PLANNING AND DESIGN OF A STRUCTURAL ENGINEERING LABORATORY

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PROJECT REPORT

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF ENGINEERING IN CIVIL ENGINEERING OF THE BHARATHIAR UNIVERSITY

DEPARTMENT OF CIVIL ENGINEERING

Kumaraguru College of Technology

COIMBATORE - 641 006.

DEDICATED TO OUR BELOVED PARENTS

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SYNOPSIS

KEY TO SYMBOLS

1. SYNOPSIS

India is developing country. Constructions of new projects like multistorey buildings, bridges, Dams, tunnels, highways, etc., Strengthens the economical and social status of the people.

civil engineering play a vital role in the construction field. They are also responsible for the safety and durability of structures built.

The safety of the structures cab be assured only by presenting the elemnets of an structure. Hence,testing of the components of the buildings or any other structures becomes necessary.

The main aim of this project is to establish a structural engineering laboratory to enable testing of various properities of the structural elements.

We have discussed in detail the planning of a structural engineering the infra structure facilities and the necessary equipments to be installed. have been considered

INTRODUCTION

2. KEY TO SYMBOLS

l = Effective of the section

A= c/s area of the section

D = depth of the section

T = Mean thickness of the Hange.

I = Moment of nertion of the section

Z = Section modulus

γmin = Minimum radius of gyration

K = stiffenes of member

D. F = Distribution factor of the member

Fy = Yield stress

Fcb = Elastic critical stress

σbc = Maximum permissible bending stress

tck = Characteristicc compressive strength of concerete

τc =shear stress in member

σac, Cal = calculated average axial compressive stress

σbc, Cal = calculated compressive stress due to bending

τva = Maximum permissible average shear stress

σac = maximum permissible compressive stress

The measurements of loading and loading of testing specimens are done by

1.Proving ring

2.Strain gauges

3.Hydraulic jack

The following are the other equipments needed for testing of elements.

1.Gantry girder.

2.Pipes

3.1 Loading Frame:

Loading frames are the fabricated equipments used to test the elements like beam, slab, column and wall panels. The capacity of frame varies according to our requirement.

In this project, we adopt two loading frames, having capacities 500 KN and 1000 KN.

3.1.1. Loading Frame (capacity 500 KN)

This loading frame is used to conduct the tests on beams and slabs. A typical frame of this type is as shown in figure (1).

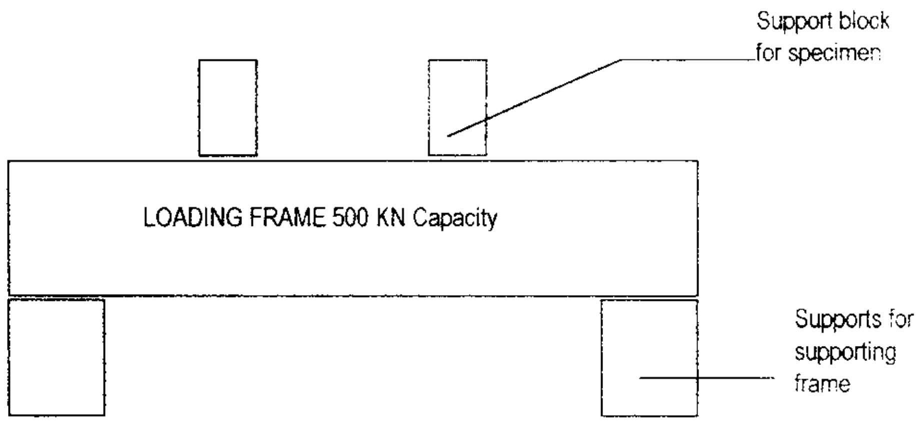

Fig (1)

It consists of an I. Section as the frame and is supported by a support block made up of built-up section. Above this arrangement, support blocks of adjustable span is provided for supporting the specimen.

3.1.2. Loading Frame: (1000 KN capacity)

The loading frame, which is like a portal frame, columns and wall panels. As shown in figure(2),

The beam (BC) can be adjusted up and down according to the height of

3. INTRODUCTION

The structural engineering is the branch of engineering which deals with structural analysis and structural design. After analyzing the structures, they are designed for the calculated forces. This also includes the selection of proper material be used in the construction. It will be necessary to ascertain the engineering properties of the materials used in the construction, to be sure of their performance after the construction.

The basic properties to be evaluated in general are the following.

1. Flexural Strength.
2. Shear strength.
3. Maximum deflection
4. Buckling strength
5. Ultimate strength
6. Durability
7. Compressive strength.

The above mentioned properties are tested in a structural engineering laboratory using the following equipment's:

1. Loading frame.
2. Frame loading system
3. U. T. M.
4. Pulsator

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3.2. Frame Loading (2000 KN capacity)

The frame loading is equipment fabricated as a built - up Section having a capacity of 2000 KN, used to test the frames (portal or multistory frames) for lateral forces and vertical loads. And also used to test a particular column or beam in the frame. This can be done lay the facility provided in lab as cellar portion.

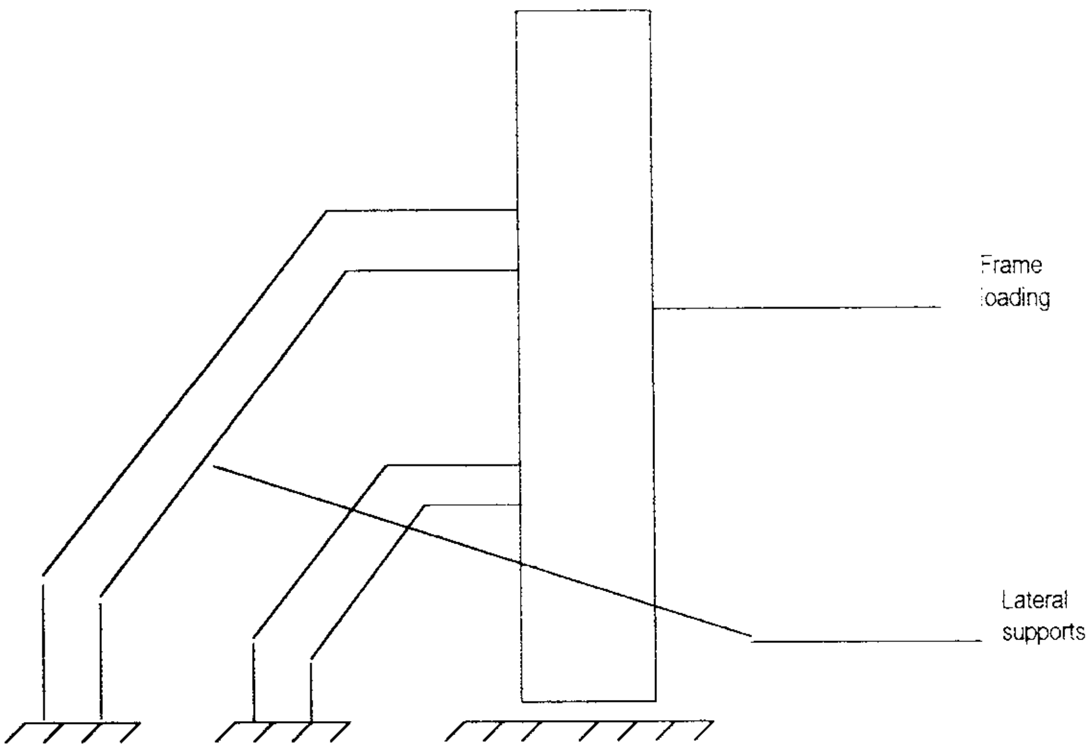
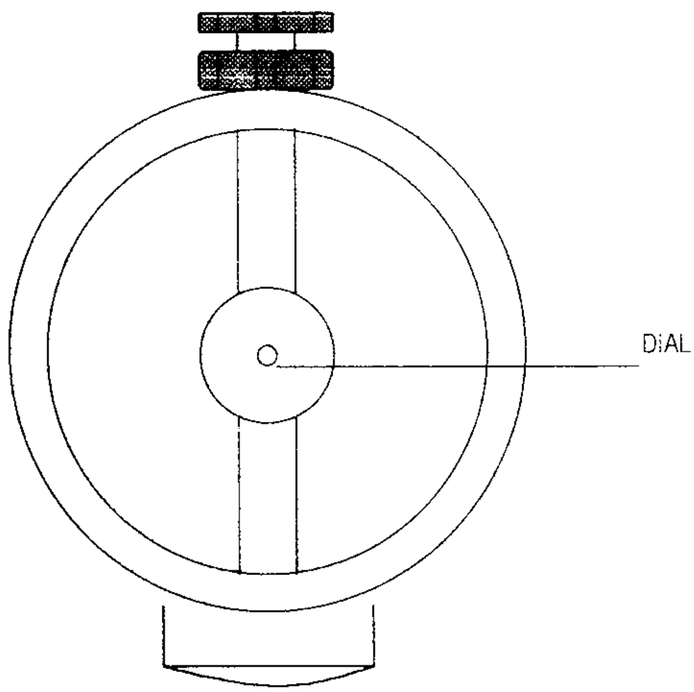


Fig (3)

3.4 <u>Proving Rings:</u>

The proving rings are made of special steel carefully forged to give maximum strength and machined to give high sensitivity commensurate with stability, ensuring long life and accuracy.



PROVING RING

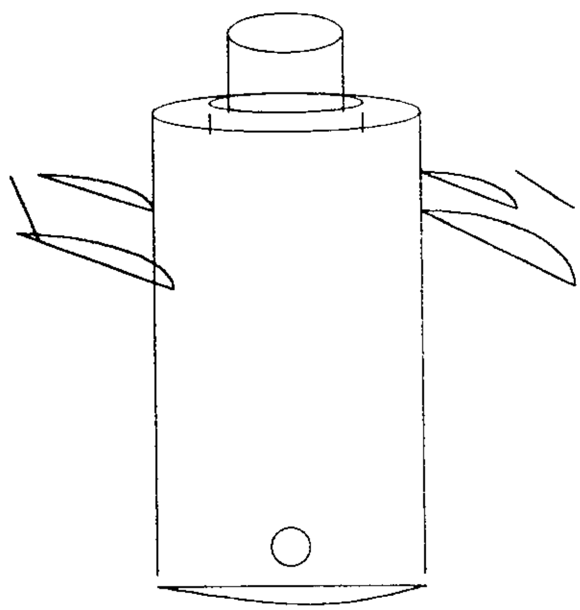
Fig (5)

3.5 <u>Pulsator:</u>

Pulsators are the machines operated by the hydraulic principle, used for dynamic loading of the structural elements. The ranges of pulsator are, Lateral supports are provided to withstand the moment developed at bottom connection of frame and the cellar roof slab. The web portion of frame loading is provided with bolt holes throughout the height to enable the application of load to frame according to the testing requirements.

3.3 Hydraulic Jack:

Hydraulic jacks have multipurpose utility, i.e. application of loads while engaged in field investigation, determination of load carrying capacity of piles in the field, tensioning of wires in pre - cast structures, loading of members of any structure for deformation characteristics etc. all jacks have a piston travel of 75mm and jacks up to 500 KN capacity are provided with retraction springs.



HYDRAULIC JACK

Fig (4)

specimen tested. The connection b/w column and beam are made by bolting. The column flange section is provided with bolt holes throughout the length of it to facilitate the above

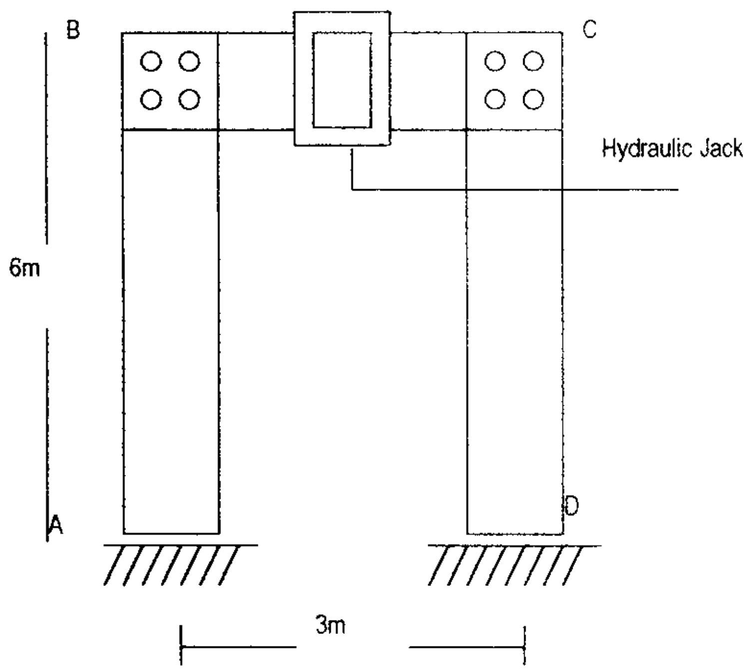


Fig (2)

reason. The loading is done through hydraulic jack, fixed at the center span of beam BC using bolts.

