Strengthing Steel Frames by Using Post Tensioned Cable

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Abstract: The aim of this paper is to determine the suitable technique for strengthening steel frames by using post tensioned cables. In this paper four techniques for post tensioning steel frame and a comparison between these techniques are achieved.The analysis and results are obtained by using ANSYS program. In The first technique the cables are post tensioned in the positive moment region. In the second technique the cables are post tensioned in the positive and the negative moment region. In the third is to the cables are post tensioned between the columns the last technique is to attached inclined post tensioned cables between the column and pass through a roller fixed in the rafters.
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Introduction

Post tensioning is one of the most effective techniques for strengthening an existing structure or a newly designed one to overcome the increase in service load without replacement of parts of the structure, many researches deal with this solution.

In 1985 **Dunker *et al.*** [1] presented a research strengthening of existing single-span steel-rafter and concrete deck bridges, in the same year **Dunker *et al.*** [2]. Designed a manual for strengthening single-span composite bridges by post-tensioning. **Klaiber *et al.***[3] worked on, strengthening of an existing continuous-span, steel-rafter, concrete deck bridge by post-tensioning, in 1990. **Ayyub *et al.*** [4] presented a paper on pre-stressing a composite girder subjected to a positive moment in 1990. **Ayyub *et al.*** presented in 1992 two papers one was on Experimental study for pre-stressed composite girder subjected to negative moment [5], the other was the analytical study for the last research [6].In 1993 **Klaiber *et al.*.** presented a research in *Strengthening of an existing continuous-span,steel-stringer,concrete-deckbridge*[7]. **Phares *et al.***[9]. presented a research strengthening of steel girder bridges using FRP in August 2003. In May 2003 Nazir, [10] presented a research on pre-stressed arch steel bridge.

The objective of this paper is to recognize the suitable technique in strengthening steel frames by using post tensioned cable and calculating the maximum load capacities for each techniques and comparing them.

The paper is divided into two sections. The first section: describes the types, loads of the used frame and it's dimensions., The second section: describes the techniques of post tensioning for the frame. Four techniques have been used to find the best one to obtain the maximum load capacities. Finally the conclusions are obtained.

The Model Used for the Main Frame.

The trusses dimensions are indicated in figure (1), the truss height is 38ft (1158.24cm); each panel length is 27ft (822.96cm). The Analysis is carried out for simple warren truss bridge under the effect of Dead load and Live load + impact. The summation of these loads is 300kips (133.5ton) as indicated in figure (6-1). In all the models the post tension force is 206kips (91.67ton).

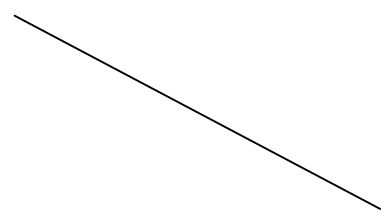

Fig.1, main frame layout

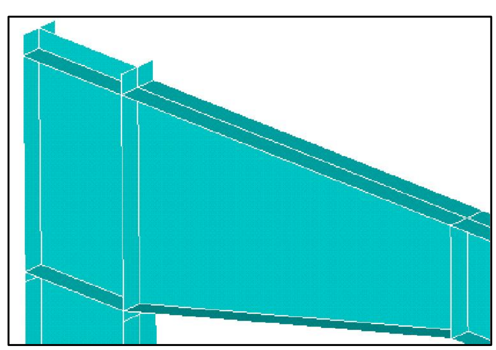

Fig.2, corner connection and the used stiffener and hunch

Model of Frame after post tensioning

Four techniques are used for post tensioning steel frame.

1st. technique: In this technique the cables are used in the positive moment region of the rafter. Two post tensioned cables are used between the two inflection point of the frame's rafter. The cables are attached to a bracket 120mm below the rafter flange; the length of the bracket is 500mm. Two stiffeners are used at the ends of the brackets. The thickness of the bracket and the stiffeners are 40mm.Shell element63 [8] is used to model the frame's flanges and webs of the columns and the rafter and also to model the stiffeners and the bracket. A meshing with aspect ratio equal to 1 is used. This size of meshing is used after various variable sizes of meshes which have been tried. And it was found that the used mesh size gives reasonable results. Cables of 20mm diameter are used. beam element 4 [8] is used to model the cables where it carries only axial load. In the cable's meshing the cables were divided into various numbers of divisions which gives nearly the same results the division used is 2 which represent the minimum number of Division.

