PARAMETRIC STUDY OF CABLE STAYED BRIDGE

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ABSTRACT
Aim: To study the static behavior of cable stayed bridges and effect of various parameter on cable stayed bridge. To carry out comparative study of cable stayed bridges **Methodology:** In this paper parametric study of cable stayed bridge is carried out. In this study three span, two plane cable stayed bridge with box girder deck is considered. For analysis IRC class AA moving load is considered and its effect on cable stayed bridge girders is studied. Analysis is carried out with help of MIDAS CIVIL software. The various parameters were considered for analysis of cable stayed bridges; those are side span to main span ratio, upper strut height, cable system, number of cables per plane and cable diameter. We have studied the effect of above parameters on maximum girder moment, deflection, shear force, axial force in the girder. **Results:** With the increase in side to main span ratio maximum moment is decrease up to certain limit and then increases. With increase in number of cables maximum moment in girder decreases. **Conclusion:** Maximum moment in the girder is reduced for ratio 0.5 by 12.53% as compare to side span to main span ratio 0.35. It is found that maximum moment in girder decreases with increase in number of cables. It decreases by 47.74% for 20 cables per plane as compare to 8 cables per plane.There is no significant change in the maximum moment in girder with increase in cable stiffness.

***IndexTerms* - Cable stayed bridge, Parameter, Finite Element Model, MIDAS CIVIL, IRC class, Deck & Pylon.**

INTRODUCTION
Bridges play very important role in development of society and human life. Bridge is also an important element in a transportation system, as its capacity governs the capacity of whole system, its failure or defective performance will result in serious disruption of traffic flow. Cable stayed bridges have good stability &optimal use of structural materials, aesthetic, relatively low design and maintenance costs, and more efficient structural characteristics. Therefore, this type of bridges are becoming more and more popular and are usually preferred for long span range compared to suspension bridges. In terms of cable arrangements, the most common type of cable stayed bridges are fan, harp, and semi fan bridges. Because of their large size and nonlinear structural behavior,the analysis of these type of bridges is more complicated than conventional bridges. In these bridges, the cables are the main sources of nonlinearity. Obtaining the optimal distribution of post-tensioning cable forces is an important task and plays a major role in optimization in the design of cable stayed bridges. In this paper analysis is carried out with the help of MIDAS CIVIL Software.

OBJECTIVES
Objective of this investigation is to study the static behavior of three span cable stayed bridge. In this study for static analysis we have used MIDAS CIVIL software to find maximum moment, torsional moment, shear force, axial force in the deck. For analysis we have considered various parameters such as side span to main span ratio, upper strut height, cable system, number of cables per plane, cable diameter. We have studied the effect of various parameters on the analysis of cable stayed bridge girder. Results obtained those are presented in the graphical and tabular forms.

METHODOLOGY
In this paper analysis of three span double plane cable stayed bridge is carried out. A complex structural linear analysis is carried out with the help of software MIDAS CIVIL. For linear analysis IRC class AA is considered as moving load on bridge. Software automatically finds critical position of this loads and gives the result. Various parameters and its effect on maximum moment, maximum torsional moment, and maximum axial force, maximum shear force and maximum deflection in the girder.

Various parameters considered and assumed data are as follows (Fig 1).

i) Side span to main span ratio-0.35, 0.4, 0.45, 0.5, 0.55, 0.60

ii) Number of cables per plane-7,8,10,12,16 and 20

iii) Cable diameter -5cm,10cm, 15cm, 20cm, 25cm and 30cm

Total span of 600m is considered H type tower is provided of 2m x 2m with overall height 80 m of reinforced cement concrete. Width of deck 7.5 m.(fig 2)

