International Journal of Scientific & Engineering Research, Volume 8, Issue 3, March-2017
ISSN 2229-5518

Study of Pratt Truss bridge with post-tension members of different layouts for strengthening

Yogish C.B.*, Devaraj V**
*(Research student, Assistant Executive Engineer KRIDL, Bangalore, India
Email: yogishcbasava@gmail.com)
** (Professor in civil department, UVCE, Bangalore, India
Email: professor.devaraj@gmail.com)

ABSTRACT -- Majority of steel bridges in India and abroad are structurally deficient and functionally obsolete. The total no of bridges in India is 127154, out of which 56169 or more bridges are more than 80 years old. Thus 44.0 percent of bridges that we commute have outlived their life. These bridges are strengthened by post tensioned tendon layouts to meet the current and future loading and traffic requirements. The stiffness method of analysis is suggested. The layouts are straight, one-drape, and two drape tendon layouts are proposed and the tendons do not coincide with the truss members. However the tendon layout can be internal or external. Applications of these methods are rare in steel structures, but high-strength steel cables can be used effectively to increase the working capacity of steel structure.

Post tensioning truss bridges is a means of creating redundancy i.e., alternate load paths, in the structural system and strengthening it. Present study demonstrates the potential of strength, and serviceability. In this paper a study on post-tensioning in elastic range and the effect of member forces, deflection, resistance to repetitive loads and increase in life of the structure at a relatively low cost. This paper is an attempt made to compare the forces in members and displacements in joints of a pratt truss without and with post tensioning member of different layouts i.e. straight, one drape and two drape. The study results (1) Considerable variation in member forces. (2) Change in nature of member from compression to tension and vice-versa. (3) Decrease in joint displacement (both horizontal and vertical) depending on the profile and position of the post tensioning members.

Index Terms - Layout, one drape, post tensioning, Pratt truss, strengthening, two drape, strengthening,

1. Introduction

Over the last few decades, there has been a rapid increase in the volume and weight of heavy vehicles using national road networks. At the same time, more than sixty to seventy percent of bridge structures are over 50 years old all around the world.

Majority of the steel bridges in India and abroad are functionally obsolete due to structural deficiency, because of increase in traffic and traffic loads, environmental effects, ageing of structure and modification in standards to meet the present requirements. Hence there is a need for appropriate technique to enhance the performance of these existing bridges in consideration of economy and minimum disturbance to traffic as a method of strengthening and rehabilitation of bridges against imposing restrictions over functioning, replacement of deficient components. It is better to retain the structure because of historical and socio-political importance as heritage structure, instead of complete replacement of structure or dismantling with proposal for new bridge.

The deterioration of the existing bridges due to increased traffic, traffic loads, constant and continuous exposure to environmental conditions and structural ageing is a major problem and those bridges are not able to cope up with current traffic requirements and forced to impose restrictions over weight, traffic and number of vehicle or strengthening of deficit structural components or total replacement of the structure. Several methods developed to strengthen such deficit bridges to improve the performance, due to economic constraints, historical importance and socio-political reasons. Engineers looking for cost effective strengthening methods of bridges, of which post-tensioning is one of the popular and widely used strengthening technique has many advantages.

It is popular method of strengthening of bridges because of the (1) speed of construction, (2) minimum disruption to traffic flow, (3) easy monitoring and maintenance, (4) can be used in wide range of bridges, (5) low cost (6) future re-stressing operation could be carried out conveniently (if required). The post tensioning of bridges has been in use since 1950's and

International Journal of Scientific & Engineering Research, Volume 8, Issue 3, March-2017
ISSN 2229-5518

there are many examples throughout the world, in recent days, even the post tensioning is used in many countries for the construction of new bridges and widely used in RCC bridges. For steel bridges, literature available are very few and the techniques have no definite process and procedure.

2. Objective of present study

To analyze the Pratt truss without and with post tensioned member by three different profiles, of straight, one drape and two drape, to compute and compare the forces in members and the displacement of the joints of the pratt truss and efficiency of post tensioning with different layouts are studied.

3. Analysis of pratt truss.

In the present study, a pratt truss bridge of 64 m long, connected by 13 m wide deck slab with two lane carriage way of 6.80 m having foot path of 1.50 m wide on either side with hand railing. The Pratt truss has 16 panels of 4m each with an height of 8 m and it consists of top chord members, bottom chord members, vertical and diagonal members. RCC deck slab has to carry two lane standard IRC class A wheeled vehicular loading. The geometrical and material details are presented in Table 1.

