Textile Factory, El-Soyouf, Alexandria, Egypt

TO DEAN PIETRO BELUSCHI

DEAN OF ARCHITECTURE AND PLANNING


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PREFACE.

From the time man began to build, he has tried to simplify his building system, standardise his units, add different alterations to improve materials and facilitate ways of transporting them.

In our age where human labour is being expensive day by day, and the saving of efforts, and time is becoming considerable, preventing waste and unneeded repetition (formwork, small units) and by the great advancement in technology,...etc. The buildings are also directed to be prefabricated in factories in units then to be gathered and connected on site.

The reinforced concrete almost has the advantages of steel in its strength, the advantages of stone in its durability and insulation plus its great flexibility and ability of formation, when the concrete is prestressed it saves weight by saving about 2/3 wasted volume in beams and slabs, gives the possibility of lifting long compression members without breaking as columns, piles etc... The other great advantage is having the possibility to span long spans with very small depth relatively (1/20 - 1/35 span) or less, which allow maximum flexibility in the buildings.

Because of all those merits and conditions the prestressed precast concrete is the material of the moment and the architects, engineers and all people interested in buildings are trying to design and improve system of building, study connections, details ways of erection etc...

This project is an attempt towards using precast prestressed concrete in multistory factory buildings as a step in the way of advance of building systems.
TEXTILE FACTORY

EL-SOYOUF, ALEXANDRIA, EGYPT.

THE PROGRAM:

Because of the new development of Egypt to fulfill the main needs of the increasing population, the Government is industrializing most of the main agricultural products.

Cotton is one of the most important agricultural products and the Textile mills are concentrated in the most areas planting cotton, and specially in cities that have excess in man labour. The city of Alexandria has the two previous conditions plus being the first harbour on the Mediterranean where it would be easy to have its supplies from Europe: machinery, spare parts, materials used in the different manufacturing process. It is also fed by the cotton through existing railroads and highways. The industrial part of Alexandria lies in a district called El-Soyouf, south east of Alexandria, and it has already been filled with different mills, and because of that the land is rather rare and expensive. The Government planning was to build a factory on an area of about 300,000 square feet, having the capability to expand about 100,000 square feet, and themost
suitable and available site was 700 by 450 feet, having the long side on North with a street passing parallel to it.

**REQUIREMENTS.**

A) **Administration and utilities.**

1) Main offices 2000 sq. ft.
2) Exhibition, information, public counters: 1000 " "
3) Locker room for employees 300 " "
4) Cafeteria 700 " "

Total net area 4000 " "
+20% Total gross area 4800 " "

Total volum=4800x11 = 52800 " "

B) **Main Manufacturing Plant:**

1) Wrapping compartment 17500 sq. ft.
2) Slashing " " " "
3) Drawing in " " " "
4) Weaving " " " "
5) Inspection " " " "
6) Laboratory 240 " "
7) Lavatories etc... 240 " "
Total net area 105480 sq. ft.

+ 5%

Total gross area 110000 " "

110000 \times 22 =

Total volum 2420000 cu. ft.

C) Storage

1) Cotton storage (coming raw material) 26880 sq. ft.
2) Textile " (for distribution) 25000 " "
3) Excess " 

\[
\begin{align*}
\text{Total net area} & \quad 78760 " " \\
+5\% & \quad \text{Total gross area} \quad 82500 " " \\
\text{Total volum} \quad 82500 \times 22 = & \quad 1820000 \text{ cu. ft.}
\end{align*}
\]

D) Parking.

A parking area for about 40 cars is required for the employees.
A) The process and its needs.

The beginning of the process is wrapping the spun cotton which is on conical rolls, followed by the slashing, the drawing in, the weaving and inspection.

The wrapping machines are about 35 feet by 10; the slashing are about 40 feet by 10. For this factory it was recommended 6 to 8 wrapping machines and 6 to 8 slashing. The drawing in machines are 6 X 12 ft. each, and the weaving units are about 5 X 8. Finally, the inspection has machinery of about 60 ft. long, needing a width of about 12 to 15 ft. For the storage, the spun cotton is in boxes of about 3 X 3 X 3.

The material is transported from stage to stage by means of a special carriage of a width of 4 to 5 ft. Receiving and shipping will be by trucks and precautions should be taken to keep the percentage of humidity and temperature controlled. The minimum height required for some parts of the process is 15 ft. plus depth of ceiling.
WRAPPING.

