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Prestressed Steel Structure for Large Span Industrial Buildings

Structures métalliques précontraintes dans les ouvrages industriels

Vorgespannte Stahlkonstruktionen im Industriebau

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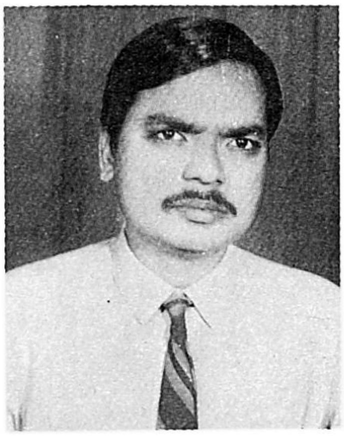

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SUMMARY
In large span industrial buildings the load bearing capacity of a member mainly depends upon its selt weight, which involves a large quantity of steel required for construction. Nowadays structural steel is one of the costliest items. Thus maximum economy in use of steel is a must. Prestressing steel structures enhances the efficiency of the structure before the structure is put to its actual use. A saving of 37% in cost is obtained by using a prestressed steel structure over a conventional structure.

RÉSUMÉ
Dans les constructions industrielles de grande portée, la surcharge des éléments porteurs dépend largement de leur poids propre, d'où l'obligation de prévoir un gros tonnage d'acier dans l'ouvrage à réaliser. Etant donné que, de nos jours, l'acier représente le facteur essentiel influant sur les coûts, l'économie en poids de ce matériau est de rigueur. La précontrainte des structures porteuses en acier permet d'augmenter le degré d'utilisation des constructions et, de la sorte, de réaliser un gain de 37% des coûts par rapport aux constructions métalliques traditionnelles.

ZUSAMMENFASSUNG
Bei grossen Spannweiten im Industriebau hängt die Nutzlast der Tragkonstruktion stark von deren Eigengewicht ab. Da Baustahl heutzutage einen Hauptkostenfaktor darstellt, ist äusserste Sparsamkeit unabdingbar. Die Vorspannung von Stahlkonstruktionen erhöht den Ausnutzungsgrad und spart etwa 37% Kosten gegenüber dem konventionellen Stahlbau.

1. INTRODUCTION

1.0.1 Design example presented here is of a frame of large span industrial building (as shown in Fig. No.1). Building having a span of 39.0 m and height of 29.155 m and length 200 meters. Roof consists of precast R.C.C. slab with screed concrete and .7 layers of tarfelt. The sides are covered with siporex slabs. Brackets at 22.207 m Support gantry girder the capacity of crane is 1000/200 KN. Present frame of industrial building is made up of welded plate girder. It is compared with open web section/hollow section of mild steel and high tensile steel without and with prestressing. It is seen that considerable saving is obtained by using open web section/hollow section of HT steel with prestressing.

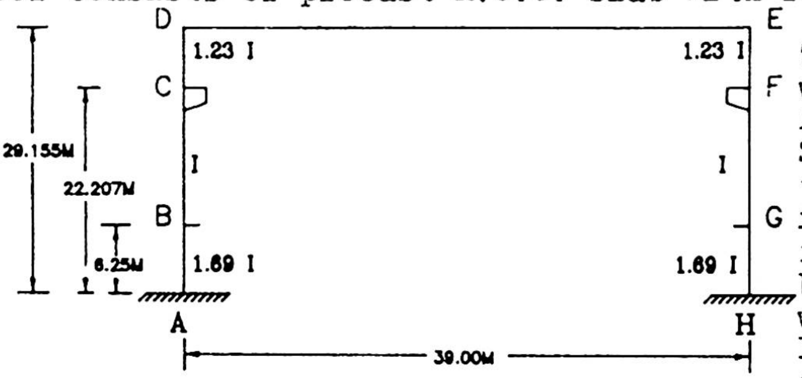


FIG. No 1.

2.0 ANALYSIS

2.0.1 Frame was analysed in detail with the help of column anology and moment distribution method for all types of loads to which it will be subjected i) Deadload ii) Liveload iii) Crane load iv) Wind load v) Earthquake vi) Blast load. After calculating the joint moment various load combinations were adopted and it was found that maximum moment is developed in frame is as follows.