For all models the connection between the cable and the plate is achieved by connecting 6 links scattered from the cable end nodes to 6 nodes on the plate as defined in the fig (4b), the connecting nodes to the plates are chosen as six after many trial have been done by using various number of links from one link to 8links, it was found that more than four links gives suitable stress distribution on the plate of the bracket in this paper six links have been used. So the diameter of distributed links is equal to the nut diameter of connecting the cables with the plate of the bracket.

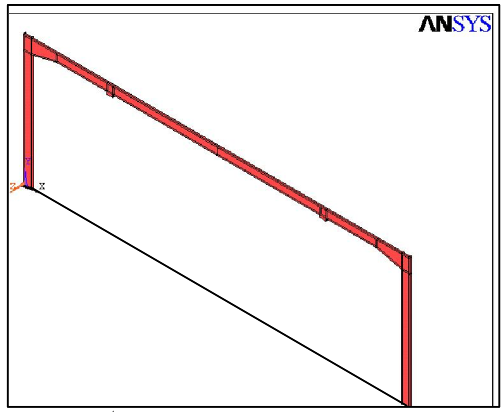

Fig.3, 1st technique layout

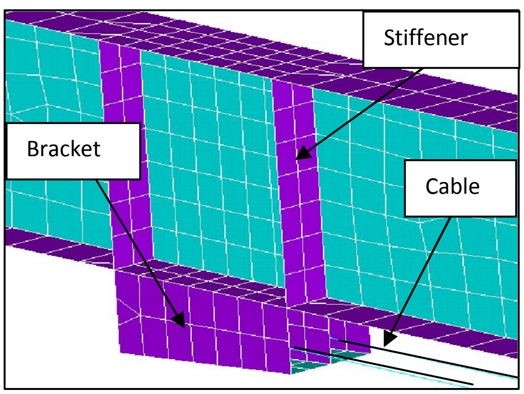

Fig.4a, connection of the cable with bracket

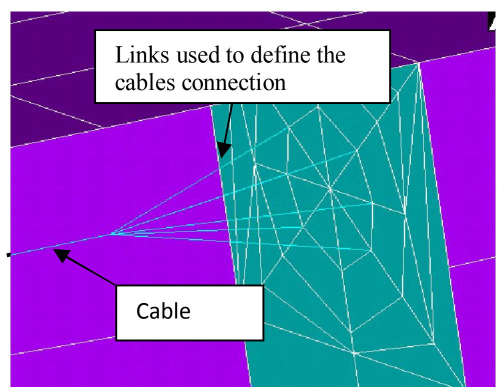

Fig.4b, connection of the cable with bracket

2nd technique: In this technique cables are used in the positive moment region and the negative moment region of the rafter. Two post tensioned cables are used in the positive moment region for the rafter. The cables, the length of the bracket and the stiffeners are the same as in technique1. Two post tensioned cables are used in the negative moment region for the rafter. The cable are attached from one side to the internal column flange and to the stiffeners of the bracket which has been used in the positive moment region from the other side.The cables are attached 40mm below the upper rafter flange. The cables length is 6ms.