SLASHING.
WEAVING.
TRANSPORTING MATERIAL.

INSPECTION.
Maximum flexibility is required.

B) Architectural Design:

Because the required area for the whole factory is double the area of the site, the solution of the problem had to go in the vertical direction although it is preferable to have the machinery always on the ground floor to reduce the construction of floor and supports.

PLANS.

The plan took the L shape having storage longer than main plant in the south to enable the expansion of the latter and the administration facing the main street holding the central position between the two main elements.

It was noticed to have the material flow in one line (or parallel lines) from the receiving, moving to the second floor, storage, then processing by wrapping, slashing, drawing in, going down by an elevator to weaving and inspection area, final storing and shipping.

The storage and main plant are linked by a link that gathers main utilities and services and is an acceptable Architectural transition between them. Links between Administration and plant are also transition between two different elements and form an open court between them.
LOWER VIEW OF MODEL (I)
MAIN PLANT

ADMIN

STORAGE

MODEL
Basement plan:

Because the water in this soil is very near (about 4 ft. deep) it is very difficult and uneconomical to have a large basement, and a basement of only 320 sq.ft. for the main electricity, mechanical and plumbing equipments is essential in this case.

First floor plan.

The raw material is received on a platform 4 ft. high, to a lobby where it is weighed then on a conveyor directly to the second floor storage or the excess on third floor. This lobby is to protect the inner environment from the outer, to keep the percentage of humidity and the temperature the same.

In the link between the storage and plant there is vertical circulation (elevators for products and a staircase for employees.) There also is the vertical shaft that lets all the electricity and mechanical to the first, second and third floor.

In a mezzanine above that, the utilities for employees occur, and in the end of the manufacturing plant there is the elevators for the material from upper floor used when needed.

The bays were chosen 48 ft. c-c, to fit the largest machines laid longitudinally (40 ft.) with 4 feet clearance.
on both sides, and in the other direction they were also chosen 48 ft. c-c to fit a single number of the 8ft. wide beams of the floor and roof. These dimensions allow maximum flexibility as recommended by the people working in the job.

The storage on the first floor is used for the material ready to be shipped. On this floor there is the second part of the process, the weaving machines, then the inspection and finally packaging and storage to shipping.

It is recommended that the weaving machines are to be put vice versa to counterbalance the horizontal force acting strongly and also air pressure machinery are better to have the lowest acoustic intensity level.

Second floor plan:

It follows the first except that in the link there is a laboratory to test samples from both sides; the main plant and the storage area. On this floor, the process begins by the wrapping, then comes slashing and drawing in machinery. The second floor of the third building is the offices and this has been given the maximum flexibility by having a 48 ft. span. There is a direct link from the directors offices to the main plant.
ELEVATIONS.

Main elevation:

Proportions between solid and void, solid masses and perforated ones, horizontal proportions and vertical were based upon a module of 8 ft. and it has been noticed to differentiate between lengths of buildings of different functions horizontally and vertically. The offices are raised on columns to give them elegance while the plant walls extend till the ground.

The inclination of the roof plus the 8 ft. module give the elevation (or perspective) of the building a very strong unity. The louvers in the glass for air conditioning openings do not disturb the continuity of the glass frame and maximum percentage of glass was used in the north elevation of the offices to maintain maximum natural light.

Side elevations:

They have the same base of the 8 ft. module although most of the walls of the side elevations are solid, having the wall panelling covering the main structure. The channel shape was used as the unit for walls instead of double T or single T because I prefer to have the joint in the rib rather than in the mid of the panel. Also in case of crack or unadjustment of any sort, the defect would be in the ribs.
MAIM ELEV. (NORTH)
CROSS SECTION.

LONGTL. SECTION.
SECTIONS.

Height provided is 17 ft., and this was because some of the machinery in the inspection area is around 11 ft. high plus possibility for mechanical, electrical and sprinkler system. This height is also to keep a good proportion of the room in section (proportion between the span and the height).

STRUCTURAL SYSTEM.

The structural system used is in precast prestressed Members of Concrete. In Egypt because the hand labour was low, and steel was very expensive (being imported) while concrete was manufactured; it was cheaper to use poured in place R.C. trying to use the minimum amount of steel. But now, as the nation is producing steel and the manual labour is raising day after day, the direction is to use prestessed and precast members (we are really in an inbetween stage where prestressing is better and more economical in special cases, mainly long spans.