Table 1. Geometrical and material details

Members		Length m	Area m2	E..kN/m2
Top Chord	32 to 45	4.0000	0.0458709	2.00E+08
Bottom Chord	46 to 61	4.0000	0.0534838	2.00E+08
Diagonal Member	1,3,..to 31	8.9440	0.0441935	2.00E+08
Vertical Member	2, 4 ..to 30	8.0000	0.0275483	2.00E+08
PT Member (Straight)	62	64.0000	0.0101616	1.60E+08
PT Member (One drape)	62	58.2404	0.0101616	1.60E+08
PT Member (Two drape	62	59.7771	0.0101616	1.60E+08

The Pratt truss without post tensioning member is a perfect and determinate truss with 32 joints and 61 members satisfying: m = (2 j - 3) condition with the introduction of post tension member of different tendon layouts and proposed as a technique of strengthening, which creates redundancy in the truss and the determinate truss become indeterminate. The pratt truss without and with post-tensioned members of different layouts are shown in fig.1.

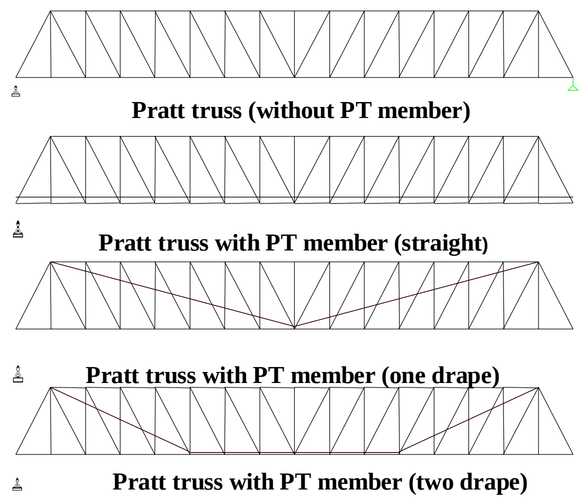

Fig.1 Pratt truss without and with PT members (Straight, One drape and Two drape)

The dead load consists of weight of 250mm thick RCC deck slab, weight of foot path on either side of carriage way, weight of hand railing on either side, self-weight of cross girder and pratt truss. The live load is considered as per IRC class A loading. Details of loading are shown in Fig. 2.

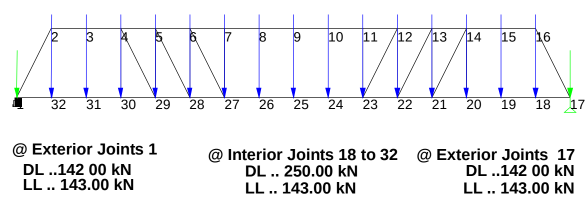

Fig. 2: Pratt truss Details of Loading at Joints

The pratt truss without and with post tensioning member is analyzed with the following assumptions (1) Material is linearly elastic. (2) post tensioning member are continuous and frictionless. (3) Load are acting at joints of the truss (4) The axial force in post tension member is constant over its length. (5) The continuity of post tensioning member is achieved through running the cable over smooth friction less pulley. The nomenclature of four configurations of Pratt truss are, without post tension members as (1+0), with straight profile as (1+1), with one drape profile as (1+2) and with two drape profile as (1+3). The analysis is performed by direct stiffness method. MATLAB program were developed for structural analysis and further Staad-Pro V8i is used to validate the results.

4. Results and discussion

The four different configuration of Pratt truss without PT cable (1+0), with post tension member of different layout, straight (1+1), one drape (1+2) and two drapes (1+3) were analyzed and forces in members are computed due to dead loads and live loads for the pratt truss.

The post tensioning force is computed by iteration based on the following constraints:

1. To achieve minimum joint displacement at joints due to dead load only.
2. No reversal of displacement in vertical direction due to dead load and live load combination.
3. No failure of members due to introduction of post tensioned members due to dead load and live load combination.

The forces in members of truss and the displacements at joints before and after post tensioning are presented in Table 2, for top chord members, Table 3 for bottom chord members, Table 4 for vertical members and Table 5 for diagonal members. The results were compared as a ratio of magnitude of forces in members of pratt truss with post tensioning of different layouts with respect to forces in members of pratt truss without post tension members.