- Buckling strength
- Lateral deflection measurement

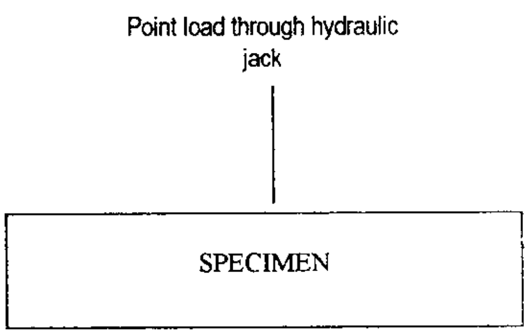
3. Tests on frames for,

- Lateral forces
- UDL over the frame
- Deflection or settlement in foundation
- Deflection of frames for lateral forces.

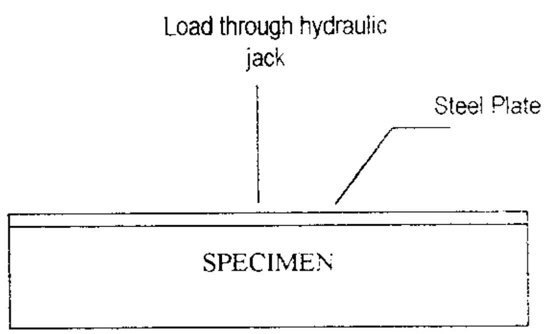
4. Tests on wall panel

3.8 Method of Loading:

In all the tests, the method in which the loading is done is similar. For a point load system, the hydraulic jack is placed just over the point and in case of uniformly distributed load system, a plate of size equal to the surface area of the specimen is placed over the specimen, the load is uniformly distributed to the specimen.



(i) Point load system



(ii) UDL system

1 Low frequency pulsator.

2 High frequency pulsator.

3.6 <u>Necessity Of Conducting Tests:</u>

Every structure that is designed and constructed by the engineering should be satisfy all service ability requirements. So there is a need to know the safety of the structure to be constructed before actual execution, in order to prevent wastage of time, money, and material. Thus the pre testing of all structural elements become necessary. The tests also performed to know the actual behavior of elements under various conditions. Some thesis may also be given after testing the elements

3.7 <u>Type Of Tests:</u>

The following are some tests performed in the structural engineering laboratory.

1. Tests on beam for

- Flexural strength
- Deflection

2. Test on column for

- Axial load testing

3.9 Measurement Of Loading:

The whole capacity of the hydraulic jack is not applied to the specimen, because the specimen may fails before the capacity of the jack. We want to know the amount of load applied to the specimen.

This can be measured by using the proving ring. This arrangement is as shown in the drawing No. 6

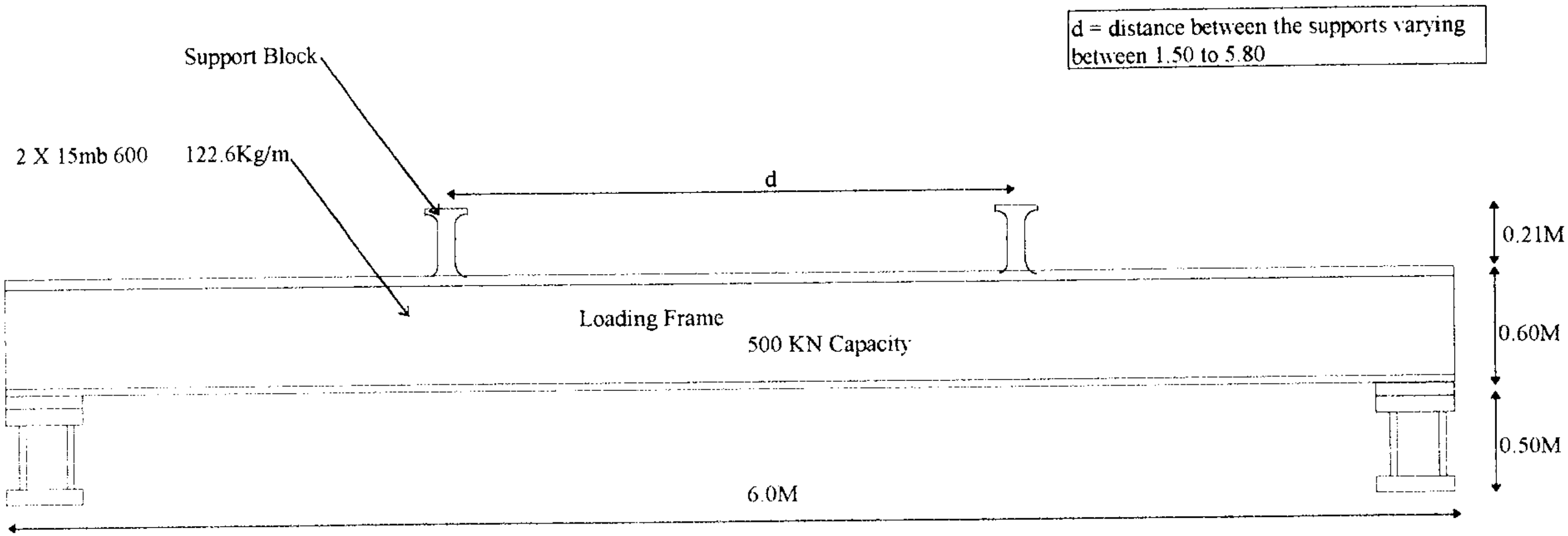
3.10 Execution Of Tests:

3.10.1 Tests On Beam:

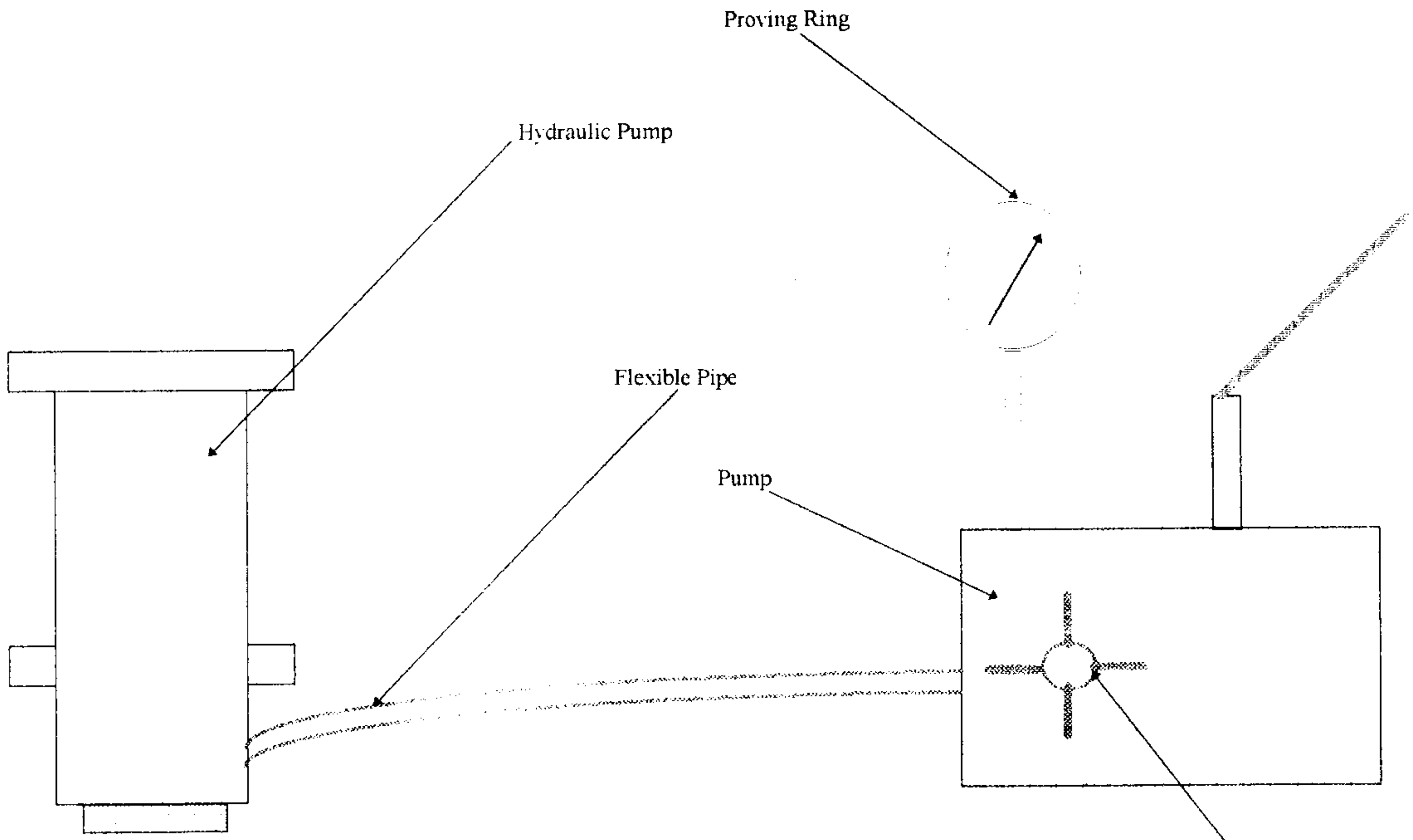
The arrangements for conducting test are shown in drawing number: 7

1. The load is applied through hydraulic jack (1500 KN capacity)
2. The deflection is measured by strain gauge and the amount of loading is measured by proving ring.
3. The specimen may be subjected to handling till it fails or not, according to the test requirements.

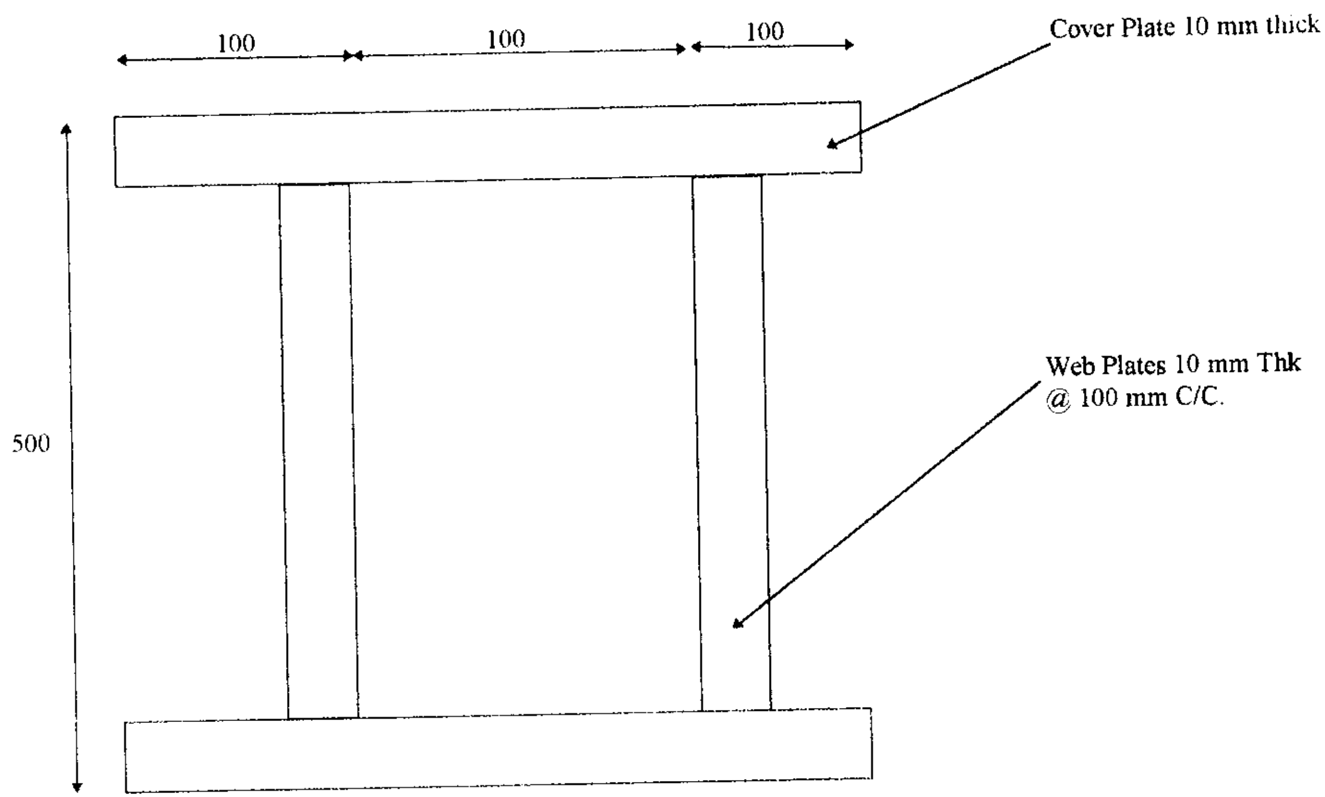
3.10. 2. Test On Column:



DRAWING NO : 12 (a)

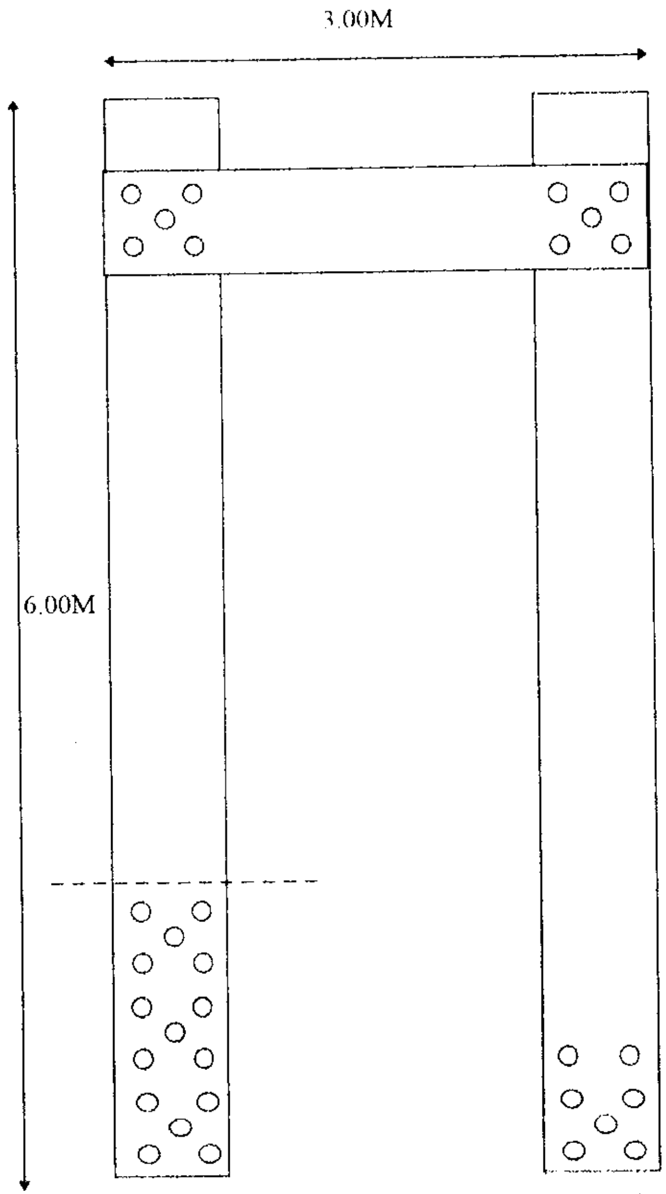


MEASUREMENT OF LOADING



DRAWING NO : 12 (b)

Support Block For Frame



LOADING FRAME 1000 KN CAPACITY

Testing arrangements are shown in the drawing no: 8

1. Loading of specimen is through jack.
2. The lateral deflections are measured by using strain gauges, and the proving ring is used to find out the amount of load applied on it.

3.10.3. Test On Frames:

Drawing no: 9 show the arrangements of testing.

1. The lateral force on one side of frame is calculated, and the force is applied through the jacks
2. Deflections on foundation block and frame are measured by using the strains gauge and the load is measured using proving ring
3. If the frame is tested for UDL on the top, a steel plate is placed over it and load applied through hydraulic jack is uniformly distributed to the frame

PLANNING METHODOLOGY

1. PLANNING METHODOLOGY

Planning involves taking into consideration, the purpose or objective of the project and the various needs inside the laboratory.

4.1. <u>Objective Of The Project:</u>

The objectives of this project are as follows

1.To establish a structural engineering laboratory with all necessary infrastructures.

2.Designing the testing equipment's needed for testing the structural elements.

3.Fixing the size of laboratory with all needs.

4.To estimate the approximate cost of the project.

4.2.

In this project, the size of laboratory is planned in such way that all necessary facilities are provided. The lab contains,

1.Testing hall with cellar portion

2.Fabrication hall.

3.Curing tank.

4.Materials store room

5.Staff room

6.Equipment and stationary room.

4.2.1 Testing Hall:

Testing hall is the area provided in any lab conducting tests. An area of $195m^2$ Is provided for the Testing hall, which includes an area of about 48 m^2 for frame loading system, which is fixed over the cellar portion.

4.2.2 Fabrication Hall:

An area of 78m2 is provided for the fabrication of structural elements like beam, column, frames, etc. the materials that are necessary for casting the elements must be stored in the materials store room. An area of $21m^2$ is provided for materials storeroom.

4.2.3. Curing Tank

All structural elements that are tested must cure before testing for getting accurate results. So there is a need for a curing tank within the lab. An area of $56m^2$ is provided for curing with a depth of 1. 50m.

4.2.4. Staff Room:

To look into the maintenance of the lab and for the guidance of conducting the tests, a staff must be needed always. For this purpose, a staff room about an area of $27m^2$ is provided.

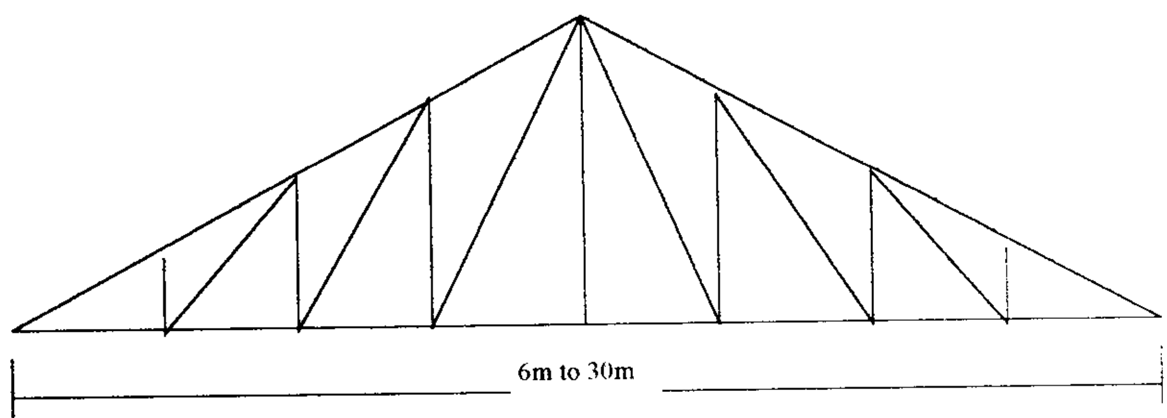
4.2.5 Equipment And Stationary Room:

The measuring equipments like proving ring strain gauges are valuable things, so they should be properly stored in a separate room. Measurement books, recording sheets and IS codebooks may be needed while doing the tests, so they are to be kept in separate room. For this purpose area of $27m^2$ is provided in lab.

The plan of the lab is shown in the drawing no: 10

The roof of the lab is provided with a howe truss spanning 15m (this truss can be provided b/w the spans 6m to 30m). They are spaced at 5m c/c, which are resting on the columns of size 350 × 500 mm. Constructed with R.C.C mix 1:2:4

A projection of length 750 mm is provide from the column towards the lab about 1.5m below the top of column to rest the gantry girder running along the length of lab (spanning 25m, supported between 5m c/c). The position of above mentioned parts are shown in the drawing no: 11



HOWE TRUSS

Fig (11)

DESIGN ASPECTS

5. PRINCIPLES OF DESIGN

Every structures designed by the engineering will be based on some principles. In this project structures designed are based on the following principles

5.1. <u>Loading Frames:</u>

5.1.1. Loading Frame (500 KN Capacity):

Loading frames are the structures like a testing machines used to test the beam, column elements etc., they are designed for the maximum bending moment, max shear forces that will occur when they are subjected to testing load.

After selecting a suitable section it is checked for the deflection criteria.

5.1.2. Loading Frame (1000 KN Capacity):

Another loading frame which is used to conduct the tests on wall panels, columns, is analysed as frame by moment distribution method. Then it is designed for the maximum net bending moment that will occur in both horizontal and vertical member of the frame.

The horizontal member is also checked for deflection. These members are connected by using high friction bolts. The bolted connections are also designed for the end moment caused when they are loaded.

1. The vertical loads from the crane.
2. The eccentricity effects induced by the vertical loads, and the impact factors.
3. Lateral thrust across the crane rail, and
4. Longitudinal horizontal thrust along the crane rail

The crane runway girders supporting bump shall be checked for bumper impact loads. The stress developed due to secondary effects such as handling, erection, temperature effects, settlement of foundations shall be appropriately added to the stresses calculated from the combination of loads as recommended by IS: 800 – 1984. The total stresses thus calculated shall be within the permissible limits. The gantry girders are to be designed for the following additional loads as per IS 875 – 1984 as given in table below.

SNo	Type Of Load	Additional Load
1	Vertical load	
	(a) EOH Cranes	25 % of Max. Static Wheel Load
	(b) HO Cranes	10 % of Max. Static Wheel Load
2	Horizontal Forces Perpendicular to rail	
	(a) For EOH Cranes	10 % of Wt. Of trolley + Wt Lifted on cranes
	(b) For Ho Cranes	5 % of Wt. Of trolley + Wt Lifted on cranes

A special concrete bed is laid below the vertical member. The stress induced in this bed shall be less than allowable bending stress (185N/mm^2) the base connections of vertical member is designed as a slab base connection.

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5.2. Frame Loading:

Frame loading system is used to test the frames for lateral forces, vertical forces, testing of a particular beam, column in the frame. The force applied to the frames, induce same amount of forces on the frame loading, that will cause axial forces and bending moment. So it is designed for the maximum B.M and Max. Shear force occurs as above.

The bottom edge is connected to the cellar root slab; the connections are designed for the moment at this point. Lateral inclined support is also provided to resist the forces. The moment at the bottom end which is connected with roof of cellar portion will became more, so as to prevent the failure of both frame and slab the lateral supports becomes necessary.

5.3. Gantry Girder:

The gantry girders are the girders, which supports the loads transferred through the travelling wheels of the crane gantry girder. The following are the effects of crane to be considered under the imposed loads.

3	Horizontal Forces Along rail	5% of static wheel load

5.4. Cellar Portion Roof Slab:

The reason for providing the cellar portion with holes (for fixing the bottom edge with slab) is to facilitate the testing of a particular beam or column in the frame to be tested. The whole portion behaves like a box culvert is structural aspect.

The top slab (roof slab) is designed for the maximum bending moment that will occur due to loading of frame through frame loading system. The maximum bending moment will occur when the frame is placed near the support.

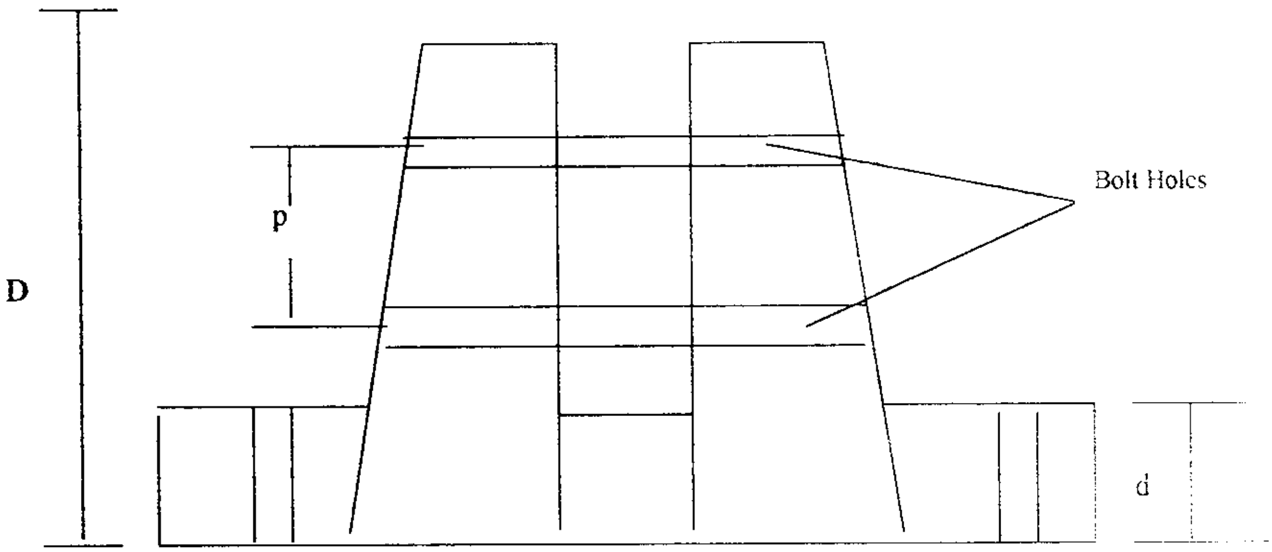
First assume the thickness of roof slab, then by applying the principle of rolling land, the maximum shear force, bending moment is found out (By influence line diagram)

Find the require thickness of slab for the max. B.M. the reinforcements are so arranged in a manner that any bar in the slab shall not cross the bolt holes in order to prevent,

1. Erosion of bars due to action of external agency
2. Avoid interception of fixing of frame loading.

5.5 Foundation Block:

This is the pre – casted block act as a foundation for any frames that are tested using frame loading testing system. The following figure shows the typical foundation block,



C / s OF FOUNDATION BLOCK

The following are design factors for the design of foundation block.