The structure of the main plant is composed of:
1) Precast prestressed columns (prestressing for lifting purposes) the columns do not have haunches to carry cranes
MODEL (2) INTERIOR EFFECT OF STRUCTURE.
because as was mentioned before the use of a special carriage so they are not subjecting to bending. Each column has a steel shoe and special plates in points of connection with bearing.

2) Precast prestressed main girders in the shortest direction of the building, in the longest direction of the building there are other girders to maintain lateral stability. These beams act as simple spans lying on neopream pads and welded to the special connections in the columns as shown in drawings.

3) The secondary beams are derived from the principal and original structural analysis and fundamentals.

If we have a load of an infinite quantity and a support of an infinite width, we shall find that due to the bending moment we shall have an infinite depth at midspan; and due to the shear and width of the support we shall have an infinite breadth of the beam.

From this analysis the idea of a beam of required depth at midspan beginning to spread the material horizontally till it gains practical horizontal proportions for execution. The first thought was to have a beam and slab system, then for economical purposes such as handling and transportation it has been designed with a flange so it is a T section with a constant cross section spreading its web horizontally as we direct towards the support.
CARDBOARD MODEL OF FLOOR UNIT.
CARDBOARD MODEL OF ROOF UNIT.
MODEL OF FLOOR UNITS.
The span is 48 ft., the breadth was assumed and the depth was calculated in sections and for the depth line due to the required moment came a sharp curve near mid span and approximately a straight line in the rest of the beam.

It was found that the weight of this beam for this large load would save about 40% of the weight of the floor structure in comparison to a T section in ordinary R.C. construction and in the case of prestressing it would save about 17%.

The reinforcement of this beam is either diagonal or straight. The diagonal has a disadvantage of letting the strands cross each other at mid span which might cause the bond area around each strand in this area not sufficient. But each strand is then kept straight in plan.

The other type of reinforcement which I prefer is to have a special fork (which is used any how) to hold the stands from breaking the side concrete when being tensionned and this simplifies the tensioning procedure in elevation the stands are inclined exactly like the T or rectangular.
ADVANTAGES AND DISADVANTAGES OF BEAM.

Assumed:
I) Prestressed concrete. 2) All precast + repeated Units (multiplicity of units.) 3) b x d (area of section) Constant. 4) Simple span. 5) Bearing wall.

DISADVANTAGES

1) Taper reduces efficiency of concrete.
2) $\frac{b}{d}$ ration inefficient as support is approached since $M = K bd^2$
3) Complexity of slab reinforcement.
4) Special fixtures to hold pretensioning steel in position.
5) Wide support may be more expensive than columns.
6) Shear stress may be high.

ADVANTAGES

1) Minor for these proportions.
2) But prismatic beam wastes concrete as support is approached to same extend (bd constant)
3) But use of jugs, marking of forms, etc. will keep extra cost low.
4) Low extra cost (usually a fork is used in T sections)
5) Wide support may be cheaper than columns (is existing wall or beam.)
6) May not be critical (long spans and prestressed concrete) besides this is a matter for proper design.
7) Used of surplus concrete (compared to prismatic beam) as support is approached to reduce slab span.
8) More favorable distribution of reactions.
9) Gives the possibility of extension of ducts for air cond. in both directions without having to perforate the beams; usually most of the perforations which
ADVANTAGES. (continued)

9) ...increase the cost are not used.

10) Save 42% of dead weight (17 % in prestressing)

II) Has a better visual appearance as a ceiling.

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4) Roof.

The roof structure is composed of main girders, the secondary beams, the same as before but put upside down to get the benefit of the slope for rain water and when erecting them the inclination is very small that the concrete could hold itself when being poured. The strands are in one horizontal plain in this case. Above the constructive slab there is a ½ inch layer of asphalt plus 2 inch heat insulator and 2 inch concrete cover. The mix of this concrete is with a special water proofing material.

It is not necessary in a very mild weather like Alexandria to have a double roof construction having a void in between. Only in very upper Egypt this would be necessary.

The dimensions of this beam is less than the equivalent on the second floor because live load is less.

5) Walls.

