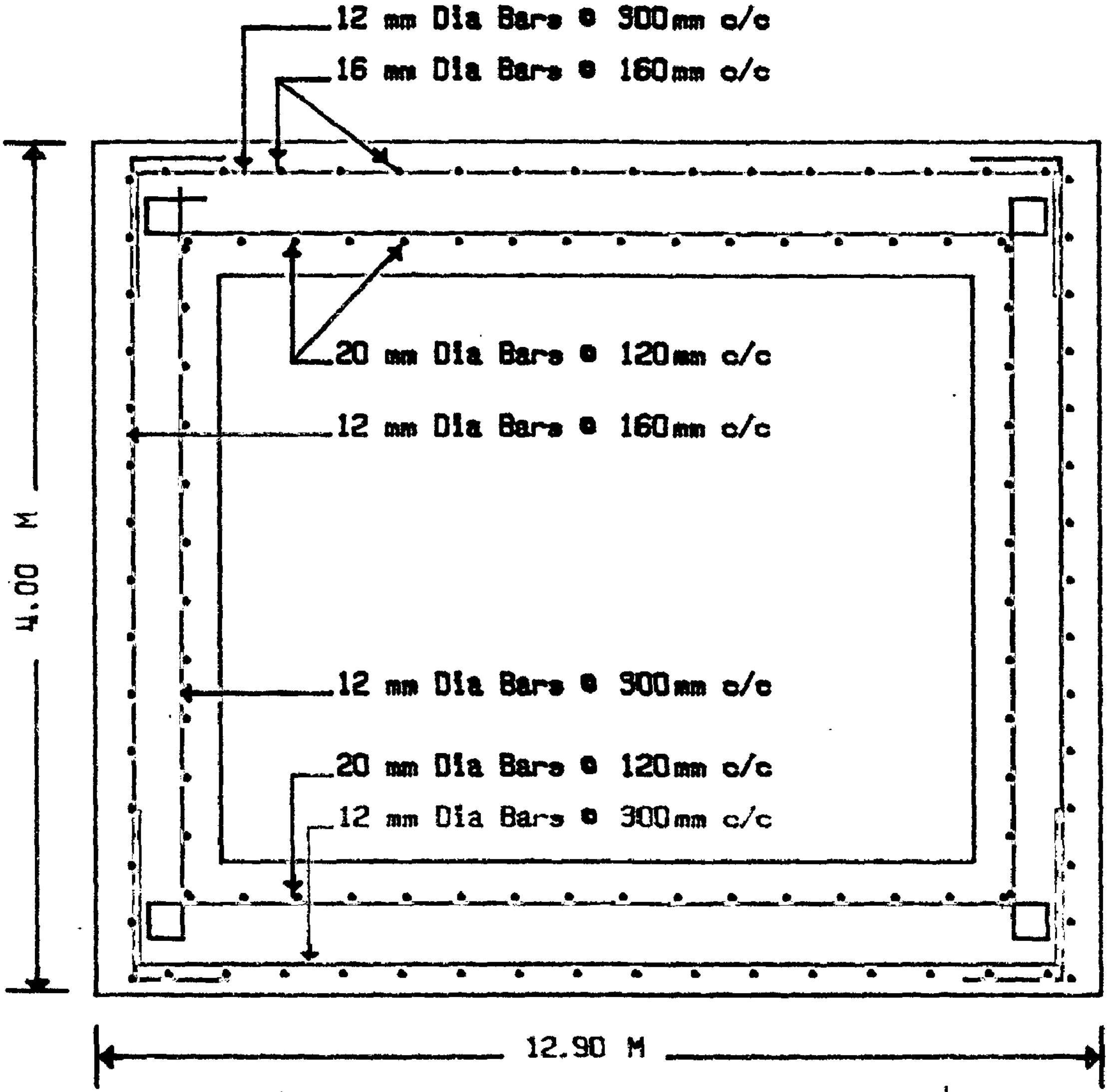
PROVIDE 75mm THICK CONCRETE LAYER OF GRADE M10 ON WELL RAMMED GROUND ON THAT PUT A BITUMEN OR EQUIVALENT MATERIAL LAYER. THEN ON THIS PROVIDE BASE SLAB.

THICKNESS OF BASE SLAB=200.00mm

PROVIDE 12.0mm DIA BARS @ 360.00mm c/c BOTHWAYS AT TOP AND BOTTOM FACE OF BASE SLAB IN BOTH DIRECTIONS AT RIGHT ANGLE



SECTIONAL ELEVATION



SECTIONAL PLAN

* NOT TO SCALE

TEST PROBLEM NO. 5

~~~~ RECTANGULAR ~~~~
~~~~ UNDERGROUND TANK ~~~~

DEPTH OF TANK IN SOIL= 4.00M
CAPACITY OF TANK IN LITRES = 100000.000
MATERIAL UNIT WEIGHT FILLED IN TANK= 9810.00N/M3
SOIL UNIT WEIGHT =16000.00N/M3
BEARING CAPACITY OF SOIL =125.00KN/M2
FREEBOARD TO TANK= .1M
LENGTH OF TANK = 5.100M
BREADTH OF TANK = 5.100M
HEIGHT OF TANK = 4.000M
WATER TABLE POSITION FROM G.L.= 1.00M

TOP FREE & BOTTOM FIXED CASE

COEFFICIENTS FOR BENDING MOMENT

.0000	.0000	.0000	.0000	.0156	.0032	-.0301
.2500	.0053	.0022	-.0072	.0155	.0052	-.0350
.5000	.0142	.0082	-.0071	.0151	.0071	-.0375
.7500	.0051	.0048	-.0050	.0057	.0041	-.0242
1.0000	-.0483	-.0320	.0000	-.0093	-.0062	.0000

CONCRETE GRADE USED =M20
HYSD BARS USED

ANGLE OF INTERNAL FRICTION OF SOIL (DEG)= 30.00
ANGLE OF FRICTION BETWEEN SOIL AND WALL (DEG)= 10.00
SUBMERGENCE AND STATIC PRESSURE CONSIDERED

TANK EMPTY CASE

x/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.00	.000E+00	.000E+00	.000E+00	-.394E+04	-.809E+03	.761E+04
.25	-.134E+04	-.556E+03	.182E+04	-.392E+04	-.131E+04	.885E+04
.50	-.359E+04	-.207E+04	.179E+04	-.382E+04	-.179E+04	.948E+04
.75	-.129E+04	-.121E+04	.126E+04	-.144E+04	-.104E+04	.612E+04
1.00	.122E+05	.809E+04	.000E+00	.235E+04	.157E+04	.000E+00

TANK FULL CASE

X/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.00	.000E+00	.000E+00	.000E+00	.979E+04	.201E+04	-.189E+05
.25	.333E+04	.138E+04	-.452E+04	.973E+04	.326E+04	-.220E+05
.50	.892E+04	.515E+04	-.446E+04	.948E+04	.446E+04	-.235E+05
.75	.320E+04	.301E+04	-.314E+04	.358E+04	.257E+04	-.152E+05
1.00	-.303E+05	-.201E+05	.000E+00	-.584E+04	-.389E+04	.000E+00

LARGEST BM(N-m)= 30324.670 AT x/H=1.000

UNIFORM THICKNESS OF WALL FROM TOP TO BOTTOM JUNCTION= 365.00mm

***** HORIZONTAL REINFORCEMENT *****

DIAMETRE OF HORIZONTAL STEEL BAR AT OUTER FACE=16.00mm

DIAMETRE OF HORIZONTAL STEEL BAR AT INNER FACE=16.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0 TO	1.5	818	818	245	245
1.5 TO	2.5	818	818	245	245
2.5 TO	4.0	818	818	245	245

***** VERTICAL REINFORCEMENT *****

DIAMETER OF VERTICAL STEEL BAR AT OUTER FACE=16.00mm

DIAMETER OF VERTICAL STEEL BAR AT INNER FACE=12.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0 TO	1.5	818	818	245	135
1.5 TO	2.5	818	818	245	135
2.5 TO	4.0	818	818	245	135