1. Total load the frame (capacity of frame loading = 2000 KN) + self. Wt

Of frame + self .Wt. of foundation block

2. B.M due to above load

3. Lateral thrust due to bolt action, within the block.

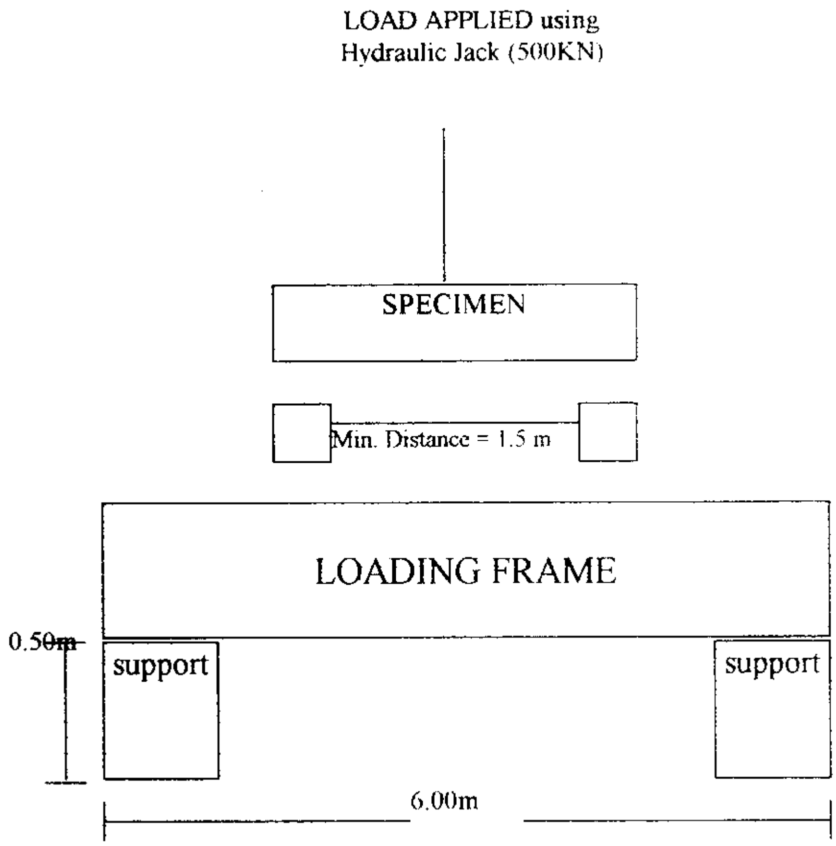
4. It should satisfy the shear stress requirements as per IS 456 - 1978.

Bolt holes are properly provided in the block so as to enable the fixing of frame with the block.

DESIGNS

6. DESIGNING

6.1. Design Of Loading Frame (500 KN Capacity):

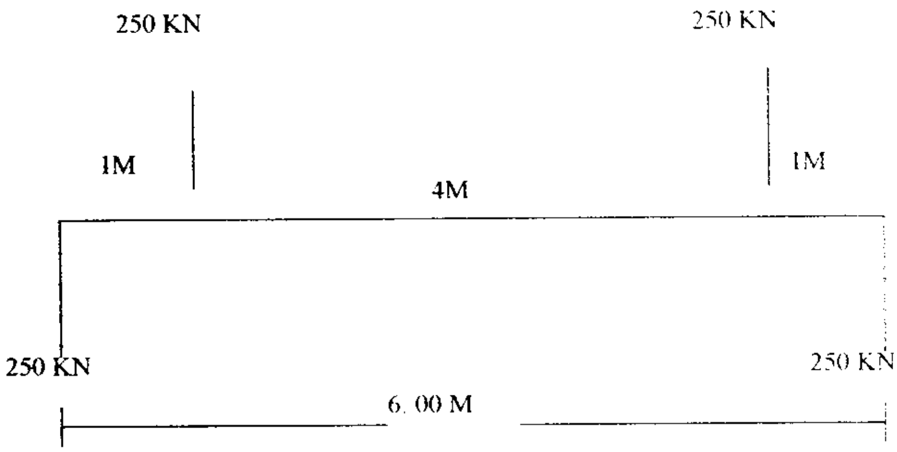


Maximum load applied to the specimen = capacity of frame = 500 KN

⇒ Load coming to either support = 500 / 2 = 250 KN

For designing the loading frame, let us consider the whole frame is tested for large specimen.

Case (iii) supports @ 1.0m from either end.

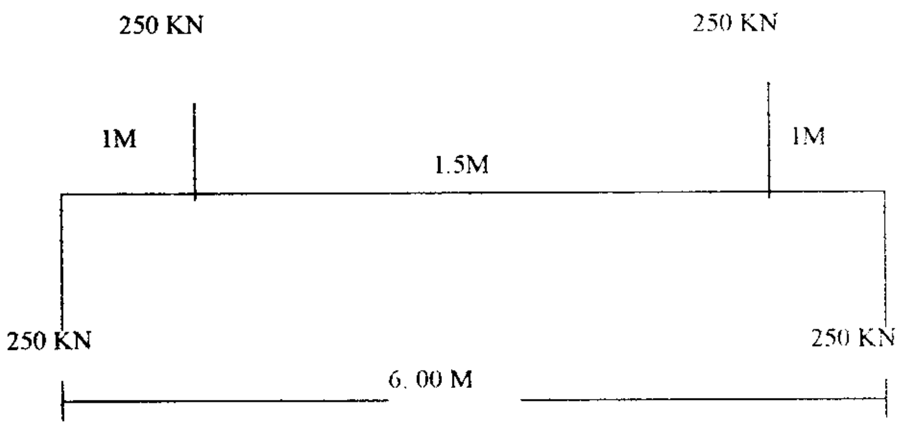


Max. B.M. occurs @ mid span,

$= 250 \times 3 - 250 \times 2$

$= 250$ Kn.

From the above, we can see that the max. B.M. till occurs ω mid span and the value increase with decrease in distance b/w supports.



Max B.M $= 250 \times 3 - 250 \times 0.75$

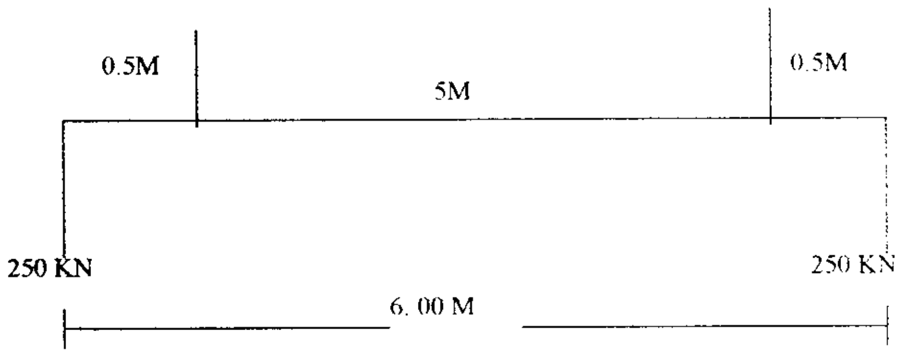
The support blocks are adjusted according to the span of the specimen

To determine the maximum bending moment and shear force in the frame, place the supports @ end and move it by 0.5m from either end towards mid span, till the minimum span is 1.5m.

Case (i) supports @ either ends.

In this case the bending moment = 0

Case (ii) supports @ 0.5m from either end.



Max. B.M occurs @ mid span

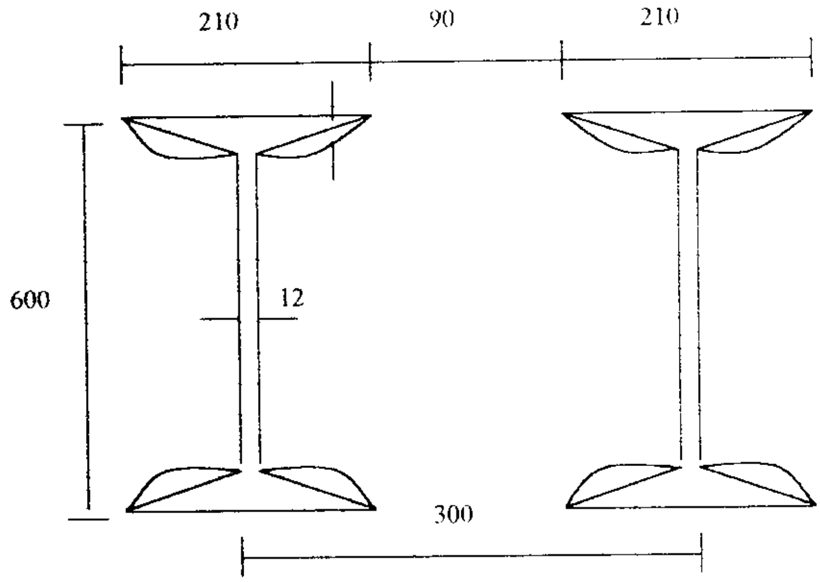
$$= 250 \times 3 - 250 \times 2.5$$

$$= 125 \text{ KN. M}$$

let us try 2. I section,

From ISI Hand Book, select,

ISMB 600 @ 1226 N/ m with $Z_{xx} = 3060.4 \times 10^3 mm^3$



$I_{xx} = 9183 \times 10^4 mm^4$

$I_{xx} = 2651 \times 10^4 mm^4$

At either support the selected section is welded using plate of 10mm thickness, to keep the c/c distance constant.

I_{xx} of the section $= 2 \times I_{xx}$ of single section

$= 2 \times 91813 \times 10^4$

$= 183626 \times 10^4 mm^4$

= 562. 50 KN. M.

Now, assume the suf wt including all components and effects.