Most of the exterior walls are of precast prestressed white concrete panels. The panels are pretensioned while erection in the longer direction leaving holes in each for post-tensioning after being tilted up.
The thickness of each panel is 5 inches and it is a sandwich of a layer of concrete 2 inches then one inch insulator then another two inches of concrete. Those panels are welded to a special steel connection on the first and second floor beams and each has a steel shoe for bearing and preventing the concrete to crack.

6) Floors.

The first floor level is composed of R.C. slab bearing on the soil which is a sand layer of an acceptable bearing capacity then a layer of the same sand but has about 50% water, and so we had to have beams to stiffen this slab, that transfer the load finally to the foundations. Over this slab there is a damp proofing Asphalt layer of ¼ inch then a layer of glass wool 2 inch then another layer of concrete 3 inches. This layer is divided into squares or rectangles to fit each machine individually and this is to prevent cracks in the slab itself also to prevent transmission of the vibrations and enlarging the sound intensity level.

The second floor is composed of the beam and the slab system plus the fiber glass layer and concrete layer divided to fit each machine separately as the first floor.

In the position of the worker in each machine there is an area of about 9 sq.ft. of wood flooring to stand upon. The top concrete mix has an additional hardning material to resist friction. It does not bother people in fairly hot countries to have terrazzo tiles or concrete as a finishing materials for floors.
7) Foundations.

Special piles are used in this particular area. Those piles have a conical cap having a special plate for the columns that are bolted in the holes provided in the concrete then grouted.
Aim of test:

The aim of the test is to know if there is unexpected failure due to shear near supports or due to combination between shear and bending and to compare the failure of designed beams with failure of rectangular and T sections.

Procedure:

Three molds of each shape of beams were formed so as to have the same conditions of proportions of mix and length of time for curing of concrete which was 7 days (strength of concrete about 85% of concrete after 28 days).

The steel wires were brought and stretched by pulling them through a wire and were put into acid to take off the galvanisation, left for one day in the steam room to rust somehow, then cut and laid into position in each beam. The wires were 6 of diameter .06 inch which was about 1% of area of cross section of concrete. When pouring the concrete a hand vibrator was used to let the concrete surround all the wires carefully and in spite of that some of the rectangular sections were not well bonded.

After a day the mold was taken off and after one week the samples were tested with hydraulic machine under loads in mid span. A plaster topping was put over some of the beam to have a horizontal smooth surface to put the cylindrical rollers on. Length of beam was 30 inches and the
CONCRETE BEAM (TAPERED) FOR TEST. 30""
CONC. TAPERED WITH FLANGE.
TESTING MACHINE BEFORE A TEST.
TAPERED TYPE: 2-1/3FT. LOADS.
TAPERED WITH FLANGE. (I) PT. LD.
TEE BEAMS. I&2PT. LDS.
Load vs. Deflection Curve

Beam (5)
- Point of failure due to double load
- Point of failure due to single load (inaccuracy of Sample 3A)
Load in lb

Deflection in inches

Beam (H)

Load deflection Curve

Point of failure, double point, d (225)

Test No.

Point of failure, single point, Id. (250 lb)

Load in lb

Deflection in inches
scale of the model was 1/20.

Result of the model:

The failure of the tapered type of beams was in position the same as the prismatic type, although the T was more efficient in bending in the two point loading test but was the same as the tapered type in the single loading test. (250 lb.) in each.

The whole experiment should be done again with steel forms to gain maximum accuracy.

The deflection results show that the maximum deflection in one of the beams was 8 inches which is due to the settlement that happened in the flange. In case of prestressing, deflection will be minimised by the horizontal force produced from steel.

Accoustical considerations:

The textiles —fortunately— are very absorbant materials, and it is quite difficult to calculate the exact reverberation time accurately but only in the site when the building is erected; however, in case the prequations for having good acoustics in this factory are four:

I) Sound insulation:

To prevent the sound from spreading out of the building and this is partially solved by having double structure in walls, floor openings and ceilings, and by laying the machinery indirectly on the structure, by having glass wool and separating the floor under each machine from the machine next to it, having a rubber joint between them, this joint is also provided between floor and structure.

An important factor is to recommend using the compressed air
weaving machines which lessen the source of sound.

2) Sound diffusion:

The sound is diffused by the irregularity of the ceiling, the cloth in the factory and machinery, there is no flatter echo between the ceiling and the floor due to those two factors. Sound travelling from side walls due to reflection will be absorbed by the cloth.