BASE SLAB DETAILS

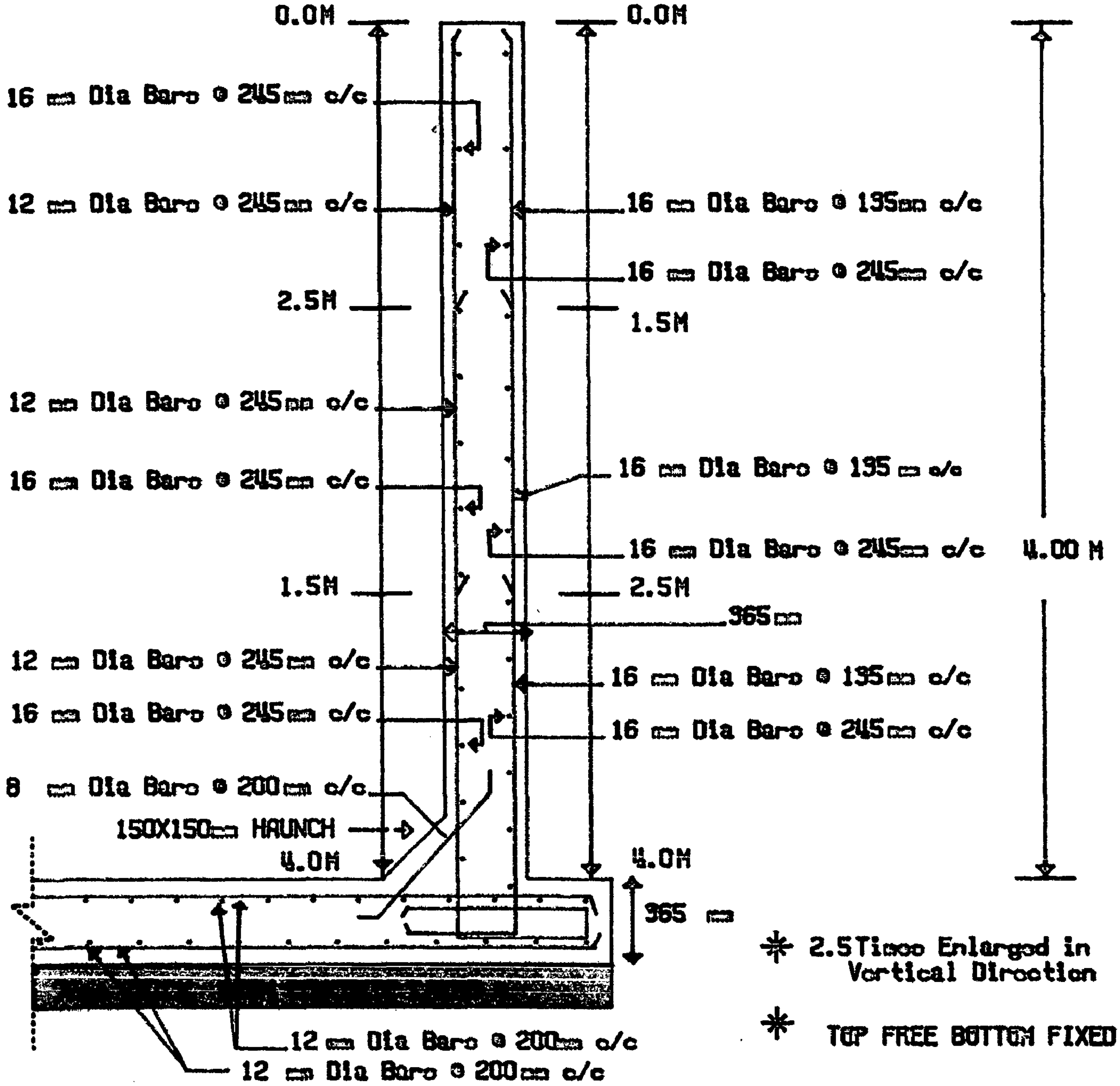
DIAMETER OF STEEL BAR USED IN BASE SLAB=12.00mm

PROVIDE 75mm THICK CONCRETE LAYER OF GRADE M10 ON WELL RAMMED GROUND ON THAT

PUT A BITUMEN OR EQUIVALENT MATERIAL LAYER.THEN ON THIS PROVIDE BASE SLAB. IF WIDTH OF TANK IS SMALL THEN THICKNESS EQUAL TO THICKNESS OF WALL IS PROVIDED IN WHOLE BASE SLAB ELSE EXTEND ATLEAST BY 1M IN BASE SLAB AND IN REST OF THE PORTION PROVIDE THICKNESS OF BASE SLAB =200.00mm. PROVIDE HAUNCH OF 150x150 mm AT WALL- SLAB JUNCTION WITH 8mm BARS @ 200mm c/c.

PROVIDE 12.0mm DIA BARS AT UPPER FACE OF BASE SLAB @ 200mm c/c WITH EFFECTIVE COVER OF 20mm IN BOTH DIRECTION AT RIGHT ANGLE.

PROVIDE12.0mm DIA BARS AT LOWER FACE OF BASE SLAB @ 200mm c/c WITH EFFECTIVE COVER OF 20mm IN BOTH DIRECTION AT RIGHT ANGLE.



SECTIONAL ELEVATION

TEST PROBLEM NO. 6

~~~~ RECTANGULAR ~~~~
~~~~ UNDERGROUND TANK ~~~~

DEPTH OF TANK IN SOIL= 4.00M
CAPACITY OF TANK IN LITRES = 100000.000
MATERIAL UNIT WEIGHT FILLED IN TANK= 9810.00N/M3
SOIL UNIT WEIGHT =16000.00N/M3
BEARING CAPACITY OF SOIL =125.00KN/M2
FREEBOARD TO TANK= .1M
LENGTH OF TANK = 5.800M
BREADTH OF TANK = 4.500M
HEIGHT OF TANK = 4.000M
WATER TABLE POSITION FROM G.L.= 3.00M

TOP FREE & BOTTOM HINGED CASE

COEFFICIENTS FOR BENDING MOMENT

.0000	.0000	.0000	.0000	.0250	.0046	-.0484
.2500	.0082	.0028	-.0112	.0264	.0074	-.0556
.5000	.0210	.0114	-.0124	.0262	.0106	-.0602
.7500	.0258	.0162	-.0098	.0194	.0106	-.0504

CONCRETE GRADE USED =M20
HYSD BARS USED
ANGLE OF INTERNAL FRICTION OF SOIL (DEG)= 30.00
ANGLE OF FRICTION BETWEEN SOIL AND WALL (DEG)= 10.00
SUBMERGENCE AND STATIC PRESSURE CONSIDERED

TANK EMPTY CASE

x/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.00	.000E+00	.000E+00	.000E+00	.113E+04	.209E+03	-.219E+04
.25	.372E+03	.127E+03	-.508E+03	.120E+04	.336E+03	-.252E+04
.50	.952E+03	.517E+03	-.562E+03	.119E+04	.481E+03	-.273E+04
.75	.117E+04	.735E+03	-.444E+03	.880E+03	.481E+03	-.229E+04

TANK FULL CASE

X/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.00	.000E+00	.000E+00	.000E+00	.157E+05	.289E+04	-.304E+05
.25	.515E+04	.176E+04	-.703E+04	.166E+05	.465E+04	-.349E+05
.50	.132E+05	.716E+04	-.779E+04	.164E+05	.666E+04	-.378E+05
.75	.162E+05	.102E+05	-.615E+04	.122E+05	.666E+04	-.316E+05

LARGEST BM(N-m)= 37795.970 AT x/H= .500

UNIFORM THICKNESS OF WALL FROM TOP TO BOTTOM JUNCTION= 400.00mm

HORIZONTAL REINFORCEMENT

DIAMETRE OF HORIZONTAL STEEL BAR AT OUTER FACE=16.00mm

DIAMETRE OF HORIZONTAL STEEL BAR AT INNER FACE=16.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0 TO	1.5	857	857	230	230
1.5 TO	2.5	857	857	230	230
2.5 TO	4.0	857	857	230	230

VERTICAL REINFORCEMENT

DIAMETER OF VERTICAL STEEL BAR AT OUTER FACE=16.00mm

DIAMETER OF VERTICAL STEEL BAR AT INNER FACE=16.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0 TO	1.5	857	857	230	230
1.5 TO	2.5	857	857	230	230
2.5 TO	4.0	857	857	230	230