Table 2: Force in Top chord members

Member	Length .. m	Forces (1+0)	Forces (1+1)	Ratio (1+1) / (1+0)	Forces (1+2)	Ratio (1+2) / (1+0)	Forces (1+3)	Ratio (1+3) / (1+0)
TOP CHORD MEMBERS Compression (+) and Tension (-) Forces .. KN								
32	4.0000	2751.00	2751.00	1.00	6398.26	2.33	7262.97	2.64
33	4.0000	3831.75	3831.75	1.00	6879.84	1.80	6854.84	1.79
34	4.0000	4716.00	4716.00	1.00	7164.93	1.52	6250.21	1.33
35	4.0000	5403.75	5403.75	1.00	7253.51	1.34	5449.09	1.01
36	4.0000	5895.00	5895.00	1.00	7145.60	1.21	5940.34	1.01
37	4.0000	6189.75	6189.75	1.00	6841.18	1.11	6235.09	1.01
38	4.0000	6288.00	6288.00	1.00	6340.27	1.01	6333.34	1.01
39	4.0000	6288.00	6288.00	1.00	6340.27	1.01	6333.34	1.01
40	4.0000	6189.75	6189.75	1.00	6841.18	1.11	6235.09	1.01
41	4.0000	5895.00	5895.00	1.00	7145.60	1.21	5940.34	1.01
42	4.0000	5403.75	5403.75	1.00	7253.51	1.34	5449.09	1.01
43	4.0000	4716.00	4716.00	1.00	7164.93	1.52	6250.21	1.33
44	4.0000	3831.75	3831.75	1.00	6879.84	1.80	6854.84	1.79

Table 3: Force in Bottom chord members

Member	Length .. m	Forces (1+0)	Forces (1+1)	Ratio (1+1)/ (1+0)	Forces (1+2)	Ratio (1+2)/ (1+0)	Forces (1+3)	Ratio (1+3)/ (1+0)
BOTTOM CHORD MEMBERS (Compression (+) and Tension (-) Forces .. KN								
46	4.0000	-1473.75	2487.24	**-1.69**	-1485.36	1.01	-1485.67	1.01
47	4.0000	-1473.75	2487.24	**-1.69**	-1485.36	1.01	-1485.67	1.01
48	4.0000	-2751.00	1209.99	**-0.44**	-2163.45	0.79	-1274.04	0.46
49	4.0000	-3831.75	129.24	**-0.03**	-2645.03	0.69	-865.92	0.23
50	4.0000	-4716.00	-755.01	0.16	-2930.12	0.62	-261.29	0.06
51	4.0000	-5403.75	-1442.76	0.27	-3018.70	0.56	1722.86	**-0.32**
52	4.0000	-5895.00	-1934.01	0.33	-2910.79	0.49	1231.61	**-0.21**
53	4.0000	-6189.75	-2228.76	0.36	-2606.37	0.42	936.86	**-0.15**
54	4.0000	-6189.75	-2228.76	0.36	-2606.37	0.42	936.86	**-0.15**
55	4.0000	-5895.00	-1934.01	0.33	-2910.79	0.49	1231.61	**-0.21**
56	4.0000	-5403.75	-1442.76	0.27	-3018.70	0.56	1722.86	**-0.32**
57	4.0000	-4716.00	-755.01	0.16	-2930.12	0.62	-261.29	0.06
58	4.0000	-3831.75	129.24	**-0.03**	-2645.03	0.69	-865.92	0.23
59	4.0000	-2751.00	1209.99	**-0.44**	-2163.45	0.79	-1274.05	0.46
60	4.0000	-1473.75	2487.24	**-1.69**	-1485.37	1.01	-1485.67	1.01
61	4.0000	-1473.75	2487.24	**-1.69**	-1485.37	1.01	-1485.67	1.01