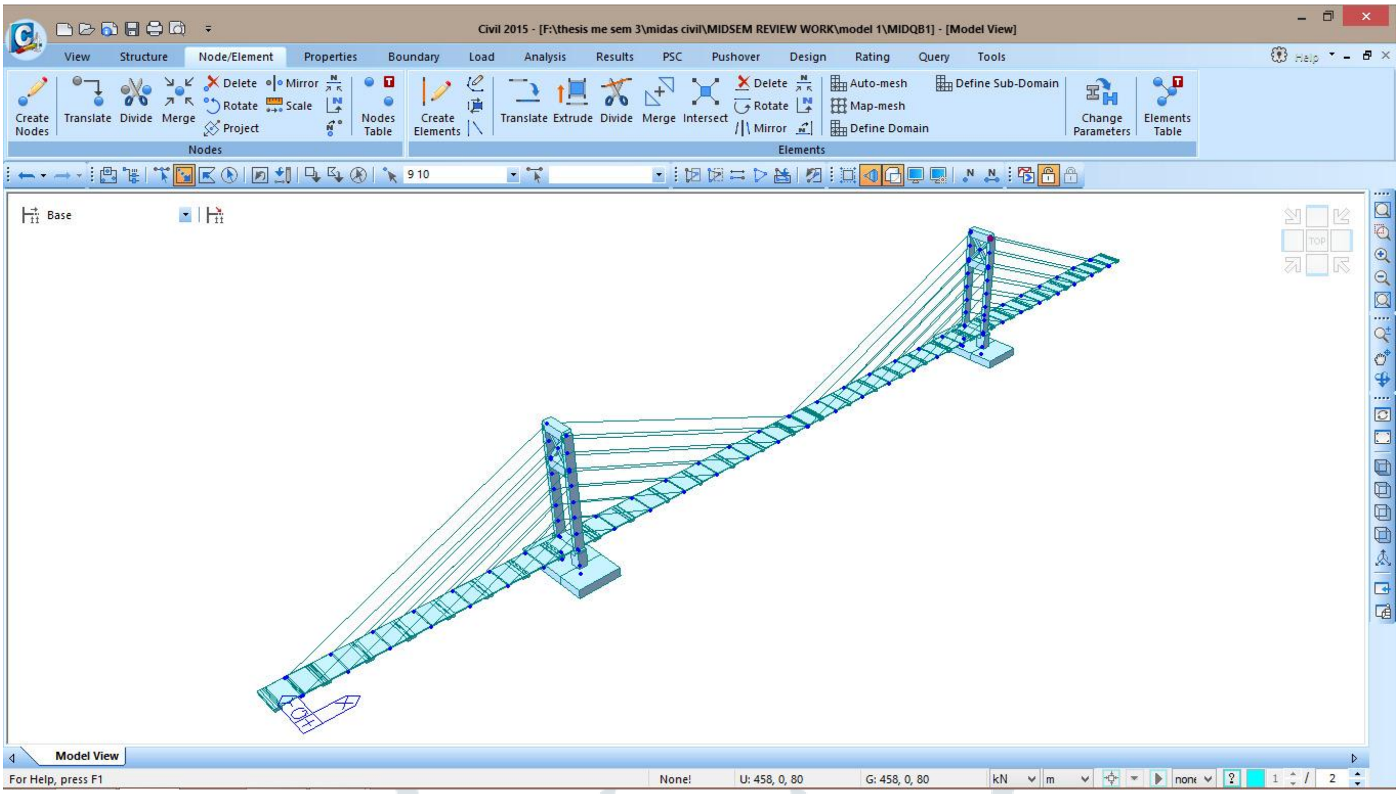


Fig.1 The finite element model

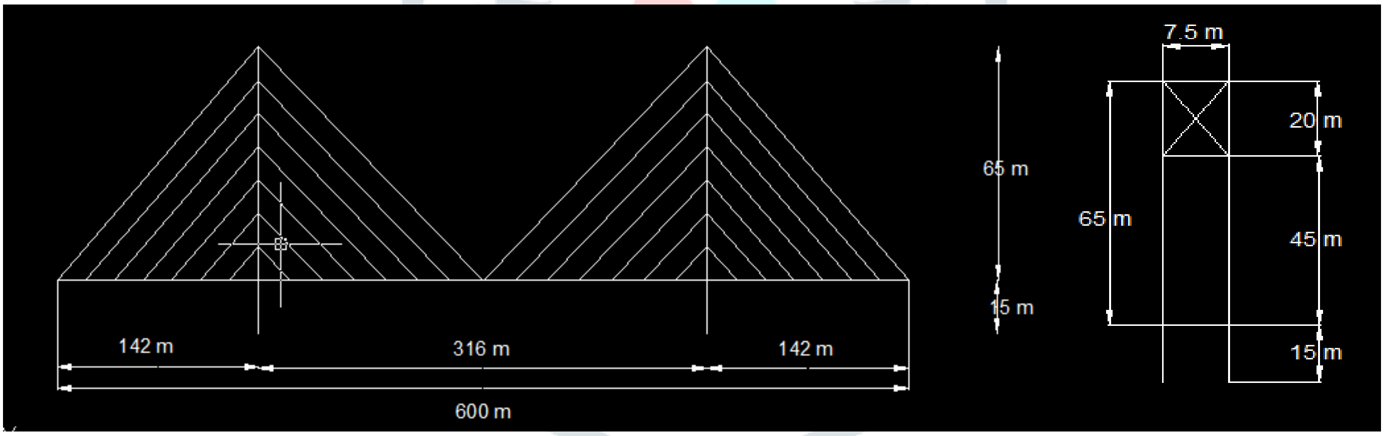


Fig.2 Schematic plan of bridge & Elevation of pylon

Unknown load factor method

Unknown load factor method is used to find out the optimum post tensioning cable force for bridge using unit displacement. The permanent stress in a cable-stayed bridge subjected to its dead load is determined by the tension forces in the cable stays. They are introduced to reduce the bending moment in the main girder and to support the reactions in the bridge structure.