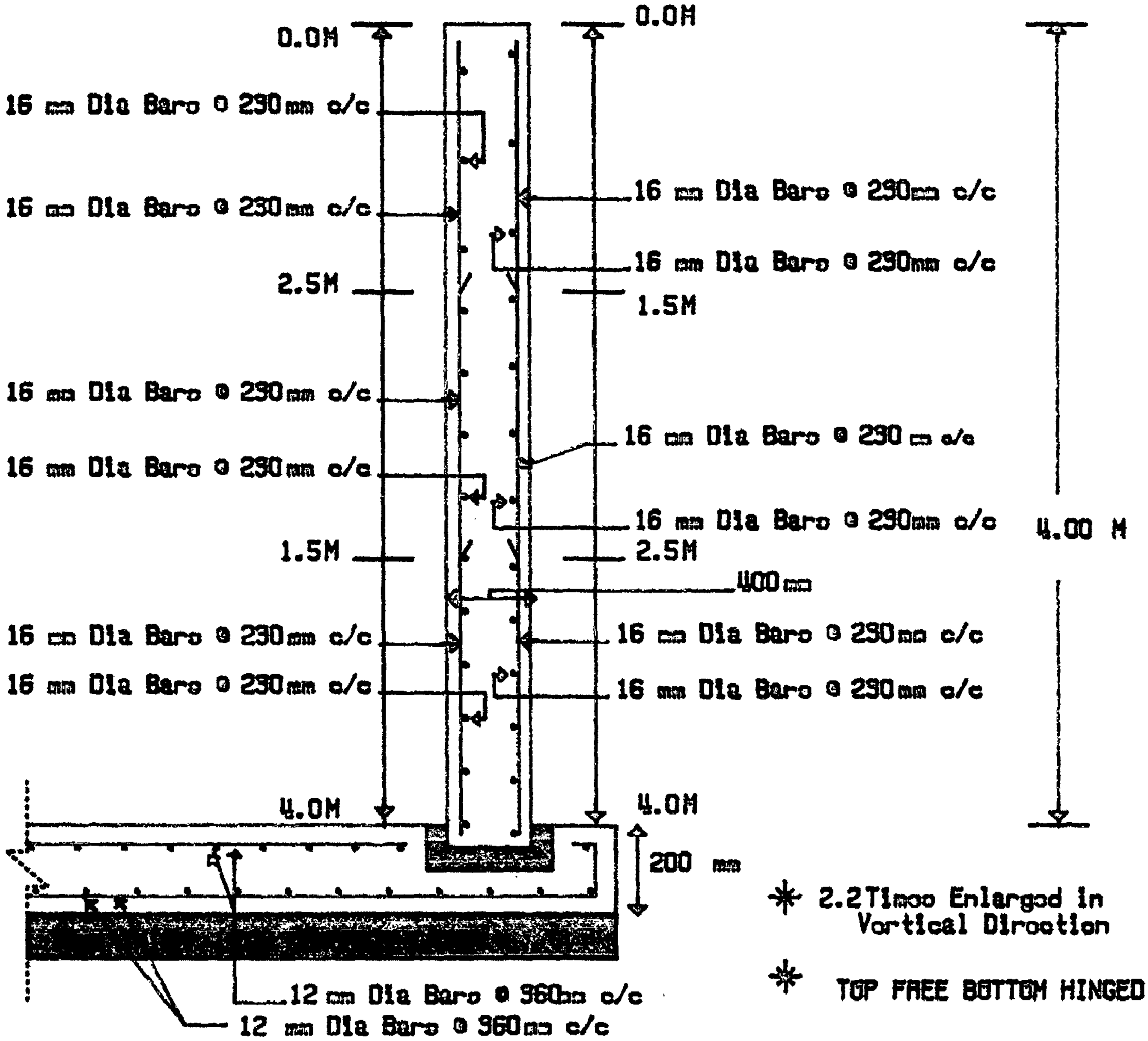
BASE SLAB DETAILS

DIAMETER OF STEEL BAR USED IN BASE SLAB=12.00mm

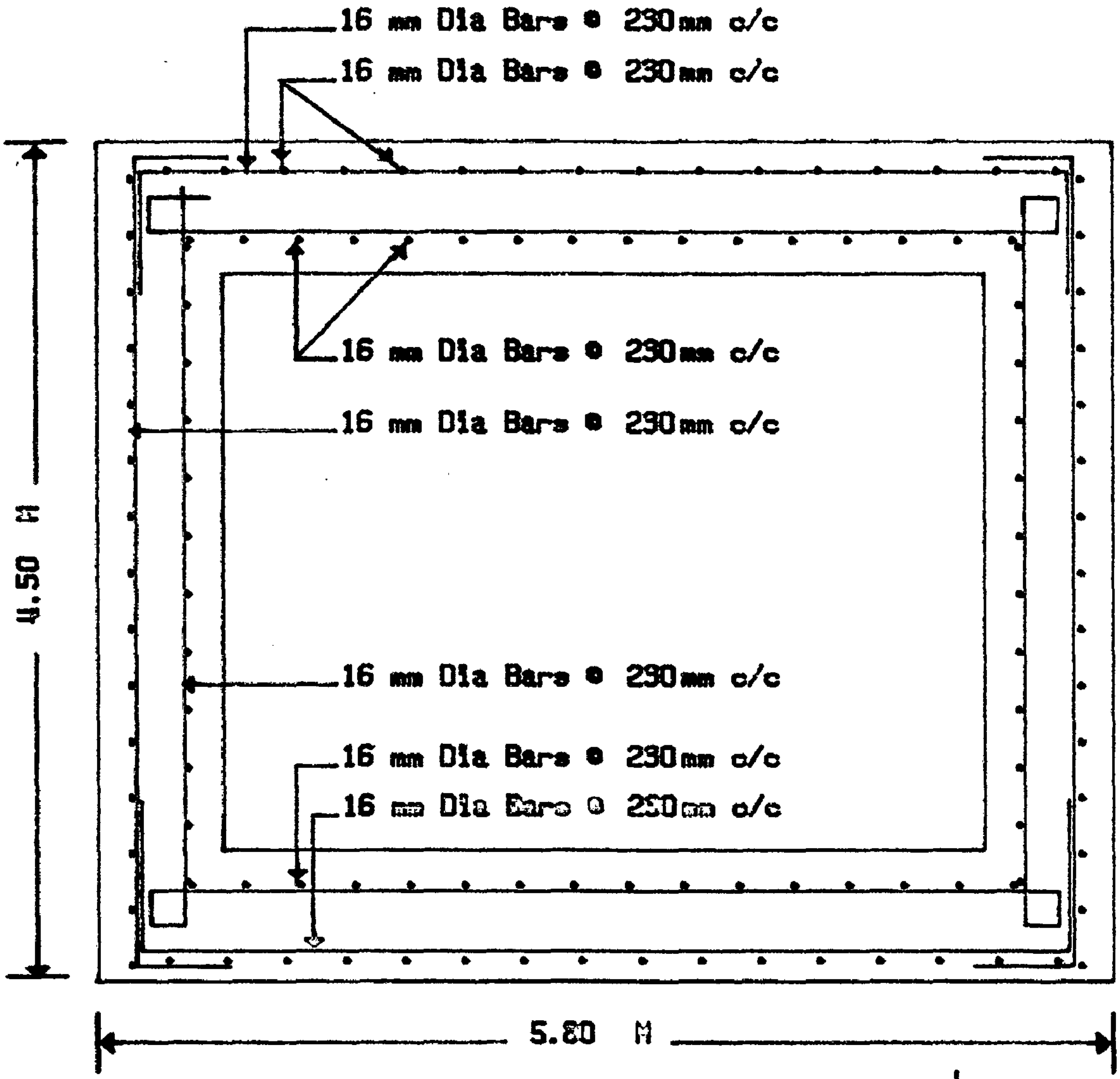
PROVIDE 75mm THICK CONCRETE LAYER OF GRADE M10 ON WELL RAMMED GROUND ON THAT PUT A BITUMEN OR EQUIVALENT MATERIAL LAYER. THEN ON THIS PROVIDE BASE SLAB.

THICKNESS OF BASE SLAB=200.00mm

PROVIDE 12.0mm DIA BARS @ 360.00mm c/c BOTHWAYS AT TOP AND BOTTOM FACE OF BASE SLAB IN BOTH DIRECTIONS AT RIGHT ANGLE



SECTIONAL ELEVATION



SECTIONAL PLAN

* NOT TO SCALE

TEST PROBLEM NO. 7

~~~~ RECTANGULAR ~~~~
~~~~ UNDERGROUND TANK ~~~~

DEPTH OF TANK IN SOIL= 4.00M
CAPACITY OF TANK IN LITRES = 100000.000
MATERIAL UNIT WEIGHT FILLED IN TANK= 9810.00N/M3
SOIL UNIT WEIGHT =16000.00N/M3
BEARING CAPACITY OF SOIL =125.00KN/M2
FREEBOARD TO TANK= .1M
LENGTH OF TANK = 5.000M
BREADTH OF TANK = 5.000M
HEIGHT OF TANK = 4.000M
WATER TABLE POSITION FROM G.L.= 1.00M

TOP HINGED & BOTTOM HINGED CASE

COEFFICIENTS FOR BENDING MOMENT

.2500	.0090	.0050	-.0060	.0120	.0050	-.0280
.5000	.0190	.0110	-.0090	.0190	.0090	-.0450
.7500	.0230	.0140	-.0090	.0170	.0090	-.0430

CONCRETE GRADE USED =M20
MILD STEEL BARS USED
ANGLE OF INTERNAL FRICTION OF SOIL (DEG)= 30.00
ANGLE OF FRICTION BETWEEN SOIL AND WALL (DEG)= 10.00
SEISMIC ZONE NO.FOR TANK LOCATION = 4
SUBMERGENCE ,STATIC AND DYNAMIC PRESSURE

TANK EMPTY CASE

x/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.25	-.205E+04	-.114E+04	.137E+04	-.273E+04	-.114E+04	.637E+04
.50	-.432E+04	-.250E+04	.205E+04	-.432E+04	-.205E+04	.102E+05
.75	-.523E+04	-.319E+04	.205E+04	-.387E+04	-.205E+04	.978E+04

TANK FULL CASE

X/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.25	.638E+04	.355E+04	-.426E+04	.851E+04	.355E+04	-.199E+05
.50	.135E+05	.780E+04	-.638E+04	.135E+05	.638E+04	-.319E+05
.75	.163E+05	.993E+04	-.638E+04	.121E+05	.638E+04	-.305E+05

LARGEST BM(N-m)= 31922.840 AT x/H= .500

THICKNESS OF WALL FROM TOP TO 1.00M= 200.00mm
THICKNESS OF WALL FROM DEPTH (= 1.00M) TO BOTTOM JUNCTION= 370.00mm

HORIZONTAL REINFORCEMENT

DIAMETRE OF HORIZONTAL STEEL BAR AT OUTER FACE=16.00mm

DIAMETRE OF HORIZONTAL STEEL BAR AT INNER FACE=16.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0 TO	1.5	581	1181	345	170
1.5 TO	2.5	824	994	240	200
2.5 TO	4.0	824	950	240	210