(a) Beam - Deadload + Liveload + Crane to the right

(b) Column - Deadload + Liveload + Crane to the right + Windload (R to L)

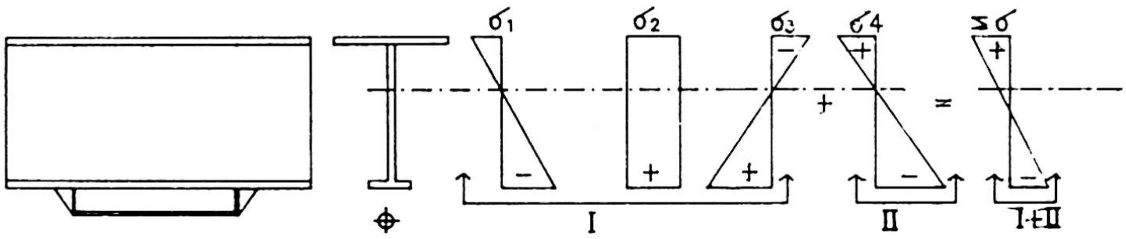
3.0 DEVELOPMENT OF THEORY

3.1 Prestressing in Steel Structure

3.1.1 Principal concept of prestressing is to provide stress of opposite sign to that from the design load in the structure. This is achieved by the initial application of calculated external force whose magnitude and direction are worked out. Considering beam as shown in Fig. No.2. Tendon is placed externally below the beam cross section on tension side. Behaviour of beam at the cross section of maximum bending moment may understood by considering two stages as indicated vide Fig. No. 2.

Maximum prestressing force can be calculated as $P = \frac{R\,A\,\phi\,Z}{Z + eA}$

Self stressing force $$P = \frac{\dfrac{M_1}{I_{xx}}\,w}{\left[\dfrac{M_1^2}{I_{xx}} + \dfrac{1}{mA_{td}} + \dfrac{1}{A}\right] l_{td}}$$



STAGE - I - FROM DEAD LOAD + PRESTRESSING
STAGE- II - FROM LIVE LOAD INCLUDING IMPACT

FIG No.2

Deflection due to prestressing is calculated from the formula

$$\delta_p = \frac{peA^2}{8EL}\left[1 - 4(a/L)^2\right]$$

where;

a = Distance between bearing to tendon;
A = Area of c/s of beam
A_{td} = Area of tendon;
e = Distance between centre of tendon to centre of beam c/s
L = Length of beam;
m = Modular ratio;
M_1 = 1 x e
P = Prestressing force;
w = Area of diagram of bending moment due to all loads on the tendon length ;
Z = Section modulus of beam fibres in compression;
δ_p = Deflection due to prestressing
ψ = Coefficient of buckling.

4. DESIGN

Frame is designed by using different type of section/materials such as

1. Using Solid web section of M.S.
2. Using Open web section/hollow section of M.S.
3. Using open web section/hollow section of H.T. steel
4. Using Open web section/hollow section of M.S. with prestressing
5. Using Open web section/hollow section of H.T. steel with prestressing

4.0.1 Present frame which has been provided are not utilised to their capacity. So an attempt was made to reduce the section. A design was also carried out by using open web section for beam and hollow section for column of mild steel as well as high tensile steel without and with prestressing. It is observed that considerable reduction in cost is obtained by using open web section/hollow section of H.T. steel with prestressing. The typical section adopted is as shown in Fig. No. 3.