= 20 KN / m

Therefore B.M $= \frac{wl^2}{8} = \frac{20(6)^2}{8}$

= 90 KN.m

Total BM = 90 + 562.50

= 652.50 KN.m

Let us design the loading frame as built – up beam

Assume, f_y = 250 N / mm2 from IS code 800 – 1984, σ_{bc} · 0.66 f_y

$Z_{req} = M / \sigma_{bc} = \frac{652.50 \times 10^6}{0.66 \times 250}$

$= 3954.55 \times 10^3 \text{ mm}^3$

for safety increase it by 50 %

$= 5931.82 \times 10^3 \text{ mm}^3$

Check for web buckling:

Slenderness ratio for web

$$= \frac{h1 \sqrt{3}}{T_w}$$

$$= \frac{509.7 \sqrt{3}}{12}$$

$= 73.57$

For this value, σ_{ac} from table5.1 of IS: 800 – 1987

70	112
73.57	
80	101

$\Rightarrow 112 - 11 \times 3.57 / 10$

$= 108.07\ N/mm^2$

$\sigma_{ac} = 108.07\ MPa$

Load carring capacity of web under support block,

$\sigma_{ac} \times T_w \times B = 108.07 \times 12\ (600 + 300)$

$= 1167.15\ KN > 250\ KN$

Therefore SAFE

$$I_{yy} = 2[I_{yy} + Ah^2]$$

$$= 2\,[2651 \times 10^4 + [\,15621\,(150)^2]$$

$$= 75596.5 \times 10^4\ mm^4$$

$$\sigma_{bc} = \frac{M}{I} \times y$$

$$= \frac{652.50 \times 10^6}{183626 \times 10^4} \times 300$$

$$= 106.60\ N/mm^2$$

$$< 0.66\ N/mm^2$$

Therefore SAFE

<u>Check for shear:</u>

MAX SF $= 250 + 60$

$= 310$ KN

Average shear stress,

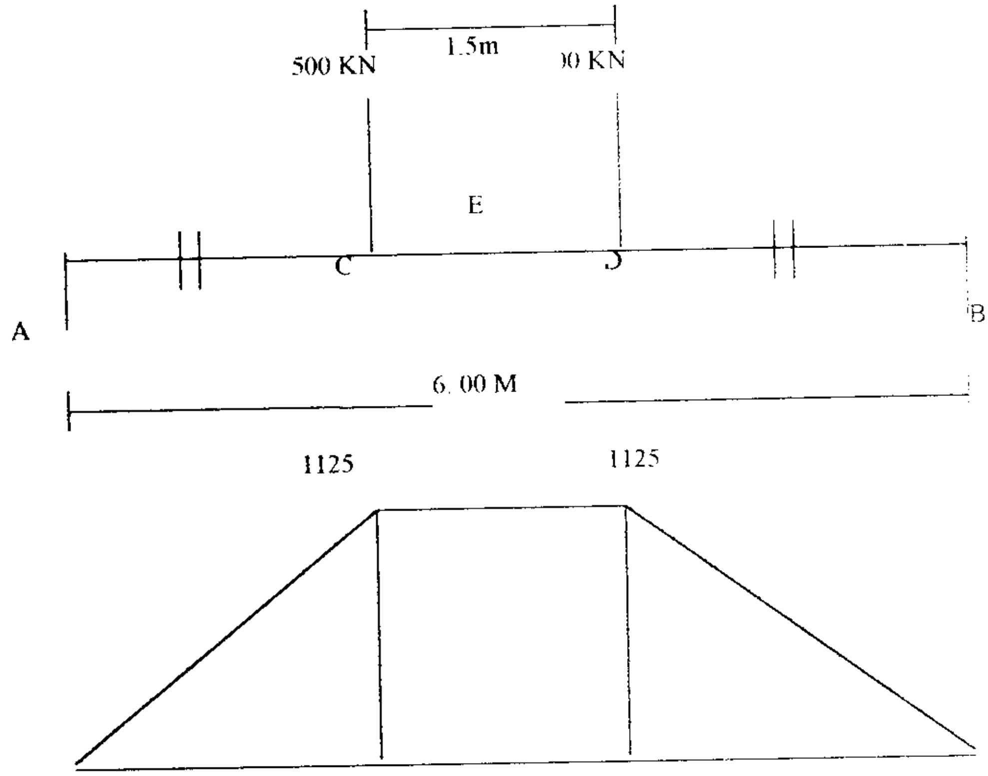
$$T_{Va} = \frac{310 \times 10^3}{600 \times 2 \times 12}$$

$$= 21.53\ N/mm^2$$

$$< 100\ N/mm^2$$

Therefore SAFE

The maximum deflection is @ center of span (E)



Area b/w A and E

$$= A = (\tfrac{1}{2} \times 2.25 \times 1125) + (0.75 \times 1125)$$

$$= 2109.38 \text{ m}^2$$

$$y = \frac{A\bar{x}}{EI} = \frac{2109.38 \times 10^6 \times 1.95 \times 10^3}{2 \times 10^5 \times 183626 \times 10^4}$$

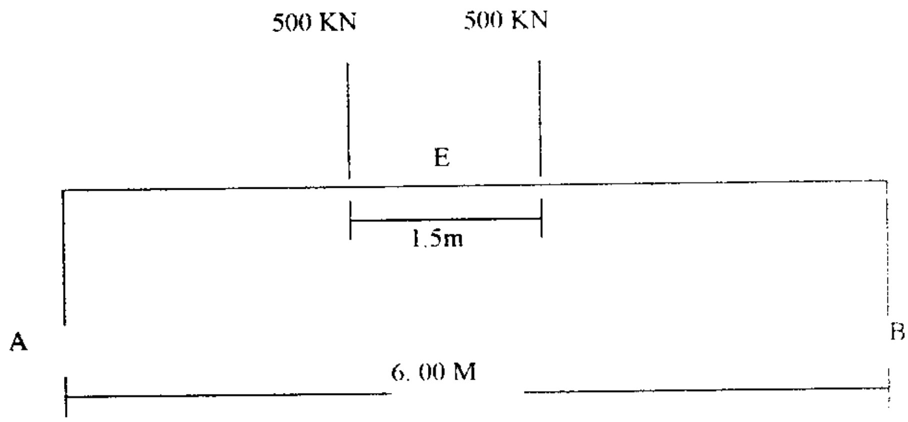
$$= 11.20 \text{ mm} < 1/325 \times 6000$$

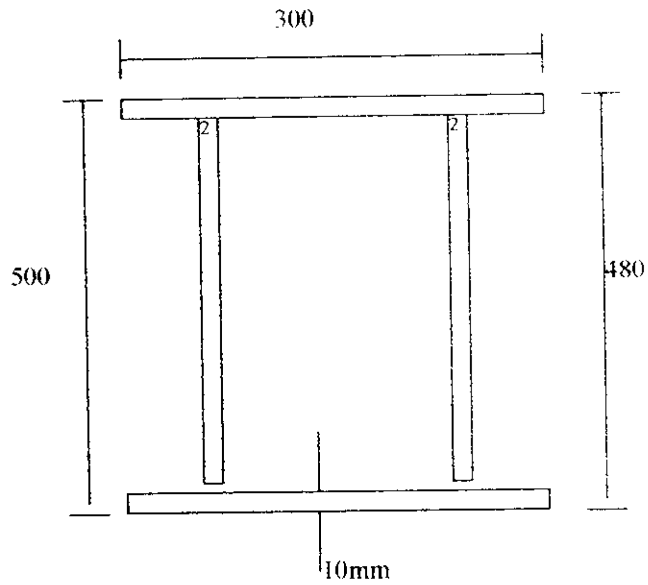
$$= 18.46 \text{ mm}$$

Therefore SAFE

Check for deflection:

The maximum deflection occurs when the distance b/w the two supports will be minimum i.e. 1.5m





$$I_{xx} = 2 \quad \frac{8(480)^3}{12} + \frac{300\,(10)^3}{12} + (300\times 10)\,(245)^2$$

$$= 2.53 \times 10^8\, mm^3$$

$$I_{yy} = 2 \quad \frac{10(300)^3}{12} + \frac{480\,(10)^3}{12} + (480\times 8)\,(50)^2$$

$$= 0.321 \times 10^8\, mm^3$$

$$\gamma_{xx} = \sqrt{\frac{I_{xx}}{A}} \quad \sqrt{\frac{2.53 \times 10^8}{13680}} \quad =135.99mm$$

$$\gamma_{yy} = \sqrt{\frac{I_{yy}}{A}} \quad \sqrt{\frac{0.34 \times 10^8}{13680}} \quad = 48.44mm$$

6.1.2 Design of supports for loading frame:

They are designed for maximum reaction that will occur due to loading.

MAX. Reaction = 250 KN

By self Wt.

Reaction = 120 KN

Total Reaction = 250 + 60

= 310 KN

Height of supports = 0.50m

These are directly supported on the floor level,

$$\text{Area required} = \frac{\text{Total load}}{\text{All. Compressive Stress}}$$

$$= \frac{310 \times 10^5}{150}$$

$< 0.6f_y$

$= 150 \text{ N/ mm}^2$

$= 2066.67 \text{ mm}^2$

For safety, increase the area by 50%

$= 3100 \text{ mm}^2$

Try a depth of 500mm, 300mm width box plate girder with two web plates of 8mm thick and 10 mm thick core plate connected by 5mm weld.

Therefore Eff. span = 0.3 m

The load distributed to loading frame through support block as point load @ with span

Therefore MAX. BM $= \frac{wl}{4}$

$= \frac{255\,(0.3)}{4}$

$= 19.56$ KN m

Z_{xx} req $=$ m / $0.66\,f_y$

$= 19.56 \times 10^6 / 165$

$= 118.55 \times 10^3\ mm^3$

For safety, increase it by 50%

$= 177.83 \times 10^3\ mm^3$

Try 2 ISJC 200 @ 107 N / m

(length of section = 510 mm)

connected back to back by welding with cover plates of 5mm thick on both top and bottom.

$$\lambda = \frac{500}{48.44} = 10.32$$

10	150
10.32	
20	148

150 – 2 / 10 × 0.32

= 149. GYN / mm^2

Allowable load = Area × stress

= 13680 × 149.94

= 2051.19 KN > 250 KN

Therefore SAFE

6.1.3 <u>Design of support blocks for supporting specimen:</u>

These are designed to carry a load

= load coming through specimen

= 250 KN

Add a self Wt. = 5 KN

Total Weight = 255 KN

They are supported over the loading frame

Spanning a length = 90 mm

c/c distance = 300 mm

The detailed drawing of all components are shown in the drawing No: 12

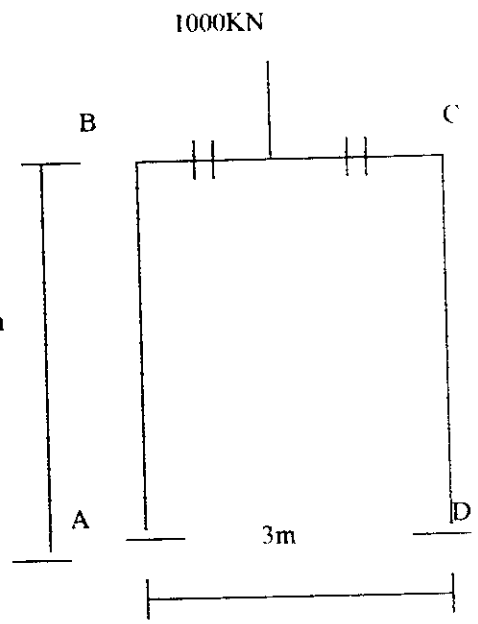
6.2. Design of loading frame:

Capacity = 1000KN

Height of frame = 6m

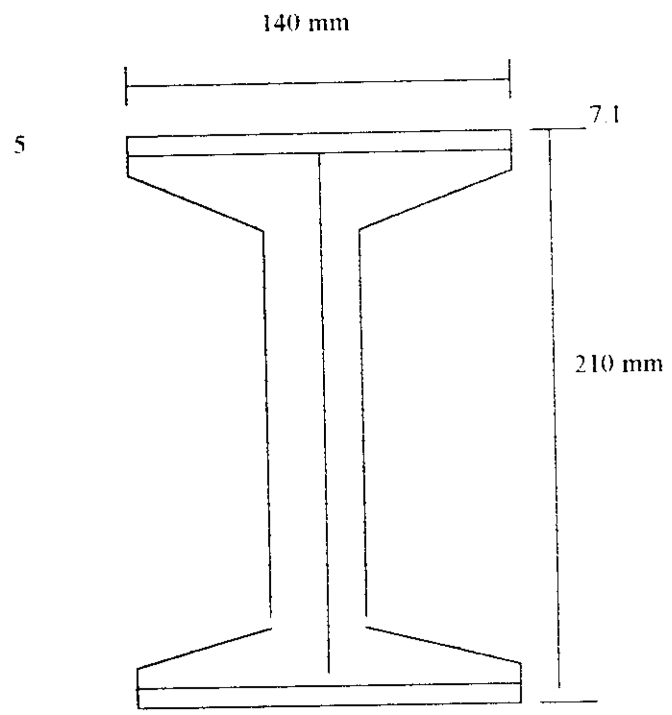
Width of frame = 3m

The hydraulic jack of 1000 KN capacity is fitted in central span of frame beam.



Let us select a trial section for both the beam BC and columns AB, CD.