The used element meshing is used as the first technique

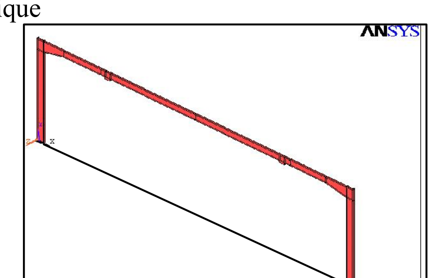

Fig.5, 2nd technique layout

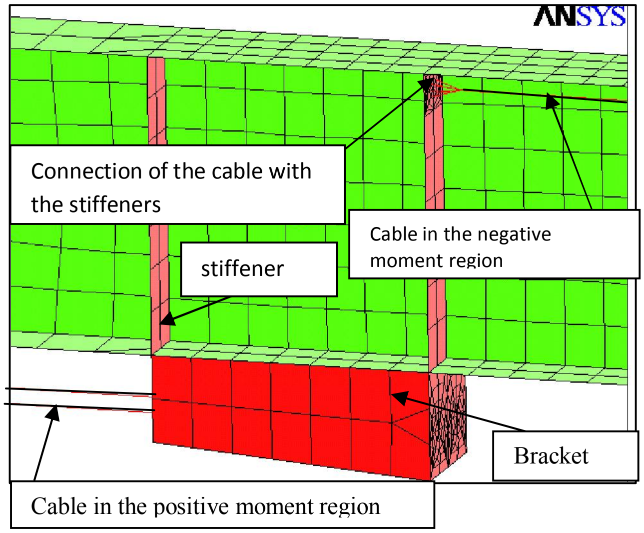

Fig.6, cable connection with bracket and stiffener

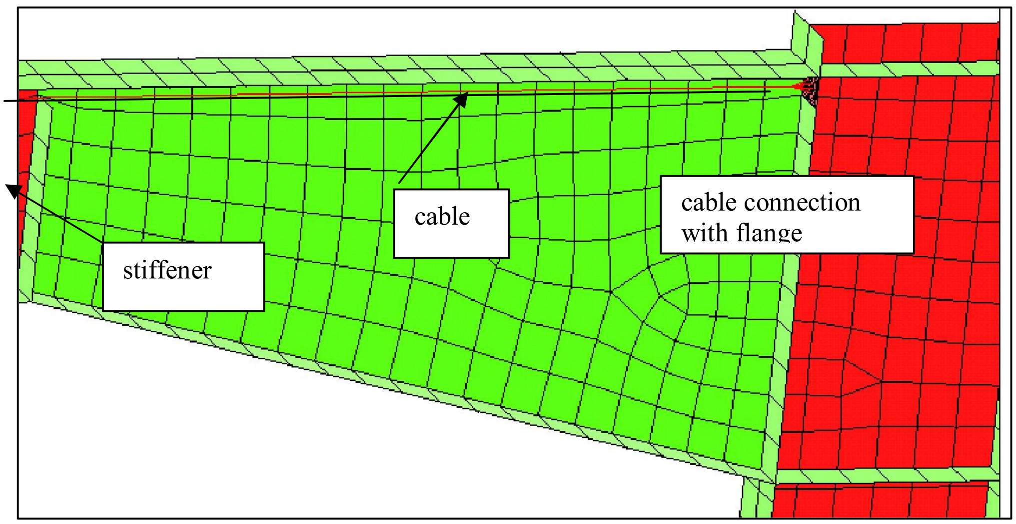

Fig.7, cable connection with flange

3rd technique:

In this technique Cables are attached between the flange of the column, two cables are used between the two columns flange there position was below the hunch by 15cm, the column flange increased in the region of the cable fixation by using a plate with width 300mm thickness 30mm height 210mm the length of the cables are 29.4m.