Table 4: Force in Vertical members

Members	Length m	Forces (1+0)	Forces (1+1)	Ratio (1+1) / (1+0)	Forces (1+2)	Ratio (1+2) / (1+0)	Forces (1+3)	Ratio (1+3) / (1+0)
VERTICAL MEMBERS (Compression (+) and Tension (-) Forces .. KN								
2	8.0000	-393.00	-393.00	1.00	-393.00	1.00	-393.00	1.00
4	8.0000	2161.50	2161.50	1.00	963.17	0.45	-816.25	**-0.38**
6	8.0000	1768.50	1768.50	1.00	570.17	0.32	-1209.25	**-0.68**
8	8.0000	1375.50	1375.50	1.00	177.17	0.13	-1602.25	**-1.16**
10	8.0000	982.50	982.50	1.00	-215.83	**-0.22**	982.50	1.00
12	8.0000	589.50	589.50	1.00	-608.83	**-1.03**	589.50	1.00
14	8.0000	196.50	196.50	1.00	-1001.83	**-5.10**	196.50	1.00
16	8.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	8.0000	196.50	196.50	1.00	-1001.83	**-5.10**	196.50	1.00
20	8.0000	589.50	589.50	1.00	-608.83	**-1.03**	589.50	1.00
22	8.0000	982.50	982.50	1.00	-215.83	**-0.22**	982.50	1.00
24	8.0000	1375.50	1375.50	1.00	177.17	0.13	-1602.25	**-1.16**
26	8.0000	1768.50	1768.50	1.00	570.17	0.32	-1209.25	**-0.68**
28	8.0000	2161.50	2161.50	1.00	963.17	0.45	-816.25	**-0.38**
30	8.0000	-393.00	-393.00	1.00	-393.00	1.00	-393.00	1.00

Table 5: Force in Daigonal members

Members	Length m	Forces (1+0)	Forces (1+1)	Ratio (1+1) / (1+0)	Forces (1+2)	Ratio (1+2) / (1+0)	Forces (1+3)	Ratio (1+3) / (1+0)
DIAGONAL MEMBERS (Compression (+) and Tension (-) Forces .. KN								
1	8.9440	3295.41	3295.41	1.00	3321.38	1.01	3322.06	1.01
3	8.9440	-2856.02	-2856.02	1.00	-1516.24	0.53	473.21	**-0.17**
5	8.9440	-2416.63	-2416.63	1.00	-1076.86	0.45	912.60	**-0.38**
7	8.9440	-1977.24	-1977.24	1.00	-637.47	0.32	1351.99	**-0.68**
9	8.9440	-1537.86	-1537.86	1.00	-198.08	0.13	1791.38	**-1.16**
11	8.9440	-1098.47	-1098.47	1.00	241.31	**-0.22**	-1098.47	1.00
13	8.9440	-659.08	-659.08	1.00	680.69	**-1.03**	-659.08	1.00
15	8.9440	-219.69	-219.69	1.00	1120.08	**-5.10**	-219.69	1.00
17	8.9440	-219.69	-219.69	1.00	1120.08	**-5.10**	-219.69	1.00
19	8.9440	-659.08	-659.08	1.00	680.69	**-1.03**	-659.08	1.00
21	8.9440	-1098.47	-1098.47	1.00	241.31	**-0.22**	-1098.47	1.00
23	8.9440	-1537.86	-1537.86	1.00	-198.08	0.13	1791.37	**-1.16**
25	8.9440	-1977.24	-1977.24	1.00	-637.47	0.32	1351.99	**-0.68**
27	8.9440	-2416.63	-2416.63	1.00	-1076.86	0.45	912.60	**-0.38**
29	8.9440	-2856.02	-2856.02	1.00	-1516.24	0.53	473.21	**-0.17**
31	8.9440	3295.41	3295.41	1.00	3321.38	1.01	3322.06	1.01

TABLE. 7 Joint Displacements at Roller Support and Mid span

Joints	1+0	1+1	Ratio	1+2	Ratio	1+3	Ratio
Horizontal direction							
17	27.673	18.132	0.655	16.782	0.606	1.292	0.047
25	13.837	9.066	0.655	8.391	0.606	0.646	0.047
Vertical direction							
25	-93.563	-84.917	0.908	-66.954	0.716	-35.878	0.383