For the beam, try a built up section size 500 × 800 mm with 10 mm thick plates connected by weld of size 5 mm.



$$I_{xx} = 2\ 1161.2 \times 10^4 + \frac{140(5)^3}{12} + (140 \times 5)(1025)^2$$

$= 1896.78 \times 10^4\ mm^4$

$$\sigma_{bc} = \frac{M}{I} \times y$$

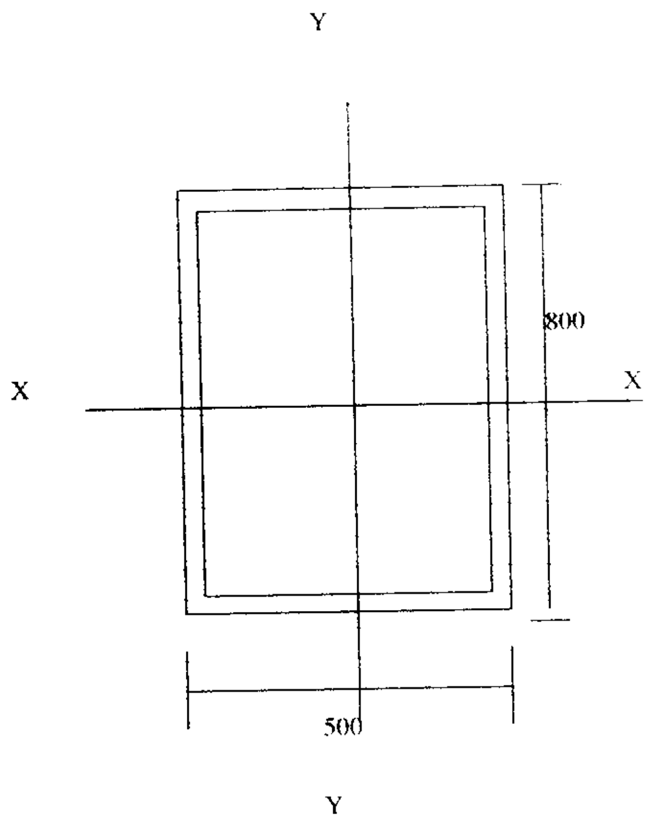
$$= \frac{19.56 \times 10^6}{1896.76 \times 10^4} \times 205$$

$= 108.28\ N/mm^2$

$< 0.66\ f_y$ (All. Bending Comp. Stress)

$= 165\ N/mm^2$

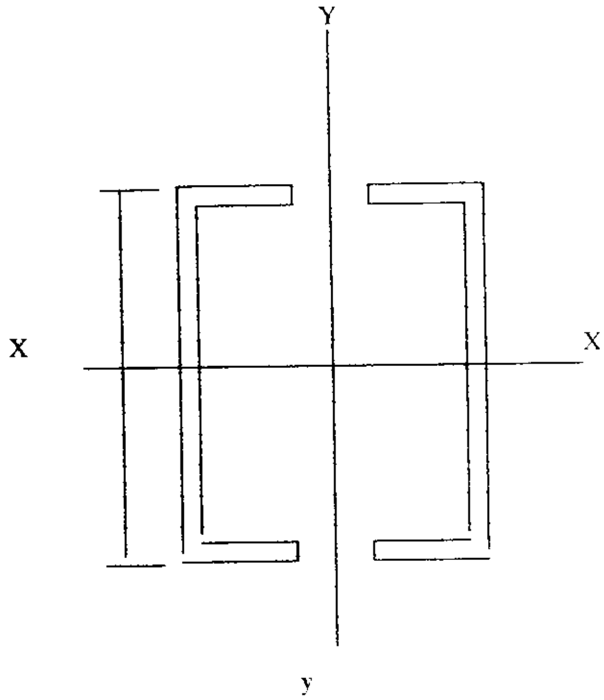
Therefore SAFE



$$I_{xx} = 2\left[\frac{500(10)^3}{12} + (500 \times 10)(395)^2\right] + \frac{2\ 10\ (800)^3}{12}$$

$$= 2.57 \times 10^9\ mm^4$$

For the column also try a built up section of size equal to 500 × 500 mm with 10 mm thick plate as shown in figure.



$$I_{xx} = 4 \; \frac{150(10)^3}{12} + (150\times 10)\,(245)^2 + 2\; \frac{10\,(490)^3}{12}$$

$$= 0.568 \times 10^9\,\text{mm}^4$$

$$I_{yy} = 4 \; \frac{10\,(150)^3}{12} + (10\times 150)\,(175)^2 + 2\; \frac{490\,(10)^3}{12}$$

$$= 0.783 \times 10^9\,\text{mm}^4$$

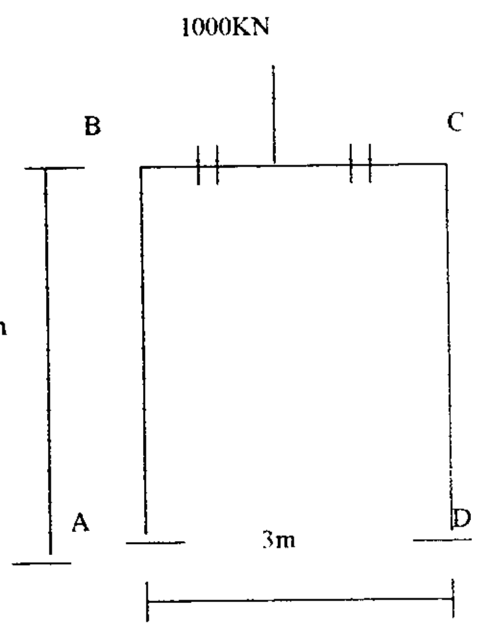
$$\frac{I_B}{I_C} = \frac{2.57\times 10^9}{0.568\times 10^9} = 4.24$$

$I_B \quad = 4.24\ I_C$

The beam (BC) can be adjusted according to the height of the specimen. So it is necessary to analyse the frame for maximum and minimum height @ which it is placed.

Let us analyse the frame by moment distribution method.

Case (i) When the height of frame will be maximum (i.e., 6m)

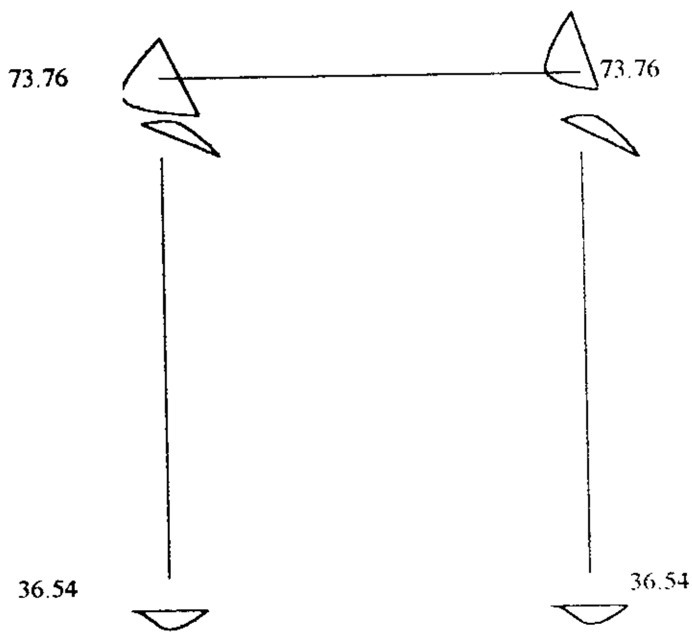


JOINT	MEMBER	K = J / l	S.K	D.F = K / S.K

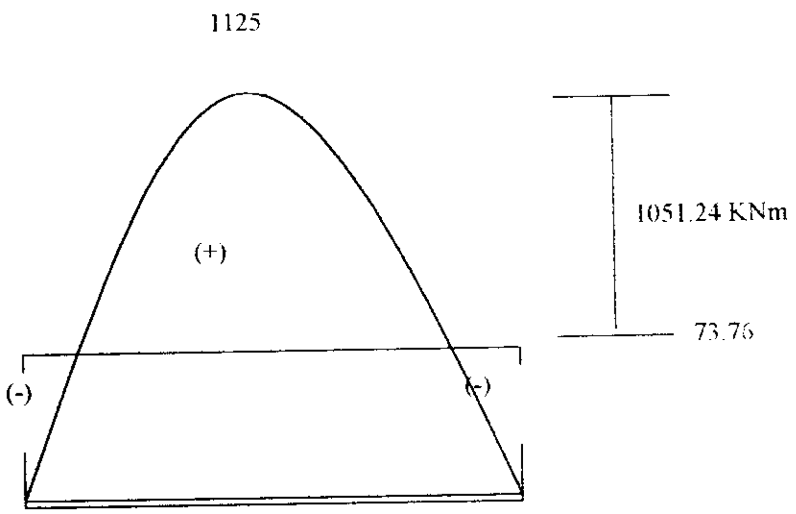
A	AB	-	-	-
B	BA	0.17I	1.58I	0.11
	BC	1.41I		0.89
C	CB	1.41I	1.58I	0.89
	CD	1.71I		0.11
D	CD	-	-	-

JOINT	A	B		C		D
MEMBER	AB	BA	BC	CB	CD	DC
D.F	-	0.11	0.89	0.89	0.11	-
F.E.M	-	-	-375.00	+375.00	-	-
Dist	-	+ 41.25	+333.75	- 33.75	-41.25	-
C.O	+20.63	-	-166.88	-166.88	-	-20.63
Dist	-	+18.36	+ 148.52	+ 148.52	- 8 . 36	-

C.O Dist	+9.18 -	- +8.17	-74.26 + 66.09	-74.26 + 66.09	- - 8.17	9.18 -
C.O Dist	+4.09- -	- +3.64	-33.05 + 29.42	+33.05 -29.42	- - 3.64	4.09 -
C.O Dist	+0.82 -	- +0.72	-6.55 + 5.82	-6.55 + 5.82	- - 0.72	0.82 -
FINAL MOMENTS	436.54	+73.76	- 73.76	+73.76	- 73.76	-36.54

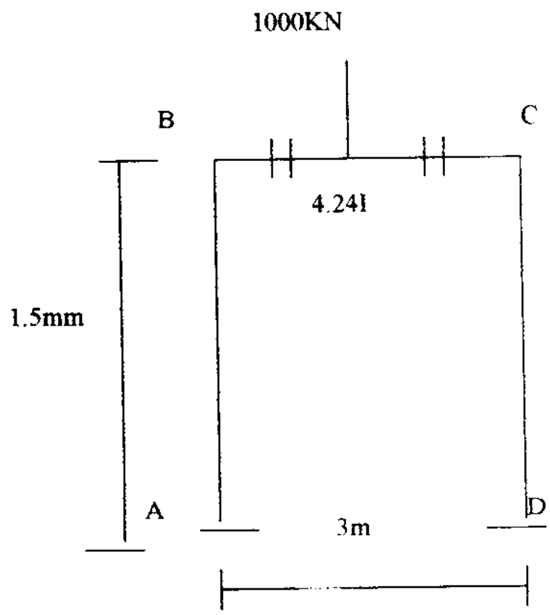


For Beam



Net B.M = + 1057. 24 KN.m

Case (ii) when the beam is @ minimum height (i.e. 1.5m)

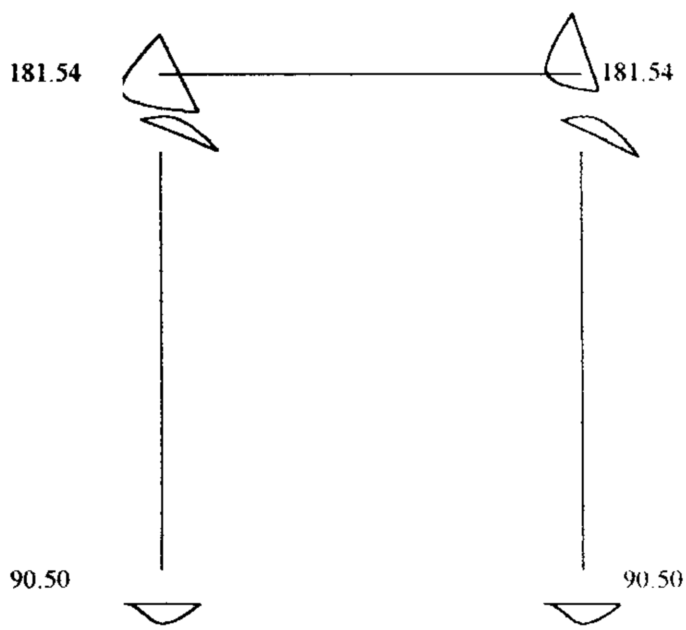


Distribution factor:

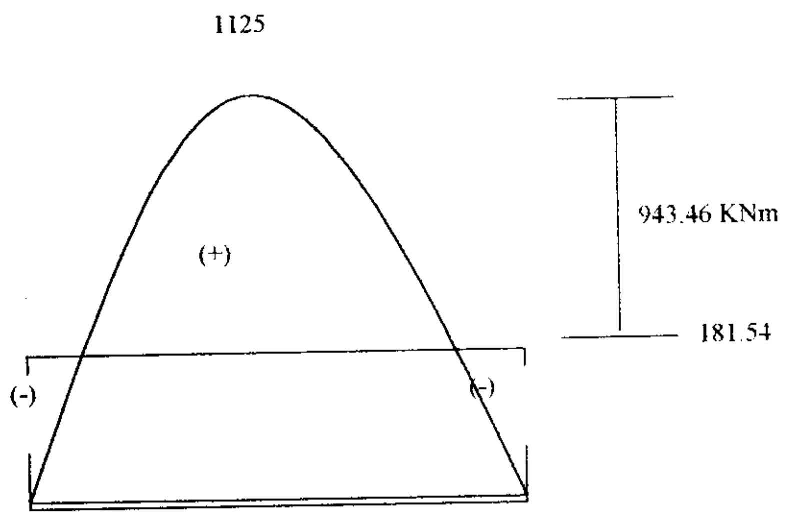
JOINT	MEMBER	K	∈.K	D.F
A	AB	-	-	-
B	BA	0.67I	2.08I	0.32
	BC	1.41I		0.68
C	CB	1.41I	2.08I	0.68
	CD	0.67I		0.32
D	DC	-	-	-

JOINT	A	B		C		D
MEMBER	AB	BA	BC	CB	CD	DC
D.F	-	0.32	0.68	0.68	0.32	-
F.E.M	-	-	-375.00	+375.00	-	-
Dist	-	+ 120.00	+255.00	- +255.00	-120.00	-

C.O Dist	+20.40 -	- +13.87	-43.35 + 29.48	-43.35 + 29.48-	- - 13.87	-20.40 -
C.O Dist	+6.94 -	- +4.72	-14.74 + 10.02	-14.74 + 10.02	- - 4.72	6.94 -
C.O Dist	+2.36- -	- +1.60	-5.01 + 3.41	-5.01 + 3.41	- - 1.60	2.36 -
C.O Dist	+0.80 -	- +0.55	-1.71 + 1.16	-1.71 + 1.16	- - 0.55	+0.80 -
FINAL MOMENTS	90.50	+181.54	- 181.54	+181.54	- 181.54	-90.50



For Beam



Net B.M = + 943.46 KN.m

From above,

Maximum net bending moment = 1051.24 KN.m.