VERTICAL REINFORCEMENT

DIAMETER OF VERTICAL STEEL BAR AT OUTER FACE=12.00mm

DIAMETER OF VERTICAL STEEL BAR AT INNER FACE=16.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0 TO	1.5	542	542	205	370
1.5 TO	2.5	824	824	135	240
2.5 TO	4.0	824	824	135	240

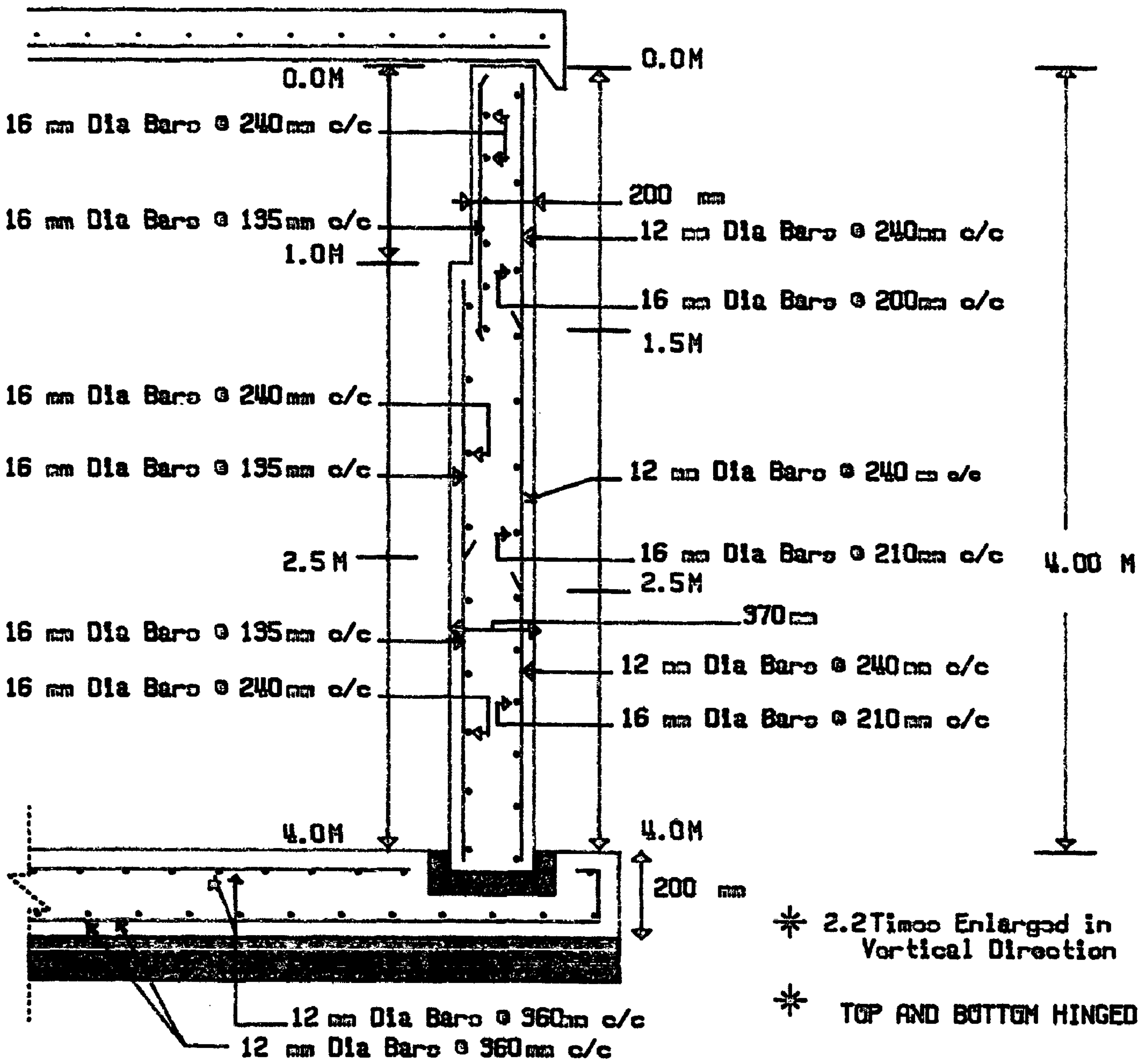
BASE SLAB DETAILS

DIAMETER OF STEEL BAR USED IN BASE SLAB=12.00mm

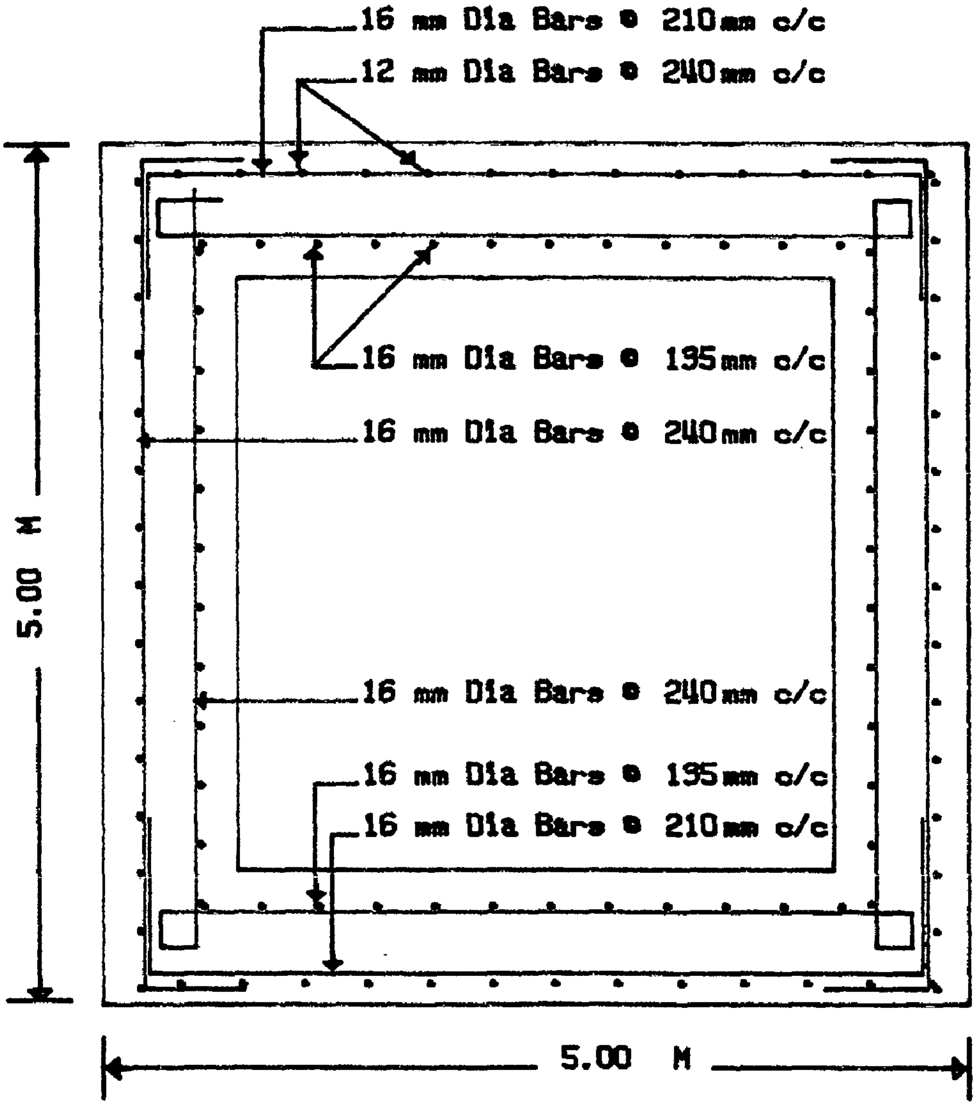
PROVIDE 75mm THICK CONCRETE LAYER OF GRADE M10 ON WELL RAMMED GROUND ON THAT PUT A BITUMEN OR EQUIVALENT MATERIAL LAYER. THEN ON THIS PROVIDE BASE SLAB.