3) Reverberation time:

This is expected to be large because of the large volume of the plant but as mentioned before the cloth itself would absorb it.

Reverberation time \( T_r = 0.16 \frac{V}{E \times A} \) (in the metric system)

\( V \), volume of room and \( E \times A \) = summation of the area of surfaces in room. We notice that the more "V" is, the more \( T_r \) is, and in case it is very large we could increase \( E \times A \) by adding absorbative blankets in panels between secondary beam in the ceiling.
ILLUMINATION

The openings in the walls are only for human purposes and this to let the workers not have the feeling of being imprisoned. The amount of glass is minimum to lessen the thermal loss and the illumination is mainly from mixed light lamps hung from the ceiling, they are specially for factories, and best for distinguishing colours.

The idea of the saw tooth was abandoned due to;
1) The irregular distribution of light
2) Lets light in half day or less while the factory works 24 hours
3) Direct light casts shadow on machinery which is not desirable.
4) High cost of saw tooth construction.
AIR CONDITIONNING

Main system is composed of individual units that have heating and cooling coils. The outside air is fed into them and is compressed to the ducts as shown then the fans absorb percentage of returned air and the air continues its circulation.

Humidity is controlled by a separated system of pipes that spray water automatically when humidity ratio goes down.

It is noticed that the beam system allows movements of ducts in two directions.

Humidity is controlled by hung pipes that spray water.

Miscellaneous

There is the main sprinkler system to secure the plant in case of fire. Each sprinkler has an automatic valve that allows water when it is heated to a certain degree.

The Electrical cables are simply spreading in a simple grid, they pass through the voids from the difference between the slab and beam height over the main girder.

There is also the alarm bell in case of emergency, a loudspeaker system to call employees and fire tubes hung on each column for quick use.
STRUCTURAL DESIGN.
Prestressed Concrete Formulee

\[ Z = \text{section Modulus} \]

\[ Zt = \frac{IcG}{Ct}, \quad Zb = \frac{IcG}{Cb} \]

\[ IcG = \frac{1}{3} ab + \frac{1}{3} bc^3 + (\frac{1}{12} et^3 + ctd) \]

\[ Zb = \frac{M \text{ total} - \eta Md}{\eta (fb i) - (fb)} \]

\[ \eta \approx 0.08 \]

Md = Moment due to load of girder.

fbi = Allowable compression in concrete at transfer = 0.6 \( f'c \)

fb = Final allowable compression = 0 or -6 \( f'c \).

\[ As = \frac{F}{fs} = \frac{Mt}{0.65 h \times fs} \]

Ultimate compression stress in prestressed concrete \( f'c \) = 6000 psi

Ultimate tension in steel \( f's \) = 160,000 psi.

Working stresses in concrete = 3600 psi.

Working stresses in steel = 80,000 psi.
Design of secondary prestressed beams floor(2).

Span = 48'
Assume width = 12''
Assume depth = \( \frac{\text{span}}{20} = 2.4' \approx 30'' \)
Weight of beam = \((2.5 \times 1 \times 48)\) I50

Weight of slab = \((4.5 \times 48 \times 4/12)\) I50

Weight of beam + slab = \((120 + 72)\) I50 = 28800 lb

Wt. per ft. of length = \( \frac{28800}{48} \) = 600 lb/ft'

Wt. of cover = \( 8 \times 2/12 \times 48 \times I50 \) = 9600 lb

Wt. per foot of length = \( \frac{9600}{48} \) = 200 lb/ft'

Wt. of machinery + LL = I50 lb/ft²

Wt. per ft. of length = I50 \times 8 = I200 lb/ft'

Total load per ft' = 600 + 200 + I200 = 2000 lb/ft'

Max. Moment = \( \frac{2000 + 48^2}{8} \) = 575000 lb/ft.

Reaction = \( 2000 \times 24 \) = 48000 lb.

M(dead) of beam = \( \frac{600 \times 48^2}{8} \) = 172000 lb-ft.

fbi = .6 \times 600

= 3600 \times I44 = 520000 lb/ft²
$$Z_b = \frac{M_{total} - M_d}{f_{bi} - f_b}$$

$$= \frac{575000 - 172500 \times 0.8}{0.8 \times 520000}$$

$$= \frac{435000}{415000} = 1.05 \; \text{ft.}$$

$$= 1.05 \times 12^2 = 1820 \; \text{in}^2 \quad \text{(Required section Mod.)}$$

Get $Z_b$ for assumed section.