The cable tension should chose in such a way that bending moments in the girders and the pylons are eliminated or at least reduced as much as possible. Hence, the deck and pylon would be mainly under compression under the dead load.

The analysis program MIDAS CIVIL provides the unknown load factor function, which is based on an optimization technique. It can also used to calculate the load factors that satisfy specific boundary conditions (constrains) defined for a system. Initial pre-stress forces can be calculated through optimizing the equilibrium state.

The calculation of the ideal cable prestress forces by the optimization is restricted to the linear analysis as the different loadings are superposed. The initial cable pre-stressing forces are obtained by the unknown load factor function and the initial equilibrium state analysis of a cable-stayed bridge.

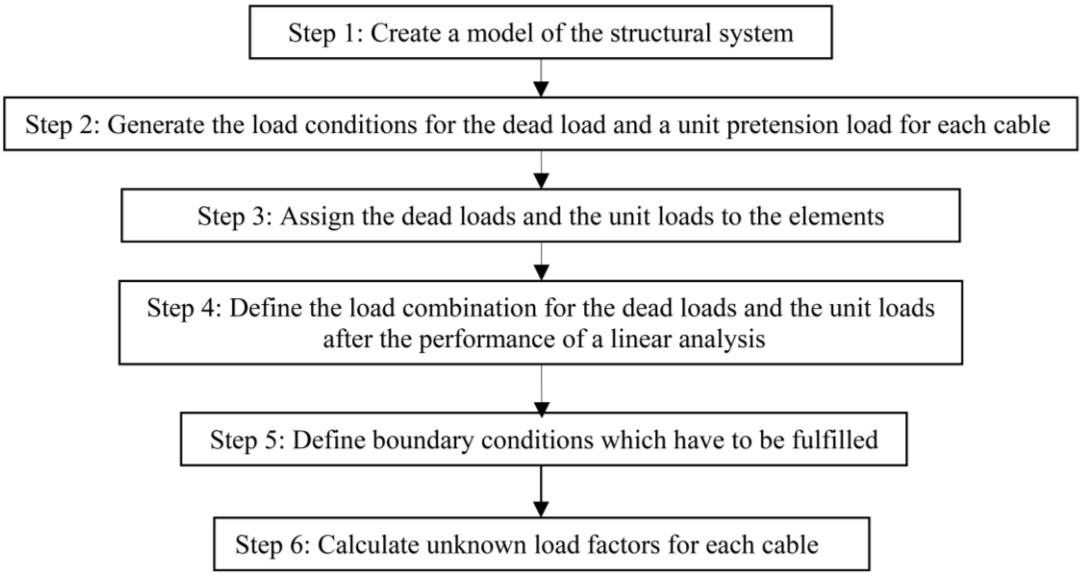
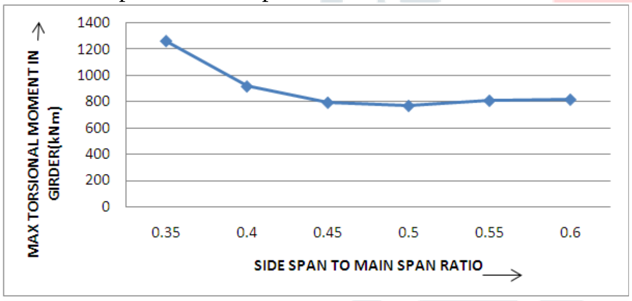


Fig.3 Flowchart for cable initial prestress calculation

RESULT AND DISCUSSION

i) ***Parameter - Side span to main span ratio:*** From Fig.4, maximum moment in girder decreases from side span to main span ratio 0.35 to 0.5 and then increases for ratio 0.55 and for 0.6.Maximum moment in the girder is reduced for ratio 0.5 by 12.53% as compare to span to main span ratio 0.35. For side span to main span ratio 0.5, maximum moment in the girder is minimum. With reference to Fig. No. 5 we found that there is significant decrease in torsional moment as compare to ratio 0.35. Torsion moment decreases by 38.92% for ratio 0.5 compared with maximum moment for side span to main span ratio 0.35. From Fig.6, Axial force also decreases upto side span to main span ratio 0.5. From Fig.7, maximum Axial force in girder suddenly decreases by 53.57% for ratio 0.5 as compare to initial ratio. We got minimum shear force for side span to main span ratio 0.5.Therefore economical side span to main span ratio is in between 0.45 to 0.55 (Table 1).