THICKNESS OF BASE SLAB=200.00mm

PROVIDE 12.0mm DIA BARS @ 360.00mm c/c BOTHWAYS AT TOP AND BOTTOM FACE OF BASE SLAB IN BOTH DIRECTIONS AT RIGHT ANGLE



SECTIONAL ELEVATION



SECTIONAL PLAN

* NOT TO SCALE

TEST PROBLEM NO. 8

~~~~ RECTANGULAR ~~~~
~~~~ UNDERGROUND TANK ~~~~

DEPTH OF TANK IN SOIL= 2.50M
CAPACITY OF TANK IN LITRES = 100000.000
MATERIAL UNIT WEIGHT FILLED IN TANK= 9810.00N/M3
SOIL UNIT WEIGHT =16000.00N/M3
BEARING CAPACITY OF SOIL =125.00KN/M2
FREEBOARD TO TANK= .1M
LENGTH OF TANK = 8.500M
BREADTH OF TANK = 4.500M
HEIGHT OF TANK = 2.800M
WATER TABLE POSITION FROM G.L.= .50M
ANGLE OF INTERNAL FRICTION OF SOIL (DEG)= 30.00
ANGLE OF FRICTION BETWEEN SOIL AND WALL (DEG)= 30.00
SEISMIC ZONE NO.FOR TANK LOCATION = 3
SUBMERGENCE ,STATIC AND DYNAMIC PRESSURE
CONCRETE GRADE USED =M20
HYSD BARS USED

****

DESIGN OF TANK AS CANTILIVER

****

STEM WALL DETAILS

~~~~~~~~~~~~~~~~~~~~

THICKNESS(M)= .20
REDUCED TO 20CM AT TOP

WATER FACE REINFORCEMENT (FROM TOP) IN STEM

REINFORCEMENT FROM	TO (M)	BARDIA (MM)	SPACING C/C (MM)
.00	1.50	16.00	280.00
1.50	2.80	16.00	140.00

EARTH FACE REINFORCEMENT (FROM TOP) IN STEM

REINFORCEMENT FROM	TO (M)	BARDIA (MM)	SPACING C/C (MM)
.00	1.50	16.00	400.00
1.50	2.80	16.00	200.00

DISTRIBUTION REINFORCEMENT ON EACH FACE

BARDIA	SPACING
10.00	280.00

BASE SLAB DETAILS

THICKNESS OF BASE SLAB= .20
TOE SLAB LENGTH= 1.00
HEEL SLAB LENGTH= 1.30
~~~~~~~~~~~~~~~~~~~~

HEEL REINFORCEMENT DETAILS

TOP FACE

BARDIA	SPACING
16.00	290.00

BOTTOM FACE

BARDIA	SPACING
16.00	330.00

DISTRIBUTION REINFORCEMENT ON EACH FACE

BARDIA	SPACING
10.00	280.00

TOE REINFORCEMENT DETAILS

TOP FACE

BARDIA	SPACING
16.00	290.00

BOTTOM FACE

BARDIA	SPACING
16.00	140.00

DISTRIBUTION BARS ON EACH FACE

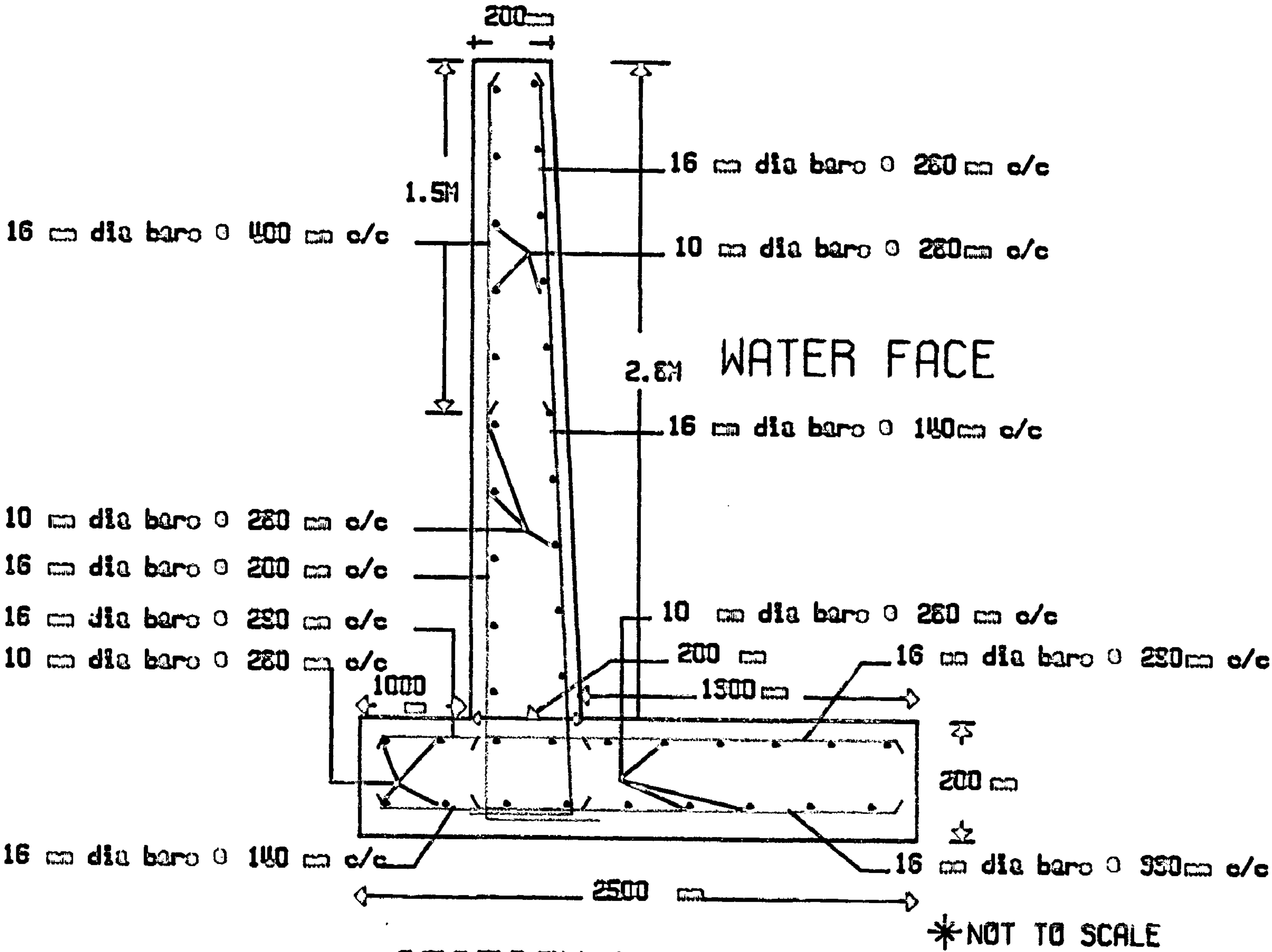
BARDIA	SPACING
10.00	280.00

PROVIDE CONSTRUCTION JOINT AT BASE.
DIAMETER OF STEEL BAR USED IN BASE SLAB=12.00mm .

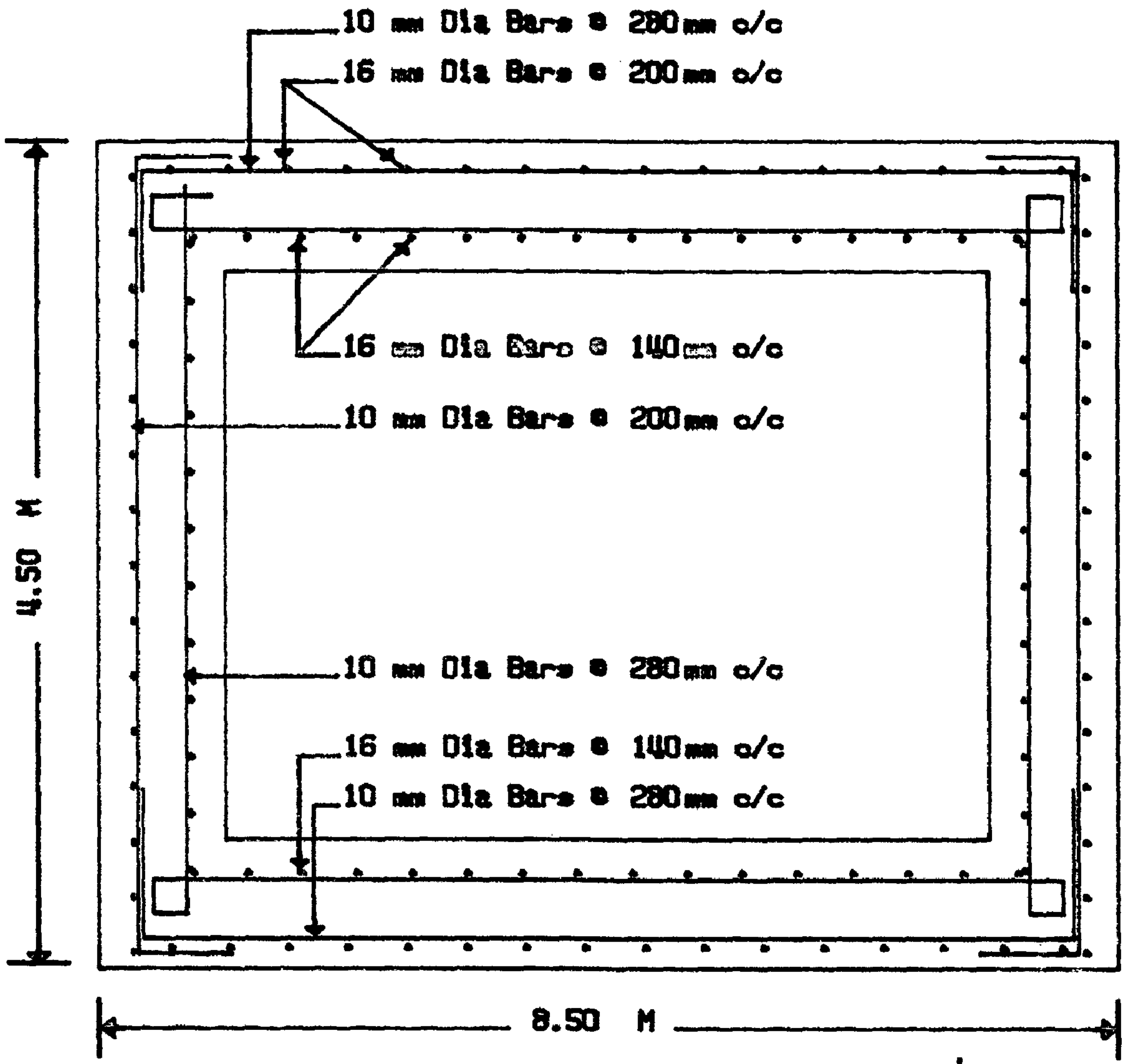
PROVIDE 75mm THICK CONCRETE LAYER OF GRADE M10 ON WELL RAMMED GROUND ON THAT PUT A BITUMEN OR EQUIVALENT MATERIAL LAYER. THEN ON THIS PROVIDE BASE SLAB.