Table 6: Joint displacements of pratt truss

Node	Resultant Displacemnts mm 1+0	Resultant Displacemnts mm 1+1	Ratio (%) (1+1) / (1+0)	Resultant Displacemnts mm 1+2	Ratio (%) (1+2) / (1+0)	Resultant Displacemnts mm 1+3	Ratio (%) (1+3) / (1+0)
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	31.98	16.69	52.20	31.32	97.95	21.20	66.31
3	44.69	27.17	60.78	40.43	90.47	23.60	52.79
4	58.78	38.53	65.56	50.26	85.50	25.16	42.81
5	71.54	48.79	68.21	58.52	81.81	25.06	35.04
6	81.92	57.22	69.85	64.40	78.61	27.25	33.27
7	89.36	63.42	70.97	67.55	75.60	31.72	35.50
8	93.55	67.14	71.77	67.89	72.58	34.58	36.96
9	94.58	68.52	72.45	67.48	71.34	35.88	37.94
10	92.85	67.14	72.31	67.31	72.49	34.49	37.14
11	87.90	63.42	72.14	66.32	75.44	31.53	35.87
12	79.56	57.22	71.92	62.39	78.41	26.92	33.84
13	68.01	48.79	71.73	55.49	81.58	24.60	36.17
14	53.52	38.52	71.97	45.71	85.40	24.58	45.92
15	36.45	27.15	74.48	33.35	91.51	22.82	62.62
16	17.22	16.66	96.74	19.45	112.94	20.17	117.12
17	**27.67**	**0.04**	**0.15**	**16.78**	**60.64**	**1.29**	**4.67**
18	32.35	10.93	33.77	23.80	73.58	12.96	40.05
19	42.46	21.30	50.15	34.81	81.97	19.80	46.62
20	56.76	34.56	60.90	46.96	82.74	23.91	42.13
21	69.91	46.06	65.88	56.80	81.24	25.49	36.47
22	80.73	55.43	68.66	63.85	79.09	24.78	30.69
23	88.65	62.42	70.41	67.97	76.68	30.41	34.31
24	93.33	66.82	71.60	69.15	74.09	34.16	36.60
25	**94.58**	**68.52**	**72.45**	**67.48**	**71.34**	**35.88**	**37.94**
26	92.53	66.82	72.22	68.87	74.44	34.18	36.94
27	86.99	62.42	71.75	67.38	77.45	30.45	35.01
28	78.08	55.43	71.00	62.87	80.52	24.87	31.85
29	65.97	46.06	69.82	55.30	83.83	25.57	38.77
30	50.92	34.56	67.87	44.71	87.79	23.98	47.09
31	33.29	21.29	63.95	31.20	93.71	19.84	59.59

In general from Table 2 to Table 5 results that, In pratt truss (1+0) without post tension member, , it was observed that:.

1. The top chord members (32 to 45) and vertical members (even numbers of 1 to 31) are of compressive in nature (+ sign).

2. The bottom chord members (46 to 61) and diagonal members (odd numbers of 2 to 30) are of tension in nature (- sign).

(3) with the introduction of post tension member of different layouts, there is change in nature and magnitude of forces in member of truss and also there is

reduction in magnitude of joint displacements of truss depending on the layout of post tension member.

The forces in the members and the joint displacements of pratt truss without and with post tension members are tabulated in Table 2 to Table 6, and results were compared with respect to Pratt truss without post tension members (1+0).

With the introduction of post tension members of different layouts, the inferences were drawn were follows:

1. There is reduction and increase in magnitude of forces in truss member.

2. There is change in nature forces in members from compression to tension and vice-versa.

3. There is reduction in joint displacements of truss.

4.1 Pratt truss with post tension member straight (1+1) layout :

It is observed that there is considerable reduction in forces in bottom chord members (48 to 59) and its force ratio varies from 0.03 to 1.69.

1. It is observed from Table 2, that there is increase in magnitude of forces, ratio which varies from 1.03 to 1.69 in bottom chord members 46, 47 and 61, 60, which are nearer to the joint where the post tensioning member are connected.

2. It is observed from Table 2, that there is reduction in magnitude of forces, ratio which varies from 0.16 to 0.36 in bottom chord members 46, 47 and 61, 60, which are away from the joint where the post tensioning member connected.

3. It is observed from Table 3, that there is an increase in magnitude of forces in members 46, 47 and 61, 60 and its in nature changes from tension to compression.

4. From Table 3 to Table 5, the magnitude and nature of forces in top chord, vertical and diagonal member remains same.

4.2 Pratt truss with post tension member one drape (1+2) layout:

By introducing one drape post tension member, it is observed that …

1. There is an increase in magnitude of forces in top chord member 32 and 35 (Table 1) with force ratio of 2.33 and vertical member 14 and 18 (Table 4) with force ratio of 5.10.

2. There is considerable reduction in magnitude of forces in members other than top chord and vertical members of the truss whose force ratio varies from 0.13 to 1.03.