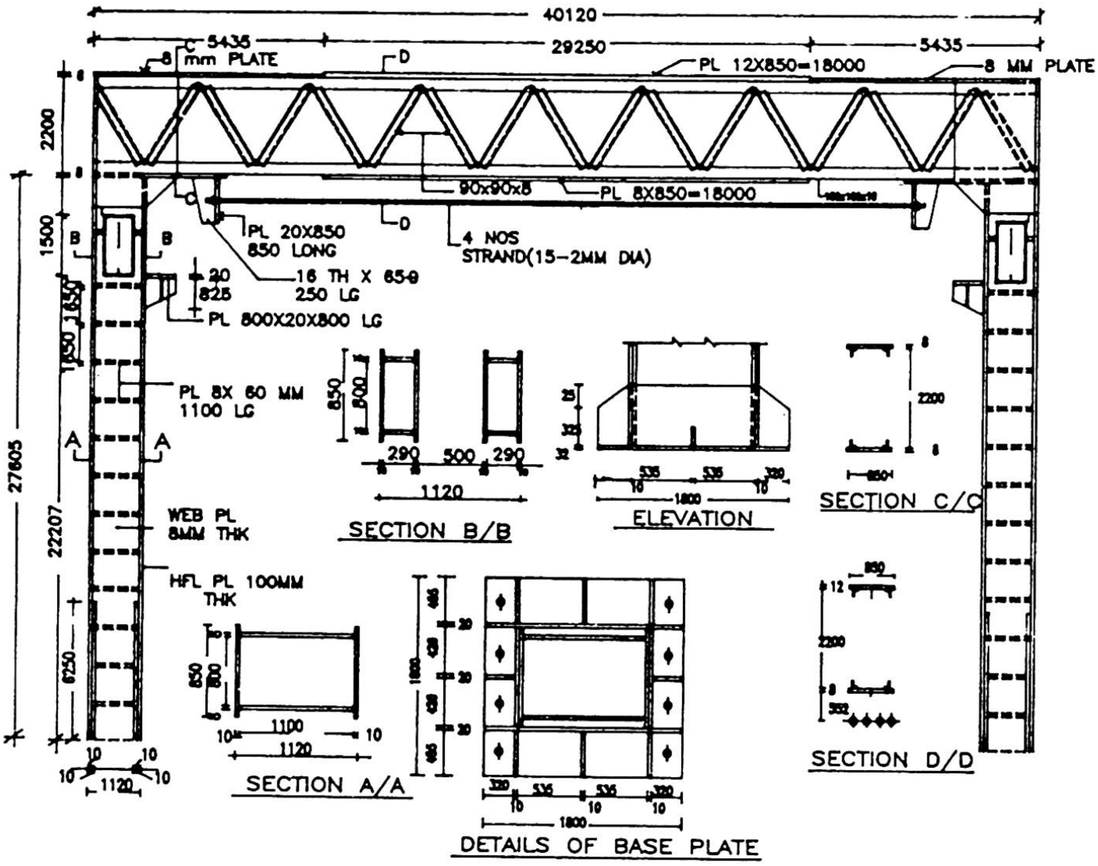


FIG. NO. 3

5. COST CALCULATION AND COMPARISON

5.0.1 Based on design prepared for frame, Estimate of quantity and cost of construction is calculated and compared (as shown in table No. 1). It is seen that a saving of 37.2 % in cost has been obtained by using open web section/hollow section of H.T. steel with prestressing as compared to conventional type of structure.

Sr. No.	Particulars	Total Cost (In Rs.)	Saving in Rs.	% Saving
1.	Structure provided at site	822952.19	-	
2.	Using solid web section	696254.48	126697.71	15.39
3.	Open web section/ Hollow section of M.S.	595037.44	227914.75	27.69
4.	Open web section/ Hollow section of H.T.	533079.59	289872.60	35.22
5.	Open web section/Hollow section of M.S. with prestressing.	557040.98	265911.21	32.23
6.	Open web section/Hollow section of HT with prestressing.	516803.55	306148.64	37.20

Table - 1

6. EXPERIMENTAL WORK - MODEL STUDIES

6.0.1 To verify the theory developed and computational result obtained, a structural model of smaller dimension was fabricated to test credibility and feasibility of this kind of study. After study it was possible to find out problem with model and resolve them to obtain finally comparable results with the prototype.

Details of model are as follows :-

1. Scale ratio = $\frac{1}{10}$; 2. Stiffness of ratio of model member = Stiffness ratio of prototype
3. Size of beam - 200x100 mm, column - 170x100 mm
4. Open web sections made up of angle and bar were used for beam and column
5. Prestressing wire - 4 mm

Complete view of model is as shown in photograph No. 1.