THICKNESS OF BASE SLAB=200.00mm

PROVIDE 12.0mm DIA BARS @ 360.00mm c/c BOTHWAYS AT TOP AND BOTTOM FACE OF BASE SLAB IN BOTH DIRECTIONS AT RIGHT ANGLE



SECTIONAL ELEVATION



SECTIONAL PLAN

* NOT TO SCALE

CHAPTER 8

CONCLUDING REMARKS

8.1 CONCLUSIONS

Development of a computer software for the analysis, design and drafting of underground R.C. tanks has been accomplished which constitutes major effort of the dissertation. The software has been made user friendly with liberal use of screen mode.

The present work reduces the engineering time elapsed in analysis and design of underground R.C. tanks, hence indirectly reduces the overall cost of the structure. The following conclusions can be made :

1. The interactive software written in FORTRAN 77 can be used for structural design of underground reinforced concrete tanks with different base conditions.
2. Walls have been designed using IS Code coefficient method. Coefficients have been given in IS - 3370 (Part IV) 1969.
3. The base slab is adequately designed for base conditions and water table positions.
4. When L/H ratio or diameter of tank exceeds 3 or 12 m respectively, then design of wall is done like cantilever wall.
5. Drafting part produces following drawings for rectangular Tank case :
   i) Sectional elevation of tank when wall is designed using IS Code Coefficient method.

ii) Sectional plan of tank.

iii) Sectional elevation of wall when designed like cantilever retaining wall.

8.2 SCOPE OF FURTHER WORK

In present work, various Indian Standard Codes have been used i.e. IS : 456-1978; IS : 3370 (Part I, III & IV) - 1969 and IS : 1893-1984. These codes now are under revision. So after their revision new codal provisions can be incorporated. Drafting of circular tanks can also be done.

REFERENCES

1. Draft of first revision of IS:3370 (Part I & II)-1965.
2. Gray, W.S., (1956), "Reinforced concrete reservoir and tanks", Concrete Publication Ltd., London.
3. Ghali, A., (1979), "Circular storage tanks and silos", Span Publication.
4. Indian Standard code of practice for plain & reinforced concrete IS:456:1978.
5. Indian Standard code of practice for storage of liquids IS:3370:1965 (Part I&II) & IS: 3370(PartIV)-1967.
6. Indian Standard code of practice for earthquake resistant design of structures, IS:1893-1984.
7. Jai Krishna and Jain, O.P., (1987), "Plain & reinforced concrete", Vol.2, Nem Chand & Bros., Roorkee.
8. Jain, Anuj Kumar (1995), "Computer aided design of underground circular tanks", M.E. dissertation, Dept. of C.E. University of Roorkee, Roorkee.
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10. John Faber & Frank Mead, (1961), "Faber's reinforced concrete", E & F.N. Span Limited, London.
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CHAPTER 8

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19. Tang Y., Tang H.T. (1992), "Dynamic response of flexibly supported liquid-storage tanks", Journal of Structural Engg., ASCE, Vol. 118, No.1, pp. 264-283.

TEST PROBLEM NO.2

~~~~ RECTANGULAR ~~~~
~~~~ UNDERGROUND TANK ~~~~

DEPTH OF TANK IN SOIL= 4.00M
CAPACITY OF TANK IN LITRES = 200000.000
MATERIAL UNIT WEIGHT FILLED IN TANK= 9810.00N/M3
SOIL UNIT WEIGHT =16000.00N/M3
BEARING CAPACITY OF SOIL =125.00KN/M2
FREEBOARD TO TANK= .1M
LENGTH OF TANK = 6.400M
BREADTH OF TANK = 6.400M
HEIGHT OF TANK = 5.000M
WATER TABLE POSITION FROM G.L.= 1.00M

TOP FREE & BOTTOM HINGED CASE

COEFFICIENTS FOR BENDING MOMENT.

.0000	.0000	.0000	.0000	.0182	.0032	-.0362
.2500	.0055	.0021	-.0085	.0210	.0054	-.0440
.5000	.0176	.0094	-.0104	.0235	.0092	-.0507
.7500	.0217	.0135	-.0091	.0174	.0092	-.0450

CONCRETE GRADE USED =M25
HYSD BARS USED
ANGLE OF INTERNAL FRICTION OF SOIL (DEG)= 30.00
ANGLE OF FRICTION BETWEEN SOIL AND WALL (DEG)= 10.00
SUBMERGENCE AND STATIC PRESSURE CONSIDERED

TANK EMPTY CASE

x/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.00	.000E+00	.000E+00	.000E+00	-.102E+05	-.182E+04	.203E+05
.25	-.308E+04	-.119E+04	.476E+04	-.118E+05	-.301E+04	.247E+05
.50	-.989E+04	-.526E+04	.582E+04	-.132E+05	-.519E+04	.285E+05
.75	-.122E+05	-.757E+04	.512E+04	-.975E+04	-.519E+04	.253E+05

TANK FULL CASE

X/H	BMvy0	BMvyb4	BMvyb2	BMhy0	BMhyb4	BMhyb2
.00	.000E+00	.000E+00	.000E+00	.223E+05	.397E+04	-.443E+05
.25	.672E+04	.260E+04	-.104E+05	.257E+05	.657E+04	-.540E+05
.50	.216E+05	.115E+05	-.127E+05	.288E+05	.113E+05	-.621E+05
.75	.266E+05	.165E+05	-.112E+05	.213E+05	.113E+05	-.551E+05

LARGEST BM(N-m)= 62146.350 AT x/H= .500

THICKNESS OF WALL FROM TOP TO 1.50M= 475.00mm
THICKNESS OF WALL FROM DEPTH (= 1.50M) TO BOTTOM JUNCTION= 505.00mm

HORIZONTAL REINFORCEMENT

DIAMETRE OF HORIZONTAL STEEL BAR AT OUTER FACE=16.00mm

DIAMETRE OF HORIZONTAL STEEL BAR AT INNER FACE=16.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0 TO	1.9	950	950	210	210
1.9 TO	3.1	1010	1012	195	195
3.1 TO	5.0	1010	1010	195	195

VERTICAL REINFORCEMENT

DIAMETER OF VERTICAL STEEL BAR AT OUTER FACE=16.00mm

DIAMETER OF VERTICAL STEEL BAR AT INNER FACE=16.00mm

HEIGHT VARIATION (IN METRE)		AREA OF STEEL AT (IN Sq.mm)		SPACING OF REINFORCEMENT AT (IN mm c/c)	
FROM	TO	OUTER FACE	INNER FACE	OUTER FACE	INNER FACE
.0 TO	1.9	950	950	210	210
1.9 TO	3.1	1010	1010	195	195
3.1 TO	5.0	1010	1010	195	195