3. In vertical and diagonal members, it is observed a considerable reduction in magnitude of member forces with force ratio 0.13 to 1.00 except in members14, 15, 17 and 18,however there is no change in nature of force.

4.3 Pratt truss with post tension member two drape (1+3) layout:

1. The magnitude and member forces near to the joint, where post tension member is connected to joint, there is increase in member forces and the force ratio varies from 1.01 to 2.64 and decrease in force is observed in other member away from those joints in top, bottom, vertical and diagonal members truss, force ratio varies from 0.17 to 0.68.

2. There is reversal or change in nature of force in top chord members (51 to 56) diagonal members and vertical member (3 to 8 and 23 to 29) which are located in and around the joint, where post tension member is connected.

4.4 Joint displacements in pratt truss:

The resultant values of joint displacements of pratt truss without (1+0) and with post tension members of different layouts (1+1), (1+2) and (1+3) are presented in Table (6) and it is observed that there is considerable percentage reduction in displacement magnitude.

The joint 17 at roller support and joint 25 at mid span of pratt truss are presented in Table 7.

1. It is observed that, there is reduction in horizontal displacement at joints 17 & 25 by 34.5%, and reduction in vertical displacement at joints 25 by 9.24% for pratt truss with straight tendon layout (1+1).

2. It is observed that, there is reduction in horizontal displacement at joints 17 & 25 by 39.35%, and reduction in vertical displacement at joints 25 by 28.44% for pratt truss with one drape tendon layout (1+2).

3. It is observed that, there is reduction in horizontal displacement at joints 17 & 25 by 95.33%, and reduction in vertical displacement at joints 25 by 61.65% for pratt truss with two drape tendon layout (1+3).

5. Conclusion …

From the above discussions the following conclusions are :

1. There is increase in force magnitude in members where the tendons are connected, however there is reduction in force magnitude in members away from the joint. Also there is reversal in the nature of forces.
2. There is higher reduction in joint displacements in pratt truss due to post tensioning .
3. Post tensioning strengthens the truss bridge and improves the performance in terms of serviceability.
4. Three different tendons layouts were studied and two drape tendon layout performed better.

6. REFERENCES:

[1] Aziznamini, Full scale testing of old steel truss bridge, Journal of Constructional Steel Research, 58, pp 843-858,2002.

[2] Bilal M. Ayyub and Haldar.A, Practical structural reliability techniques, Journal of Structural Engineering, ASCE, Vol. 110 No.8, pp 1707-1724,1984.

[3 V.Devaraj], P.M. Ravindra and Lakshmeesha Restoration and Rehabilitation of post- tensioned steel Bridges, Workshop on Retrofitting of Structures IIT Roorkee, Oct. 10-11, 2003.

[4] Ahmed Ibrahim, Bilal M. Ayyub and David Schelling, Post tensioned Trusses: Analysis and Design, Journal of Structural Engineering, ASCE, Vol 116, No.6, pp 1491-1506, 1990.

[5] K.B. Han and S.K. Park, Parametric study of Truss Bridges by the Post-Tensioning method, Canadian Journal of Civil Engineering, Vol. 32, No.2, pp 420-429, 2005.

[6] Kyoung-Bong Han & Sun Kyu park, Parametric study of truss bridges by the post-tensioning methods, Can. J. Civ. Engg, Vol.32, No2, pp 420-429, 2005.

[7] Akhrawat Ienwari and Pedro Albert, Design of pre-stressed tendons for Strengthening Steel Truss Bridges, Journal of Bridge Engineering, Vol.13, No 5, pp 449-456, 2008.

[8] A.F.Daly and W. Witarnawan, Strengthening of bridges using external post-tensioning, Paper presented at the 2nd Conference of Eastern Asia Society for Transportation Studies, Seoul, Korea, 29-3 1 October 1997.

[9] Ram Chandra. Design of Steel Structures, Vol II, Standard Book House, Delhi, 1991.

[10] James M.Gere, William Weaver.JR. Matrix analysis of Framed structures,CBS publishers 2004.

[11] H.J. Shah and S.B. Junnarkar . Mechanics of Structures, vol.II, Fifteenth Edition R.P. Patel, Rupalee Publications ,civil court Road, Anand, 1996.

[12] E. Belenya. Prestressed Load Bearing metal structures, MIR Publishers, Moscow, 1977.