The same element meshing is used as the first technique

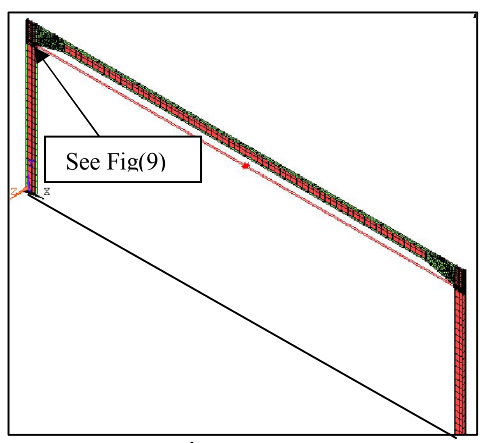

Fig.8, 3rd technique layout

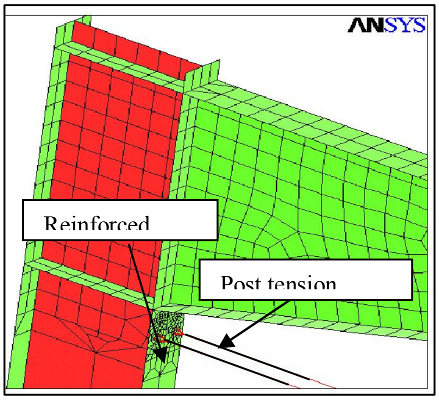

Fig.9, cable connection with flange for the 3rd technique

4th technique: In this techniques two cables are attached between the two column's flange and pass through a steel roller of 40mm diameter.The fixation point of the cables with the column's flange is stiffened by plates of 40mm the connection between the roller and the cable is defined 1rst as a contact element contact 52[8] another solution the connection is defined a link members it was found that the two solution have the same results

The same element meshing is used as the first technique

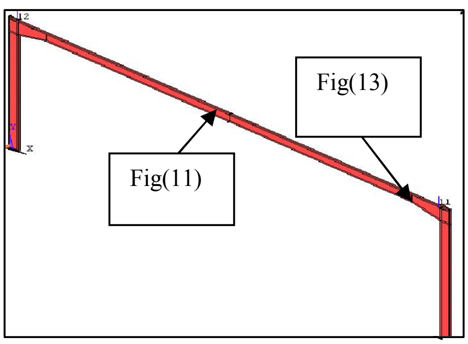

Fig.10, 4th technique layout

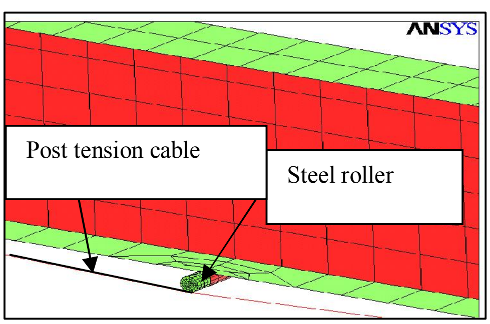

Fig.11, Connection of the cable with the roller of the 4th technique

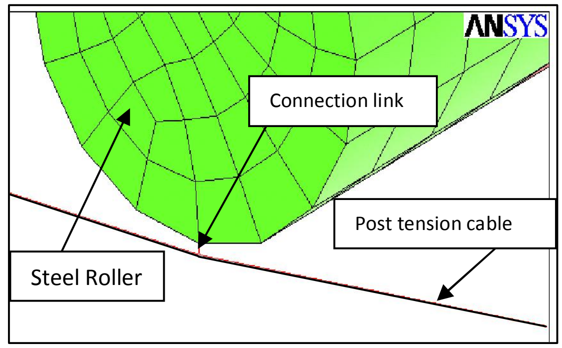

Fig.12, indication for the element used in the connection of the cable with the roller

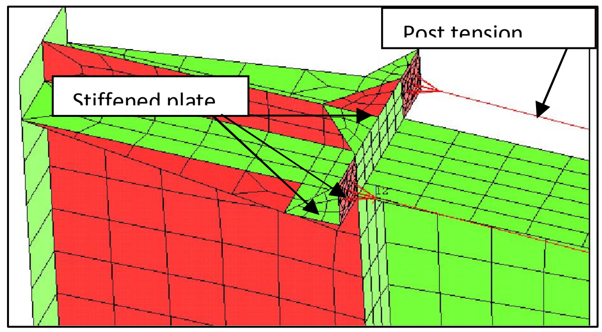

Fig.13, connection of the cable with the stiffened plates

4-Results

The relation between post tension force in each cable in the different technique and the increase percentage in the capacities in the applied load are shown in fig.15

For the 3rd technique it's found that by applying post tension force on the cable that the stress at the connection between the hunch and the rafter increase than the allowable stress so this technique has no curve in figure (15), figure.14, gives an illustration for 1st,2nd,3rd and 4th technique.