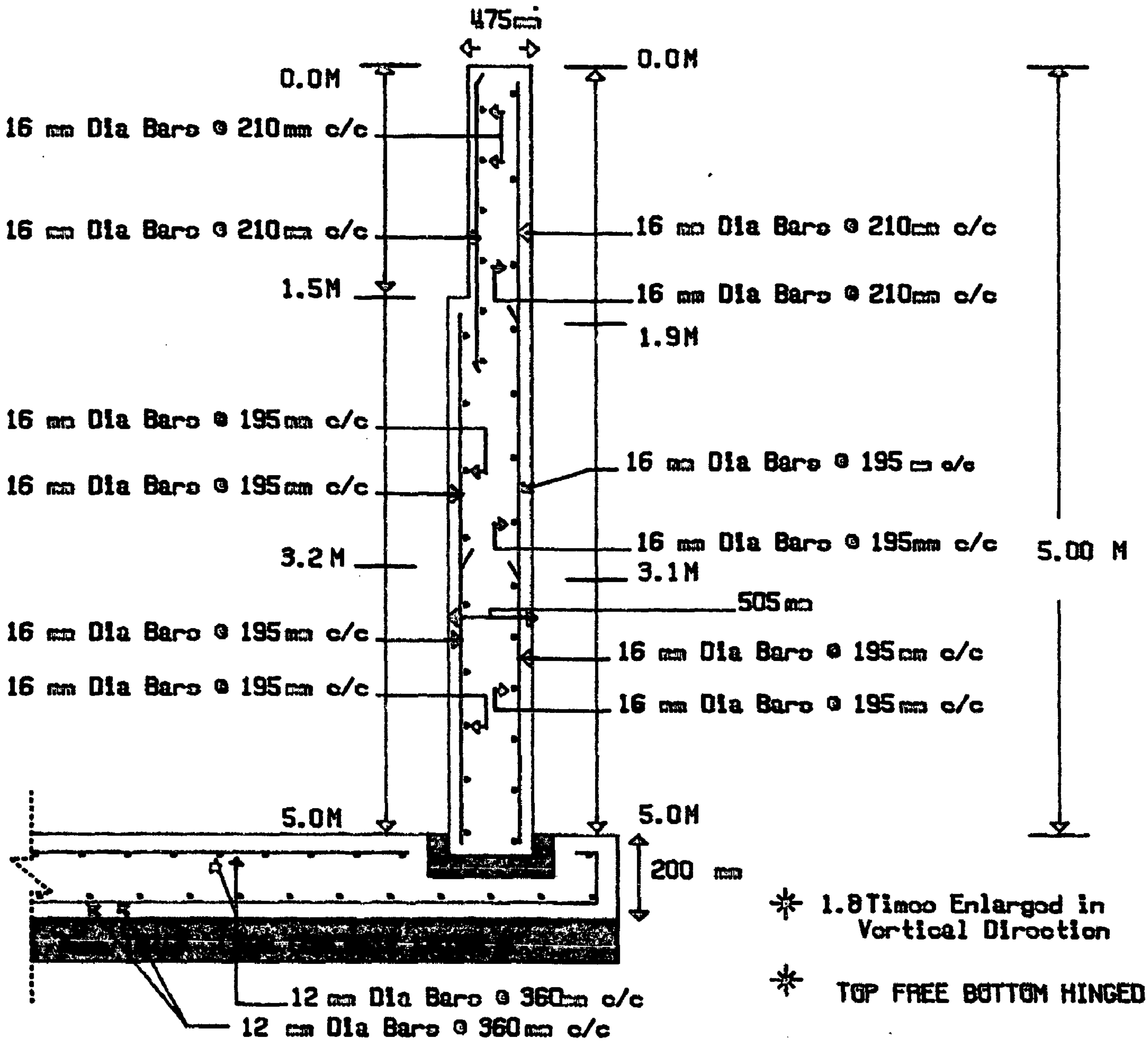
BASE SLAB DETAILS

DIAMETER OF STEEL BAR USED IN BASE SLAB=12.00mm

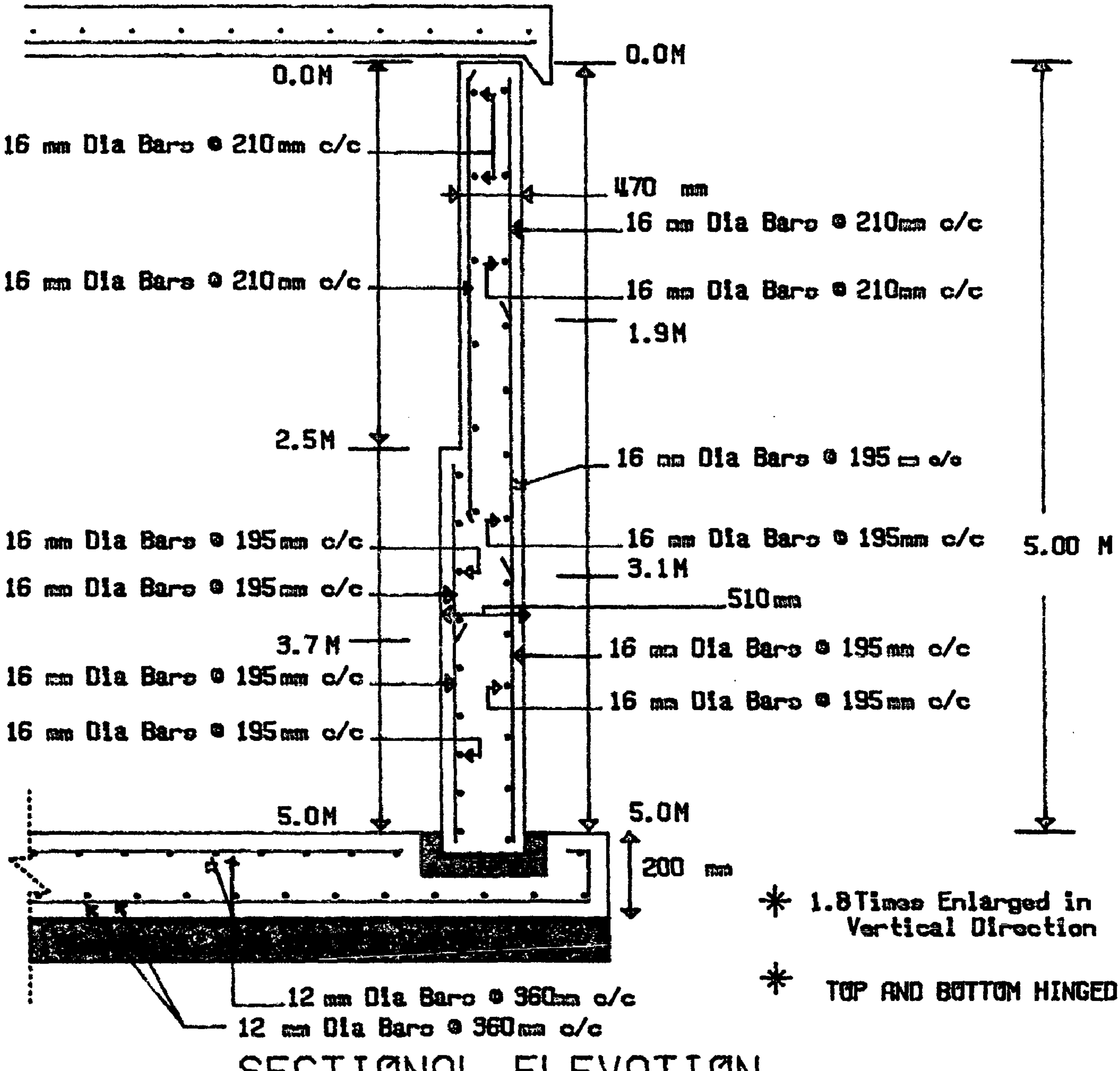
PROVIDE 75mm THICK CONCRETE LAYER OF GRADE M10 ON WELL RAMMED GROUND ON THAT PUT A BITUMEN OR EQUIVALENT MATERIAL LAYER. THEN ON THIS PROVIDE BASE SLAB.