(b) effective

$$= 6 \; \text{B}$$

$$= 0.6 \times 8 = 4.8' = 58''$$

To get $cg$ take moment area about top fiber

$$58 \times 4 \times 2 + 26 \times 12 \times 17 = (58 \times 4 + 26 \times 12) \; \text{ct}$$

$$ct = \frac{5764}{544} = 10.6''$$

$$cb = 19.4''$$

$$I_{cg} = A_1 y_1^2 + A_2 y_2^2 + A_3 y_3^2$$

$$= 19.4 \times 12 \times 9.7^2 = 21800$$

$$+ 6.6 \times 12 \times 33^2 = 860$$

$$+ 58 \times 4 \times 8.6^2 = 17200$$

$$= 39860$$

$$Z_b = \frac{I_{cg}}{cb} = \frac{39860}{19.4} = 2050 \; \text{inches}^3$$

Beam is safe.

$$A_s = \frac{M_t}{0.65 \times h \times f_s}$$

$$= \frac{575000}{0.65 \times 30 \times 80000} = 0.365 \; \text{inch}^2$$

Choose $s$ diam. $\frac{1}{4}$ = 0.398 $\text{inch}^2$
Design of Secondary Prestressed Beams in Roof:

Span = 48'
Assumed width = 8''
Assumed depth = 1/30 span ≈ 1.25' ≈ 16''
Weight of beam = (1.25 X 8/12 X 48) X 150
Weight of slab = (4.5 X 48 X 3/12) X 150
Wt. of beam+slab = (40 + 54) X 150 = 14000 lb
Wt. per ft. of length = \( \frac{14000}{48} \) = 292 lb/ft'
Weight of cover = 1/12 X 25 X 10 X 150
Wt. per ft. of length = 1/12 X 25/10 X 150 X 8 = 250 lb/ft'
Weight of L.L. = 15 lb/ft
Weight per ft. of length = 15 X 8 = 120 lb/ft'
Total load per ft.' = 292 + 120 + 250 = 662 lb/ft'
Maximum Moment = \( \frac{662 \times 48^2}{8} \) = 190000 lb/ft'
Reaction = 662 X 24 = 15900 lb
M. d of beam = \( \frac{292 \times 48^2}{8} \) = 83500 lb.ft.
fbi = .6 X 6000 X 144 = 520000 lb/ft'
\[ Z_b = \frac{M_{\text{total}} - M_d}{f_{\text{bi}} - f_{\text{b}}} \]
\[ = \frac{190000 - .8 \times 83500}{.8 \times 520000} \]
\[ = \frac{123500}{415000} = .298 \text{ ft}^3 \times 12^3 = 500''^3 \]

Get \( Z_b \) for assumed section:

\( b_{\text{effective}} = .6B = .6 \times 8 = 4.8 ~ 53'' \)

To get \( c_g \), take moment area about bottom fiber

\[ 58 \times 2 \times 15 + 14 \times 8 \times 7 = (58 \times 2 + 14 \times 8) \text{ ct} = \]
\[ \text{ct} = \frac{2524}{228} = \text{II.I} \]

\[ I_{cg} = A_1 Y_1^2 + A_2 Y_2^2 + A_3 Y_3^2 \]
\[ = \text{II.I} \times 8 \times 5.55^2 = 2740 \]
\[ + 2.9 \times 8 \times 1.85^2 = 79 \]
\[ + 2 \times 58 \times 3.9^2 = 1760 \]
\[ = \frac{5290}{5290} \]

\[ Z_b = \frac{5290}{\text{II.I}} = .476 \text{ inch}^3 \]

Beam is safe.

\[ A_s = \frac{M_t}{0.65 \times h \times f_s} = \frac{190000}{0.65 \times 16 \times 80000} = .229 \text{ inch}^2 \]

Choose 6 1/4" = .298
Design of main girder (roof)

Span = 48'
Assumed width = 12''
Assumed depth = 1/20 span = 30''

Weight of girder = \( \frac{12}{12} \times \frac{30}{12} \times 48 \times 150 \) = 18000 lb
Weight per ft. of length = 120 lb/ft'
Weight from secondary beam = 15900 X 6 = 95400 lb
Weight from beams per ft! = \( \frac{15900}{8} \) = 1990 lb/ft'