For column,

Axial Load = 500 KN

With uni axial bending = 181.54 KN.m.

6.2.1. **Beam Design:**

Now we have to check the trial section for B.M. = 1051.24 KN.m.

$$\sigma_{bc} = \frac{1051.24 \times 10^6}{2.57 \times 10^9} \times 400$$

$= 163.62\ N/mm^2$

$< 0.66\ f_y$

$= 165\ N/mm^2$

Check for shear:

$$\tau_c = \frac{F}{h.t_w} = \frac{500 \times 10^3}{800 \times 10}$$

$= 62.5\ N/mm^2$

$< 0.45\ fy$

$= 100\ N/mm^2$

Therefore SAFE

Check for deflection:

MAX. deflection $= \frac{wl^3}{EI}$

$$= \frac{1000 \times 10^3 (3000)^3}{2.1 \times 10^5 \times 92.57 \times 10^3}$$

$= 10.03mm$

Limiting deflection $= 1 / 325 \times 6000$

$= 18.46 \text{ mm} > 10.03mm$

Therefore SAFE

6.2.2 Design Of Column:

Axial load = 500KN, with a

Uni axial bending = 181.54 KN.m

Area of the section provided

$= 2 \times 7800$

$= 15,600 \text{ m}^2$

Effective length (from IS: 800 – 1984)

= 0.65L

= 3.9m (or) 0.975m

Find slendexness ratio:

$$\frac{L}{r_{min}} = S.R \qquad r = \sqrt{\frac{I}{A}}$$

$$= \sqrt{\frac{0.568 \times 10^9}{15,600}}$$

= 190.82 mm

$$\text{(i) S.R} = \frac{3900}{190.82}$$

$$= 20.43 \text{ and } \frac{975}{190.82} = 5.11$$

The interaction formula,

$$\frac{\sigma_{ac}\text{, Cal}}{\sigma_{ac}} + \frac{\sigma_{bc}\text{, Cal}}{\sigma_{bc}} < 1$$

$$\sigma_{ac}\text{, Cal} = \frac{\text{Load}}{\text{Area}} = \frac{500 \times 10^3}{15,600}$$

$$= 32.05 \text{ N/ mm}^2$$

$$\sigma_{ac}\text{, Cal} = \frac{M}{I} \times y$$

$$= \frac{181.49 \times 10^6}{0.568 \times 10^9} \times 250$$

$$= 79.88 \text{ N/ mm}^2$$

One for the Value of S.R = 20.43

From IS: 800 – 1984 (table 5.1)

Substitute in interaction formula,

$$\frac{32.05}{147.87} + \frac{79.88}{165} = 0.7008 < 1$$

Therefore SAFE

20	148
20.43	
30	145

$\Rightarrow$ 148 = 3 / 10 × 0.43

= 147.87

σ_{bc} = 0.66 f_y

= 165 N / mm^2

substitute in interaction formula,

$$\frac{32.05}{147.87} + \frac{79.88}{165} = 0.7008 < 1$$

Therefore SAFE

6.2.3. Design of battens connecting column:

According to IS: 800 – 1984,

Axial force in Batten = 2.5% of S.F in column

$$= \frac{2.5 \times 500}{100}$$

= 12.5KN

γ_{min} = 190.82mm

$1 / \gamma_{min} \times 40$

$1 / \gamma_{min}$ = 0.6 × $1 / \gamma_{min}$ of column as whole

= 0.6 × 20.43 = 12.26

$l = 12.26 \times 190.82$

$\cong 2000$ mm

Adopt line spacing of 2m c/c

No. of batten plate = 4

Size of batten plate:

M = VC / 2N

$$= \frac{12.5 \times 2000}{2 \times 2}$$

= 6250mm.KN.

Eff. Depth of battens = distress b/w .C.G. of compet members

= 300 + 1w

= 400mm

$> 2 \times 150$

$\cong 300$ mm

Period of same depth of batten plates through out the column.

Adopt 6mm thick plates

M.R $= 1 / 6 + d^2 \sigma_{bc}$

$$6250 = \frac{1 \times 6 \times d^2 \times 0.66 \times 250}{1000}$$

d $= 194.62 < 300$mm

Therefore SAFE

6.2.4. <u>Design of connection of beam and frame:</u>

the connection is made by bolts

Force is one bolt,

Assuming the plates one connected using bolts in 3 rows, force to be transmitted by one bolt,

$$1 / 3 \times 500 = 166.67 \text{ KN}$$

Assuming 100mm pitch bolts holes,

$$F = 166.67 \times 100$$

$$= 16667 \text{ KN}$$

Bolt value,

Use 25mm dia bolts,

Strength of bolt in double shear,

$$2 \frac{\pi}{4} \frac{(25)^2 \times 120}{1000} = 117.80$$

Strength of bolt in bearing,

$$= \frac{25 \times 10 \times 300}{1000} = 75\text{Kn}$$

Bolt Value = 75KN

Number of bolts required = 500 / 75

= 7 bolts < 9 bolts

Therefore SAFE

6.2.5 Design of Column base connections:

Assume allowable bearing pressure on concrete is 4 N/mm^2

Allowable bending stress in slab base as 185 N/mm^2

Area if slab base required:

Axial load column = 500 KN

This is subjected to moment. So increase the load by 50 %

Total load = 500 + 250

= 750 KN

Area of slab base required,

$$= \frac{750 \times 1000}{4}$$

$= 18.75 \times 10^4 \ mm^2$

Size of column = 500 × 500mm

Area of slab base = $(500 + 2a)(500 + 20) \ mm^2$

$(500 + 2a)^2 = 18.75 \times 10^4$

on solving these,

a = 33. 49 mm

≅ 40mm

size of slab base is 540 × 540

Area Provided = $29.16 \times 10^4 \ mm^2$

Intensity of pressure from concrete under the slabs,

$$w = \frac{750 \times 1000}{29.16 \times 10^4}$$

$$= 2.57 \text{ N/ mm}^2$$

Thickness of slab base:

$$\text{Thickness of slab base} = \left[\frac{3 \times 2.57}{185} (40^2 - 40^2/4)\right]^{1/2}$$

$$= 50.008$$

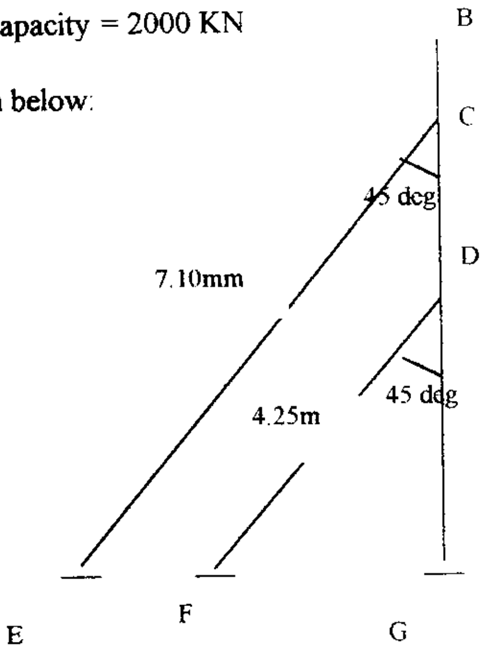
$$\cong 50\text{mm}$$

The fastenings are provided to keep the column in position

6.3. **Design of frame loading:**

Total capacity = 2000 KN

The frame is as shown below:



This can be analysed by moment distribution diagram. Assume constant EI

The total capacity of the frame is 2000 KN. The maximum B.M will occur when maximum load is at the point B. let assume that the total capacity of frame (2000KN) is acting at the point B.

Distribution factor:

From the above analysis,

The net maximum bending moment = 1855.94 Kn.m

And axial force = 1400 KN

Assume slenderness ratio as 80 and σ_{ac} = 101 N/ mm^2

Area required = $1400 \times 10^3 / 101$ = 13861.38 mm^2

Increase it by 50 % for moment actio,

Total area = $1.5 \times 13,861.38$
= 20, 792.08 mm^2

$$I_{xx} = 2 \frac{25(450)^3}{12} + 2 \frac{250\,(25)^3}{12} + (250 \times 25)\,(237.5)^2$$

$$= 1.79 \times 10^9 \text{mm}^4$$

$$I_{yy} = 2 \frac{450\,(25)^3}{12} + (450 \times 25)\,(337.5)^3 + 2 \frac{4\,(250)^3}{12} + (250 \times 25)\,(225)^2$$

$$= 4.98 \times 10^9 \text{mm}^4$$

$$\gamma_{min} = \sqrt{\frac{1.79 \times 10^4}{47500}}$$

$= 194.12mm$

$\lambda \quad = 1 \ / \ \gamma_{min}$

$= 1400 \ / \ 194.12 = 17.12$

From 5.1, IS : 800 – 1984

70	112
72.12	
80	101

$= ½ - 11 \ / \ 10 \times 2.12$

$\sigma_{ac} \quad = 109.67 \text{ N/ mm}^2$

$$\sigma_{ac}\text{ , Cal} = \frac{14000 \times 10^3}{47,500} = 29.47 \text{ N/ mm}^2$$

$$\sigma_{bc}\text{ , Cal} = \frac{Mxy}{}$$

$$= \frac{1855.94 \times 10^6}{4.98 \times 10^9} \times 350 = 129.92 \text{ N/ mm}^2$$

Substitute in Interaction formulae,

$$= \frac{29.47}{109.67} + \frac{119.92}{165}$$

= 0.98 < 1.00

Therefore SAFE

6.3.1 Design of Supports:

6.3.1.1 (i) Support DF:

	l	= 0.65L
		= 2762.50 mm
Axial force		= 47.83 KN with B.M = 1102.06 KN.m
Assume	λ	= 80 and σ_{ac} = 101N/ mm^2
But actual force		= 680 KN
Area required		= 680× 10^3 / 101 = 6732.67 mm^2

Total area required due to moment action = 1.5 × 6732.67

= 10099.01 mm^2

From stap table,

Try ISWB 500 @ 952 N / m

A = 12122 mm^2

γ = 55.69

50	132	
55.69		
60		132

132 - 10 / 10 × 5.69

= 126.31

σ_{ac} , Cal = 680 × 10^3 / 12122 = 56.09 N/ mm^2

σ_{ac} $= 126.31 \text{ N/ mm}^2$

σ_{bc} $= 0.66 f_y$

$= 0.66 \times 250$

$= 165 \text{ N/ mm}^2$

σ_{bc}, Cal $= M / Z$

$= 1102.06 \times 10^6 \; / \; 2091.6 \times 10^3$

$= 131.75 \text{ N/ mm}^2$

Substitute the value in Inter action Formula

$$= \frac{131.75}{165} + \frac{56.09}{125.31}$$

= 1.01 ⊻ 1.00 SAFE.

1.3.1.2. Support CE:

Moment = 503.60

The moment and axial force in the support CE is less than the support DF.

So provide the same section for the support CE also.