THICKNESS OF BASE SLAB=200.00mm

PROVIDE 12.0mm DIA BARS @ 360.00mm c/c BOTHWAYS AT TOP AND BOTTOM FACE OF BASE SLAB IN BOTH DIRECTIONS AT RIGHT ANGLE



SECTIONAL ELEVATION



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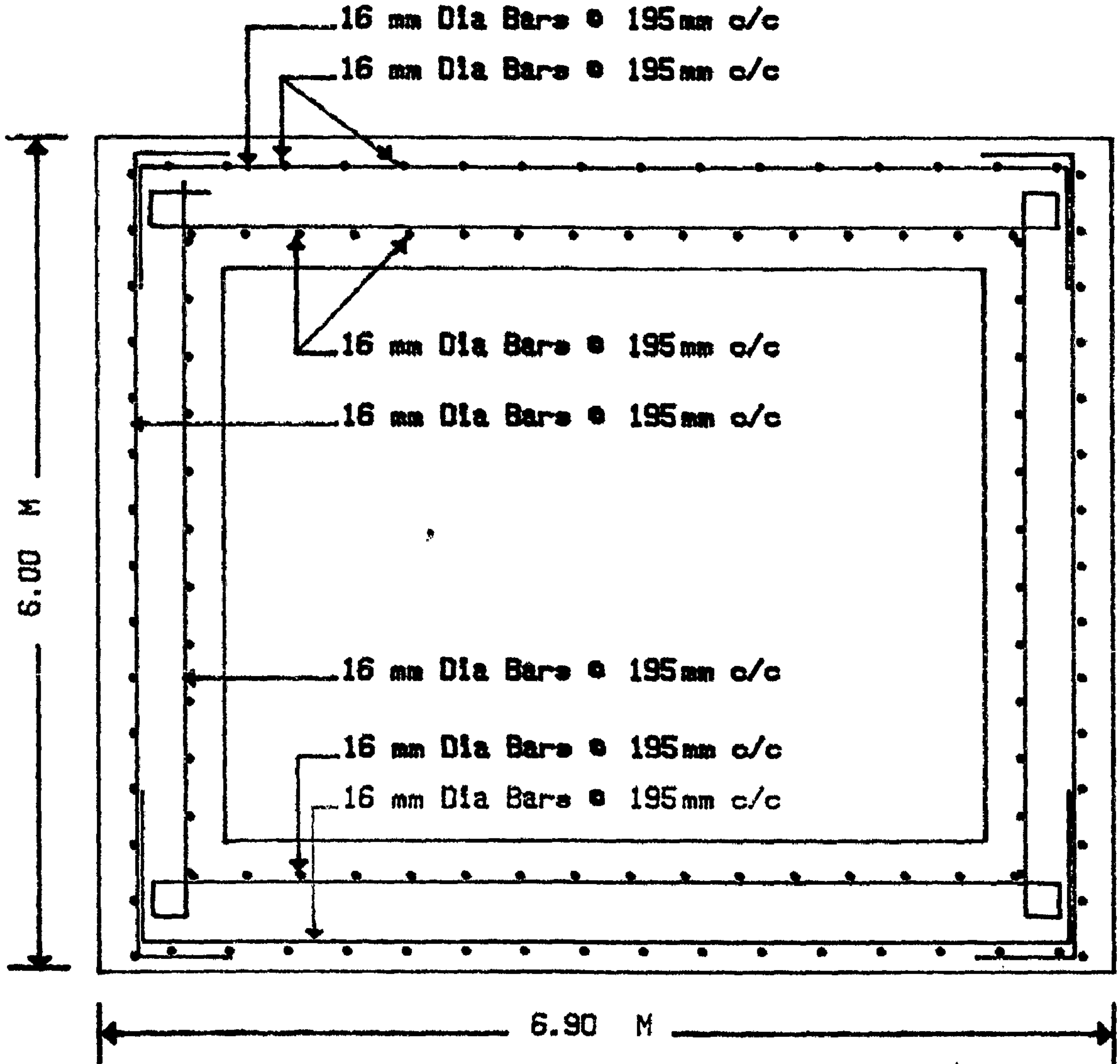
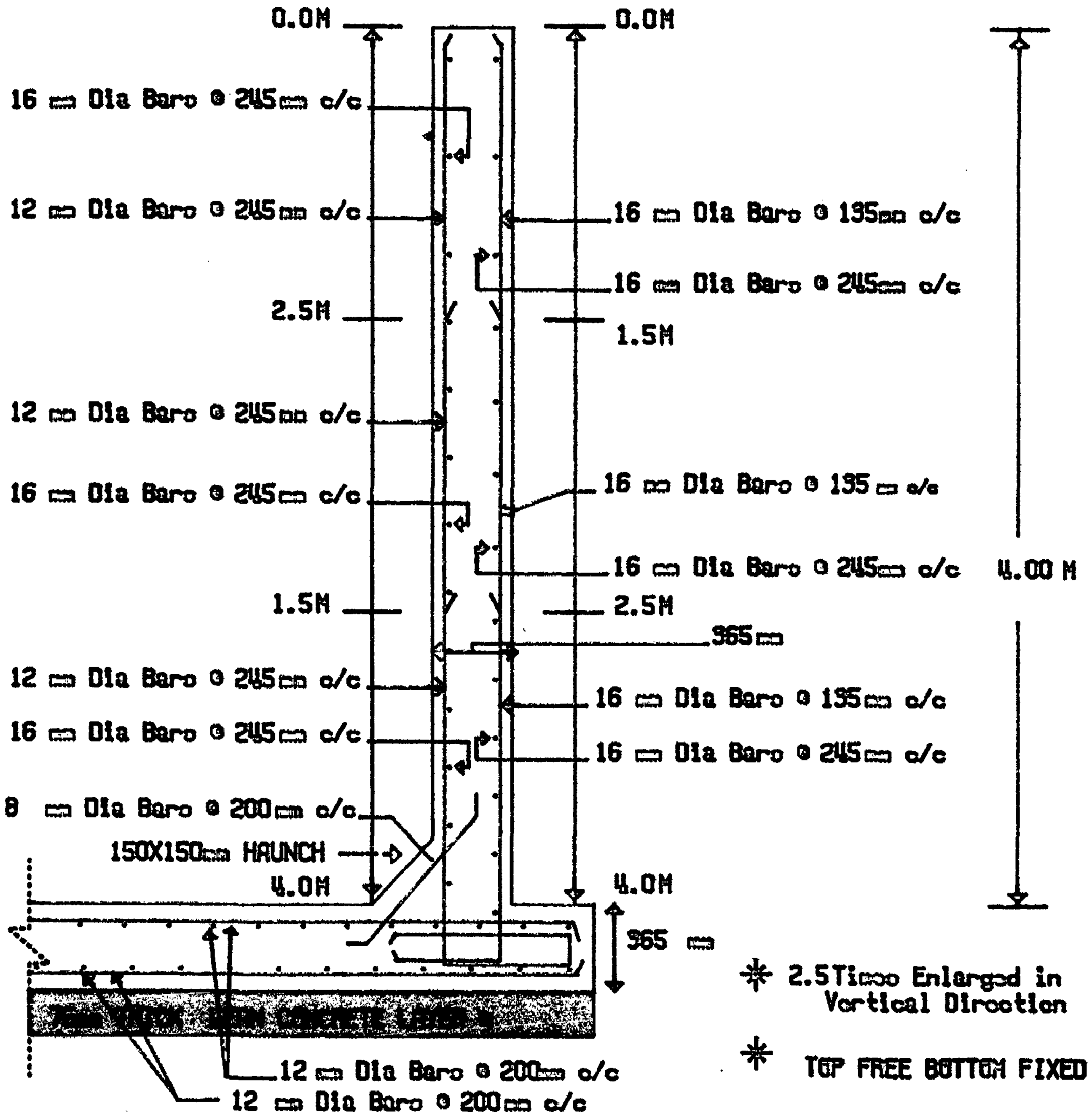


SECTIONAL PLAN

* NOT TO SCALE



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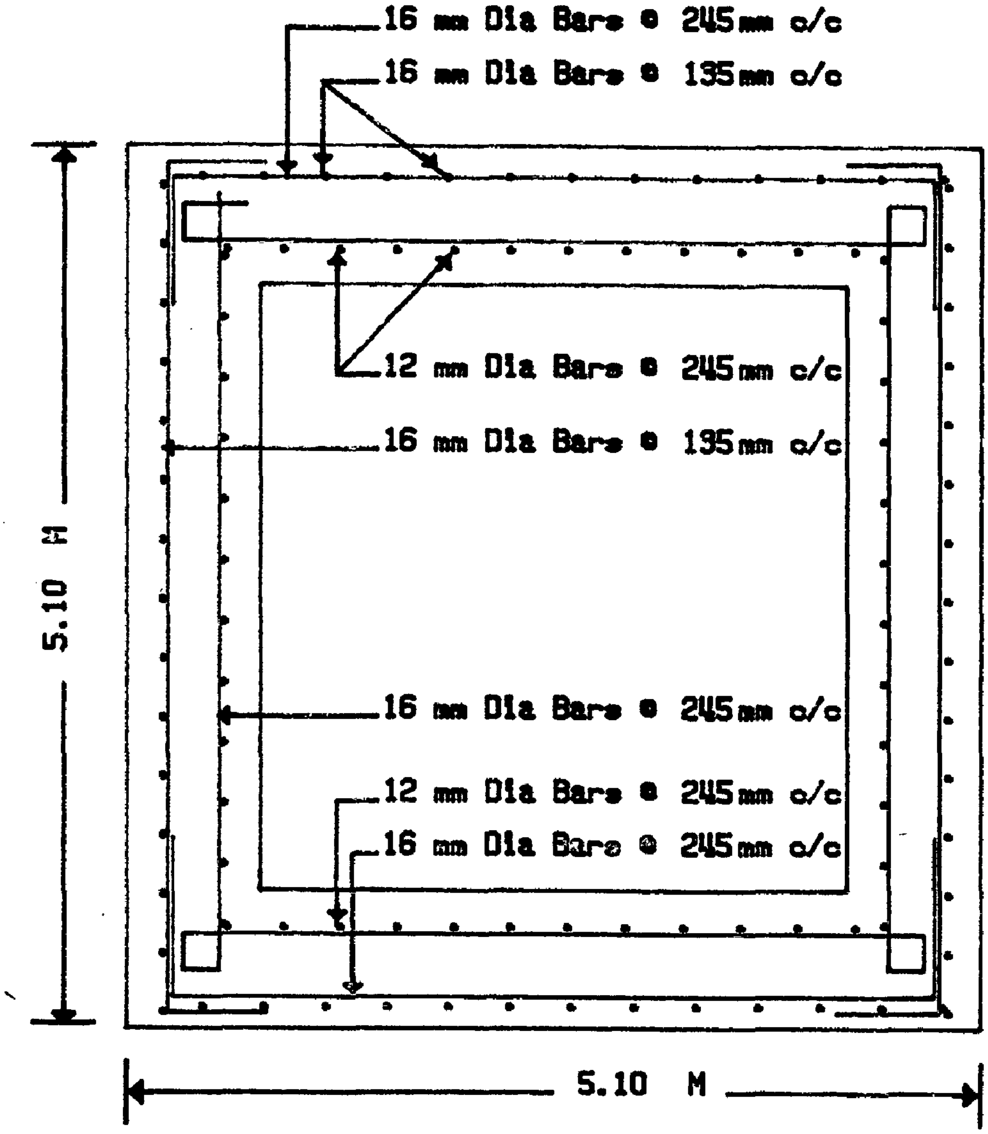

SECTIONAL PLAN

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