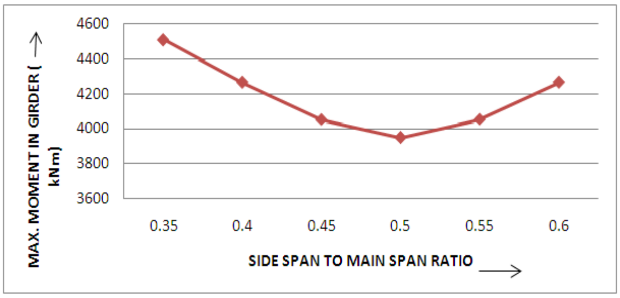
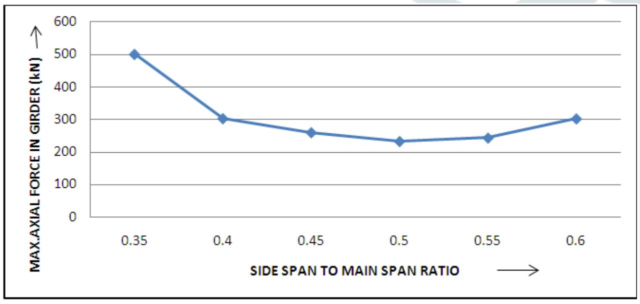


Fig.4 Variation of Max.Moment in Girder w.r.t Side span to main span ratio**Fig.5**Variation of Max.Torsional Moment in Girder w.r.t side span to main span ratio



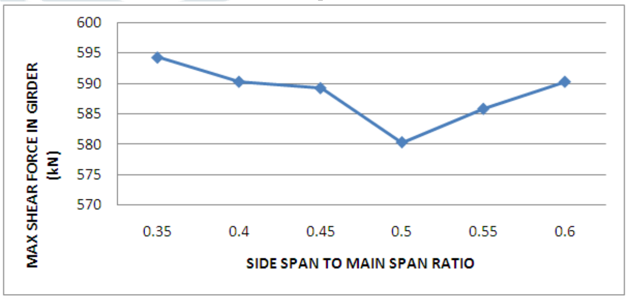


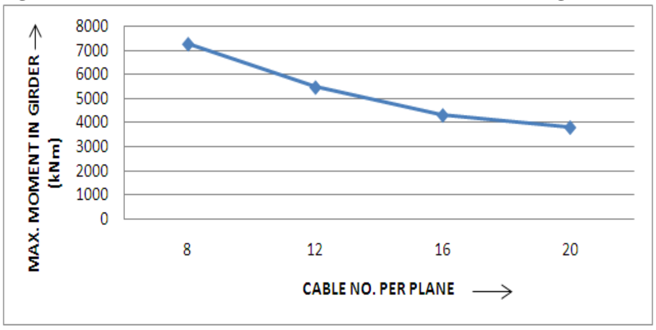
Fig.6 Variation of Axial force in Girder w.r.t side span to main span ratio

Fig.7 Variation of Max.Shear Force in Girder w.r.t side span to main span ratio

Table No. 1 Three span CSB with Side span to main span ratio

Side span to main span ratio	Max. Moment in Girder (M3) kNm	Max.Torsional Moment in Girder (MT) kNm	Max.Axial force in Girder(P)kN	Max.Shear force in Girder (V2)kN
0.35	4513.536	1261.891	501.310	595.446
0.40	4267.538	918.248	303.917	591.438
0.45	4052.595	795.491	260.928	590.391
0.50	3947.542	770.681	232.720	581.440
0.55	4053.913	810.103	244.390	586.968
0.60	4267.540	818.255	303.424	591.440