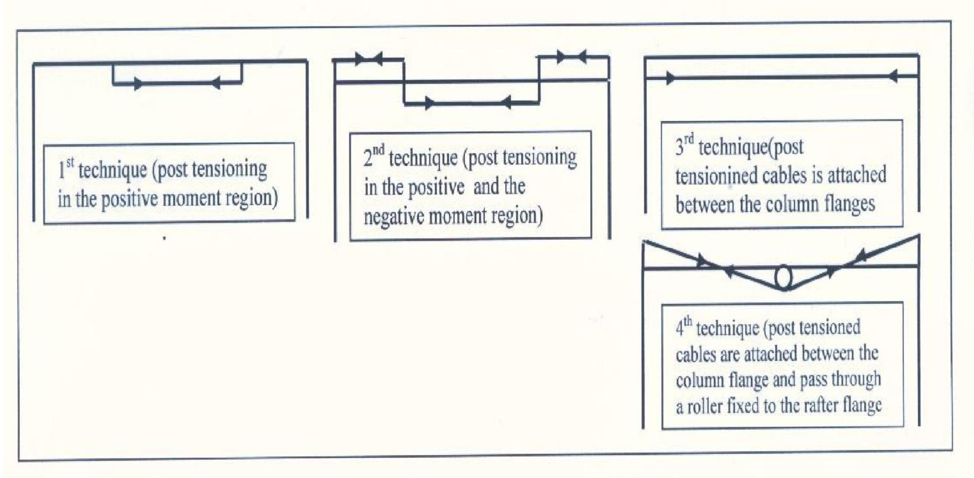

Fig.14, Illustration for technique (1, 2, 3, 4)

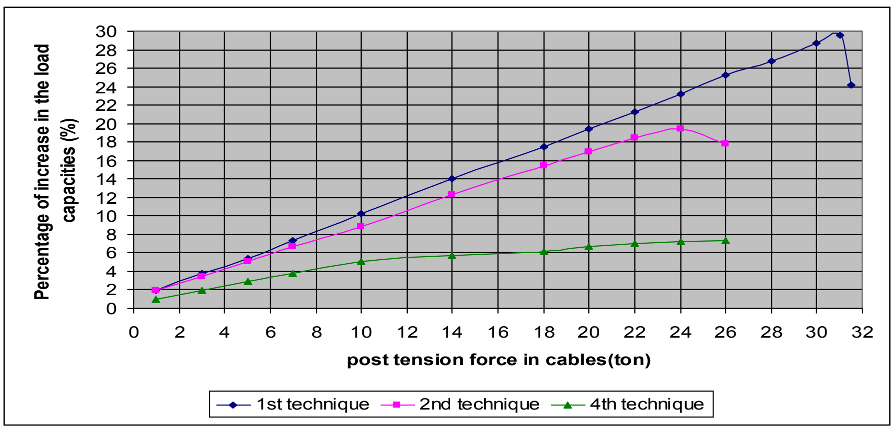

Fig.15, Increase of applied load due to application of the 1rst technique

Table(1-1) percentage of load increase due to applied post tension force

load(ton)	% 1st technique	% 2nd technique	% 4th technique
1	1.9	1.9	1
3	3.8	3.5	1.9
5	5.4	5.1	2.9
7	7.3	6.7	3.8
10	10.2	8.9	5.1
14	14	12.3	5.7
18	17.5	15.4	6.1
20	19.4	16.9	6.7
22	21.3	18.5	7
24	23.2	19.4	7.2
26	25.2	17.8	7.3
28	26.8		
30	28.7		
31	29.6		
31.5	24.2		

Conclusions

1. The maximum increase in the capacity of the applied load is achieved by using post tensioned cables in the positive moment region (1st technique)
2. The increase in the capacities of the applied load by using post tensioned cables in the positive and negative moment region of the rafter (2nd technique) is less than the 1st technique
3. The 2nd technique (post tensioning is in the positive and the negative moment region)gives the lowest stress in the rafter of the frame but increase the stress of the column than the first method
4. The percentage of increase of the applied force began to decrease after certain post tensioned force depending on the load and the span of the frame,this problem could be overcome by increasing the flange thickness at the bracket location where the flange of the beam is over stressed at this location

5. post tensioning the cables between the interior column flange(3rd technique) gives bad results where the beam stress in the negative moment region is increased and there is no increase in the capacities of the applied load
6. Minimum increase in the load capacities are obtained in the 4th technique
7. finally this analysis recommend to use post tensioning cables in the positive moment region

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