Total weight per ft.' = 1990 + 120 = 2110 lb/ft'

Maximum moment = \( \frac{2110 \times 48^2}{8} \) = 600000 lb/ft'
Reaction = 2110 X 24 = 50600 lb/ft'
Md of girder = \( \frac{120 \times 48^2}{8} \) = 54500 lb/ft

\( fbi \)
\( Zb \) = \( \frac{Mt - Md}{fbi - fb} \)
\( = 600000 - .8 \times 34500 \)
\( = \frac{572400}{415000} \times 1375 \) ft\(^3\) X 12\(^3\) = 2380 inch\(^3\)

\( Zb \) actual = \( \frac{bh^3}{12} \times \frac{I}{15} = \frac{12 \times 30^3}{12 \times 15} \) = 1800 inch\(^3\)
Increase depth = 33"

\[ Z_b = \frac{12 \times 33^3}{12 \times 15} \quad \text{= 2380 inch}^3 \]

Beam is safe

\[ A_s = \frac{M_t}{0.65 \times h \times f_s} \]

\[ = \frac{600000}{0.65 \times 33 \times 80000} \quad \text{= .385 inch}^2 \]

Choose 8 \( \frac{3}{4} \) 3 97 inch²

Design of columns (1) section A-A

\[ P = \text{Reaction on girder} + \text{own weight} + \text{weight of lateral girder} \]

Reaction = \[ = 50600 \text{ lb} \]

Own weight = \[ 15/12 \times 15/12 \times 22 \times 150 \quad = 5150 \text{ lb} \]

Wt. of lateral girder = \[ 12/12 \times 60/12 \times 48 \times 150 \quad = 3750 \text{ lb} \]

Total weight on columns = \[ 50600 + 5150 + 3750 \quad = 59500 \text{ lb} \]

\[ P = F_s \cdot A_c \left( I + n \cdot u \right) \]

\[ 59500 = 2000 \cdot A_c \left( \frac{I + 15 \times I}{100} \right) \]

\[ 59500 = 2000 \cdot A_c \left( \frac{112}{100} \right) \quad = \]

\[ A_c = \frac{59500 \times 10}{2000 \times 112} \quad = 262 \text{ inch}^2 \]

\[ 1/b = \frac{22 \times 12}{16} \quad = 16.5 \]
Factor \( = \frac{1}{8} \)

\[ \text{Ac} = \frac{22.7}{8} = 27.5 \text{ inch}^2 \]

Choose 4 \( \frac{3}{8}'' \) & stirrups \( \frac{3}{8}'' @ 10'' \)

Design of columns (2) section (A-A)

\( P = 100000 \text{ lb} = 100 \text{ Kps} \)

\[ \text{Ac} = \frac{100000}{2240} = 44.6 \text{ inch}^2 \]

Let columns = 16 X 16" & stirrups \( \frac{3}{8}'' @ 10'' \)

Design of columns (I) section (B-B)

Reaction on girder = \( = 295680 \text{ lb} \)

Own weight \( = \frac{16}{12} \times \frac{22}{12} \times 22 \times 150 = 8000 \text{ lb} \)

Weight of lateral girder \( = 3750 \text{ lb} \)

Weight from upper floor \( = \frac{59500 \text{ lb}}{366930 \text{ lb}} \)

\( P = 366930 \text{ Kps} \)

\( P = \text{fc. Ac. (I + n u)} \)

\[ 366930 = 2000 \text{ Ac } \left( \frac{112}{100} \right) \]

\[ \text{Ac} = \frac{366930 \times 100}{2000 \times 112} \times \frac{1}{0.8} = 204 \text{ inch}^2 \]

\( = 16 \times 13 = 208 \text{ inch}^2 \) Let columns 16 X 20

\[ \text{As} = \frac{1}{100} \times 204 = 2.04 \text{ inch}^2 \]

Choose 8 \( 5/8'' = 2.14 \text{ inch}^2 \) & stirrups \( \frac{3}{8}'' @ 10'' \)
Design of columns (2) section (B-B)

\[ P = 360 \text{ Kps} \times 2 \Rightarrow 720 \text{ Kps} \]

\[ Ac = \frac{720000}{2240} = 322" \]

\[ = 16 \times 24 \]

\[ As = 322 \times \frac{1}{100} = 3.22" \]

Choose 8 3/4" & stirrups ¼" @ 10".
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