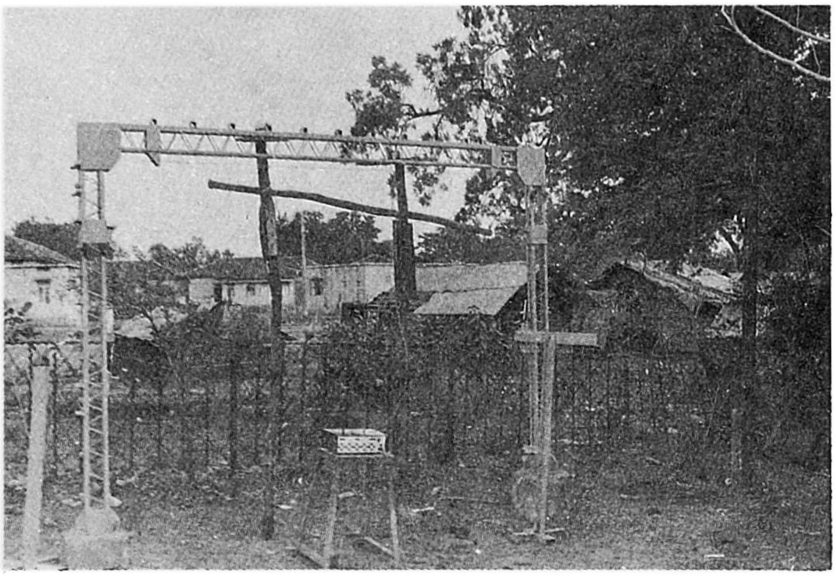


PHOTO - 1.

For obtaining comparable results, model was tested for same load condition as in prototype

a) Under No load condition:- Beam was prestressed for 800, 1050, 1400 kg force. Deflection under various locations was measured.

b) Under load condition :- Model was loaded fully by hanging weights, applying load by screw jack at different places as shown in photograph No.2. Experimental results obtained were verified for symmetry and reciprocity. They are found to be comparable with conventional results.

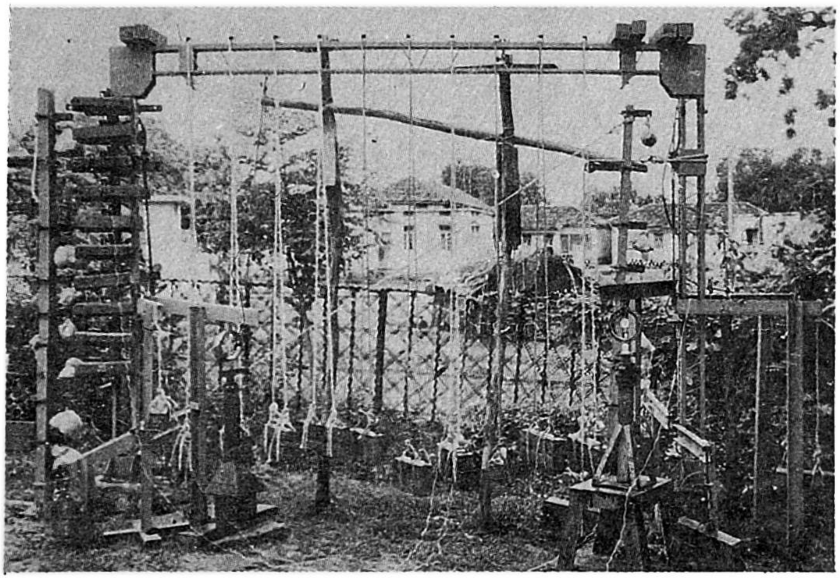


PHOTO - 2.

7. DISCUSSION AND CONCLUSION

7.0.1 Experimental verification gives the reliability of using prestressed steel structure. Theory developed can be effectively used for studying the behaviour of prestressed steel structure. This structure will definitely reduce the overall cost of project. Following are optimum parameters were decided for design of a prestressed steel structure.

1. Eccentricity $- \frac{e_y}{r_x^2} > 1$;
2. Length/depth ratio ≤ 20
3. Unsymmetrical parameter ; $\frac{y_1}{y_2} = 1.7$ to 2.0.
4. Optimum length of tendon = (0.7 to .75)L
5. Elevation of tendon t = 1.05 to 1.20.

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