The connection between two channels (built – up section) are made by batten plates.

Use 10mm thick batten plate of size 700 × 400 mm @ a spacing of 1m c/c

The web portion of channel is made with bolts holes to fix the hydraulic jacks for loading of frame and for fixing the support on another size.

The base of frame loading, and supports are connected with the slab of cellar portion with bolts. The dia of bolts may be taken as 50mm.

6.4 Design of Gantry Girder:

The following figure shows the three dimensional view of gantry girder with crane bridge, trolley etc., (electricity operated over head travelling crane).

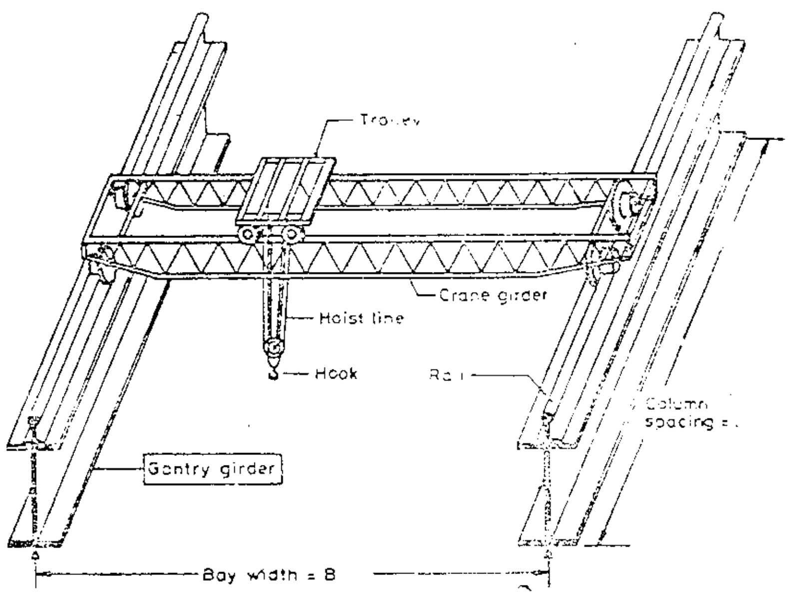


Fig. 8.1 Typical crane and gantry girders

6.4.1 Data avilable:

- C/c of crane girders = 140m
- Distance b/w wheel bases = 3.0m
- Capacity of crane = 500 KN
- Weight of crab = 40 KN
- Minimum clearence b/w center of crane girder and cross travel is 1.2m
- Weight of crane including crab is 200 KN
- C/c of column is 5m

Assume

- Self weight of girder as 2.0 KN / m
- Weight of rail section is 0.30 KN / m

Design:

When the crab is nearest to the crane girder, the wheel loads will be maximum.

Position of crab for maximum wheel load on gantry girder is shown below,

$$R_A \times 14.0 = 200 \times 14.0 / 2 + (500 + 40)(14.0 - 1.2)$$

$$\Rightarrow R_A = 593.71 \text{ KN}$$

$$\text{Maximum wheel load} = 593.71 / 2 = 296.86 \text{ Kn} \cong 300 \text{ Kn}$$

For maximum B.M, the distance b/w one wheel and the resultant of the two wheels should be bisected by the center of span as shown below,

$R_A \times 5 - 300 \times 4.75 - 300 \times 1.75 = 0$

$R_A = 390$ KN

$R_B = 390$ KN

MAX. BM due to moving load,

$M_E = 210 \times 1.75$

$= 367.5$ KN.m

Add 25% impact Moment, Viz., 91.88 KN. m

Total live load moment $= 367.5 + 91.88$

$= 459.38$ KN.m

Moment due ti\o self weight $= Wl^2 / 8$

$= 2.3 \times 5 \times 5 / 8$

$= 7.19$ KN.m

Total moment $= 459.38 + 7.19$

$= 466.57$ KN.m

The section modulus required,

$$= \frac{466.57 \times 10^6}{165}$$

$= 2827.69 \times 10^3 \text{ mm}^3$

From steel section tables,

Try ISLB 600 @ 995 N/m . with
ISMC 400 @ 494 N/m @ top, which is as shown in the figure

$I_{xx} = 72867.6 \times 10^4 + 12669\,(391.27)^4$

$504 \times 10^4 + 6283\,(184.53)^2$

$= 2.89 \times 10^9 \text{ mm}^4$

$I_{yy} = 1821.9 \times 10^4 + 15082.8 \times 10^4$

$= 0.169 \times 10^9 \text{ mm}^4$

Bending stress = M / I × y

$$= \frac{466.57 \times 10^6}{2.89 \times 10^9} \times 391.27$$

= 63.17 N/ mm^2 < 0.66 FY = 165 N/ mm^2

Therefore SAFE

Maximum Bending Moment due to Horizontal force:

Horizontal force transverse to the rail

= 10 % of (Wt. Of trolley + lifted load)

= 1 / 10 × (500 + 40)

= 54 Kn

Horizontal forces transverse to rail on each wheel

= 54 / 2 = 27 KN

Horizontal reaction at support,

= 27 / 300 × 390

= 35.1 KN

Horizontal reaction @ another end support,

= 54 – 35. 10

= 18.90 KN

Horizontal moment = 18.90 × 1.75

= 33.08 KN.m

Add 25% for impact moment,

= 25 / 100 × 33.08 = 8.27 KN.m

Total moment = 41.35 KN.m

Bending Comp. Stress in Horizontal plane,

$$= \frac{41.35 \times 10^6}{0.169 \times 10^9}$$

$= 48.93\ N/mm^2$

$< 165\ N/mm^2$

This can now checked for Elastic critical stress.

$F_{cb} = K_1 (X + K_2Y) C_2/ C_1 <$ IS: 800 – 1984

$D / T = 608.6 / 24.1 = 25.25$

$L / r_y = 5000 / 94.41 = 52.96$

From table 6.5 of IS: 800 – 1984

By Inter polation,

	X		Y
50	70.77		1060
52.96	60	80	
55	1161	1131	
	976	947	876

To find y,

$1060 - 184 / 5 \times 2.96 = 951.07$

To find x,

$1161 - 185 / 5 \times 2.96 = 1051.07$

$1131 - 184 / 5 \times 2.96 = 1022.07$

$1051.48 - 1\ 29.41 / 5 \times 2.96 = 11034.07$

$X = 1034.07$

$Y = 951.07$

From table 6.3, $K_1 = 1.00$ (IS: 800 – 1984)

Table 6.4, K_2 = 0.30

C_1 = 217. 33 mm

C_2 = 391..27 mm

Now, F_{cb} = 1.0 (1034.07 + 0.3 × 951.07) 391.27 / 217.33

= 2375 . 36 N/ mm^2

From table 6.2, of (IS: 800 – 1984)

2200	160
2375.36	
2400	160

σ_{bc} = 160 N/ mm^2

Ratio (T / tw) = 24.1 / 10.5 = 2.3 > 2

F_{cb} is not increased 20 %

Check for combinedbending compressive stress in extereme fibre:

= 63.17 + 48.93

= 112.1 N/ mm^2 < 165 N/ mm^2

Horizontal (longitudinal) forces along the rails

5% of static wheel load = 5 / 100 ×2 × 300

= 30 Kn

Ht. Of rail = 80mm
B.M in long direction = 30 (75 + 391.27)

= 139881.1 KN.mm.

Stress in long direction,

(P / A + M / Z) = 30 × 1000 / 18962 + 13988. 1 × 1000 / 10.35 × 10^6

= 2. 93 N/ mm^2

Check for Shear:

Web area $= 600 \times 10.5 = 6300\ mm^2$

Shear stress $= 300 \times 10^3 / 6300 = 47.62\ N/mm^2$

$< 0.45\ F_y$

$= 112.5\ N/mm^2$

Therefore SAFE

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Design of Connection b/w channel and I. Section:

Assume, Allowable

Shear Stress $= 100\ N/mm^2$

Bearing Stress $= 300\ N/mm^2$

Direct Value:

Use 22mm diameter rivet,

Strength of power driven rivets in single shear,

$\pi / 4\ (23.5)^2 \times 100 / 1000 = 43.35$ Kn

Strength of rivet in bearing

$23.5 \times 8.6 \times 300 / 1000 = 47.24$ KN

Therefore Rivet value = 43.35 KN (R)

MAX allowable pitch in compression,

$= 12 \times 8.6$
$= 103.2$mm

provide rivets @ 100mm c/c throught the length of the gantry girder.

ESTIMATION

7. ESTIMATION

Estimation is the process of working out the cost of the work. in this project, the approximate cost for the work which includes cost of all equipments and infrastructures.

The cost of the equipments like jacks and the proving rings are with reference to "CONCORD INSTRUMENTS PRIVATE Ltd" - Chennai.

The cost of the infrastructural facilities can be found out by plinth area method

Total plinth area = 450m^2

For a similar building (llaboratory) the plinth area rate is = 500 / m^2

Therefore, the Total amount for the building = 450 X 500.00

= Rs. 2,25,000.00

COST AT SITE

Fabrication charges including bolts	= Rs. 75.00 / kg
Cost of Steel	= Rs. 4.50 / kg
Plinth area rate / m^2	= Rs. 500.00

COST OF THE PROJECT :

1. Cost of the building = Rs. 2,25,000.00
2. Cost of the equipments = Rs.7,24.670.00
3. Cost of the loading frame :

ESTIMATION FOR EQUIPMENTS IN LAB

Sl. No.	Instrument's Name	Quantity	Price / Pc.	Total	Grand Total
1	Hydraulic Jacks with gauge & hand Pump				
	a) 100 KN Capacity	4	33350	133400	
	b) 200 KN Capacity	3	33350	100050	
	c) 500 KN Capacity	4	33805	135220	
	d)1000 KN Capacity	1	39180	39180	
					407850
2	Flexible Hose Pipe :				
	AIM 47005 - 5mtr length	12	3610	43320	
					43320
3	Tension / Compression proving Rings				
	a) 100 KN capacity				
	pad & shackles	4	10250	41000	
	calibration changes	4	8215	32860	
	b) 200 KN capacity				
	pad & shackles	3	14850	44550	
	calibration changes	3	10105	30315	
	c) 500 KN capacity				
	pad & shackles	5	14850	74250	
	calibration changes	5	10105	50525	273500
				TOTAL	724670

ESTIMATION OF COST FOR THE FABRICATION OF FRAMES						
Sl.No.	Description	Qty	L(M)	Unit Wt	Total wt	Rate
1	Loading Frame : 500 KN capacity					
	1) Frame	2	6	122.6	735.6	3310.2
	2)Support block for frame	2	0.51	7350	58.48	263.15
	3)Support block for specimen	2	0.51	7350	20.99	94.46
	4)Fabrication charges	0	0		815.07	61130.25
					Total	64797.76
2	Loading Frame : 1000 KN capacity					
	1) Column	2	6	7350	687.96	3095.82
	2)Beam	1	3.5	7350	658.56	2963.52
	3) Fabrication Charges	0	0	0	1346.52	100989
					Total	107048.3
3	Loading Frame : 2000 KN capacity					
	1) Frame	1	7	7350	2443.88	10997.45
	2)Support block for frame (A)	1	4.25	95.2	404.6	1820.7
	3)Support block for specimen (B)	1	7.1	95.2	675.92	3041.64
	4)Fabrication charges	0	0	0	3525.4	264330
					Total	280189.8
4	Gantry Girder					
	1. I - Section	10	5	99.5	4975	22387.5
	2. Channel Section	10	5	49.4	2470	11115
	3) Installation Charges	0	0	0	7445	558375
					Total	591877.5

a) 500 KN capacity = Rs. 64,797.76

b) 1000 KN capacity = Rs.107048.34

c) 2000 KN capacity = Rs.2,80,189.79

4. Cost of gantry girder = Rs.2,80,189.79

5. Cost of crane girder bridge = Rs.50,000.00

6. App. cost of structure floor= Rs.10,000,00.00

Total = Rs.27,31,895.68

Add 5% of total cost for other charges which include fitting, etc.,

= 5 / 100 X 2731895.68

= Rs. 136594.78

Total Cost = Rs. 2731895.68 + Rs. 136594.78

= Rs. 28,68,490.46

Estimated cost of the project = *Rs. 30,00,000.00* (approx.)

CONCLUSION

8. CONCLUSION

The P.G. Studies for Civil Engineering are mostly selected with experimental basis to acquire the practical knowledge. In this project, we have provided a structural engineering laboratory which will be very useful for civil engineering students both for U.G. and P.G. coursrs to perform various tests on the structural elements.

The lab so provided is upto the standard and will fecilitiate to the need.

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PHOTOGRAPHS