ii) Parameter - Number of cables per plane: For this parameter three span cable stayed bridge is considered. Initially bridge girder was fixed with 8 cables per plane and further the numbers of cables were increased from 8 to 20 per plane. From Fig.8, we found that maximum moment in girder decreases with increase in number of cables. It decreases by 47.74% for 20 cables per plane as compare to 8 cables per plane. From Fig.9,there is decrease in maximum torsional moment in the girder for 20 cable no. as compare to initial configuration with 8 cable no. It decreases by 13.30% for cable no. 20 (fig 10). From Fig.11, maximum shear force in girder also decreases with increase in number. It decreases by 23.97% for 20 cables per plane as compare to 8 cables per plane. With reference to Fig.12, maximum cable force decrease with increase in number of cable. It decreases by 61.47% for 20 cables as compare with 8 cables per plane. From Fig.13, maximum deflection in girder also decreases with increase in number of cables. It decreases significantly by 47.91% for 16 cables per plane as compare with 8 cables per plane**.** From Fig.14 and Fig.15, we found that maximum pylon moment and maximum pylon deflection increases with increase in number of cables per plane. It is found that 16 cables per plane gives least deflection in the girder as it producesless momentin the girder and it does not significantly increases moment in the pylon. There is no significant decrease in the maximum deflection of thegirder for 20 cables per plane compare with 16 cables per plane (Table 2 and 3).



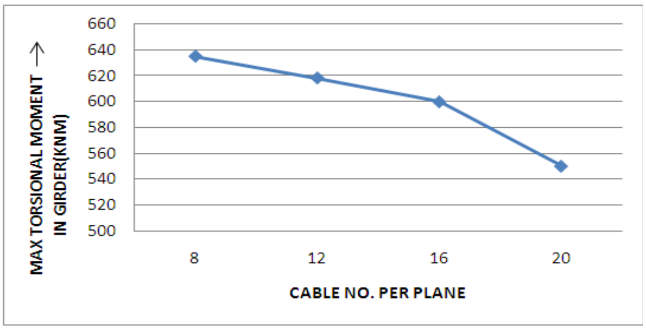
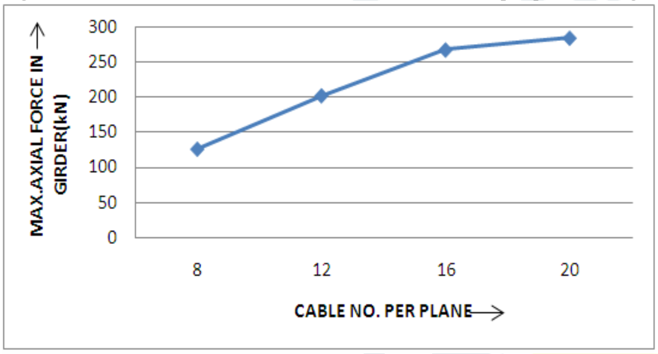


Fig.8 Variation of Max.Moment in Girder w.r.t Cable No. per planes

Fig.9 Variation of Max.Torsional Moment in Girder w.r.t Cable No. per planes



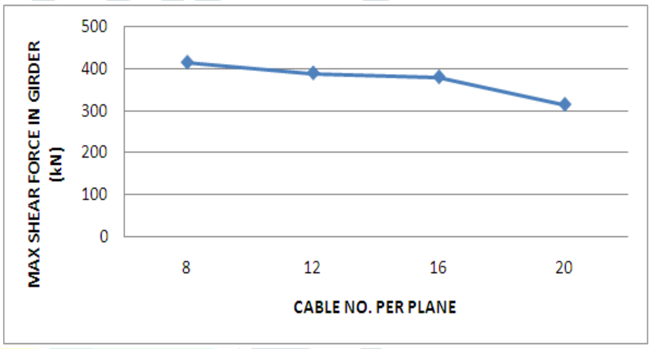
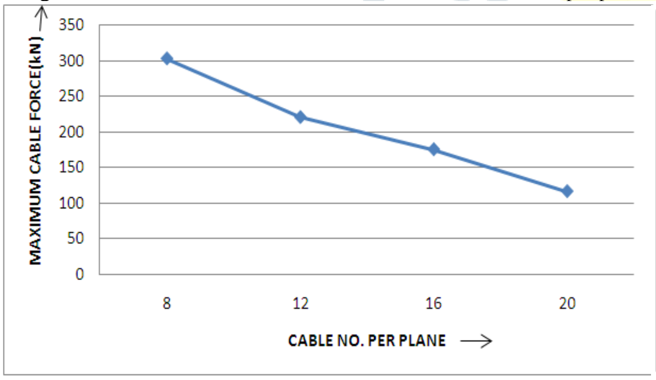


Fig.10 Variation of Max. Axial Force in Girder w.r.t Cable No. per planes

Fig.11 Variation of Max.Shear Force in Girder w.r.t Cable No. per planes



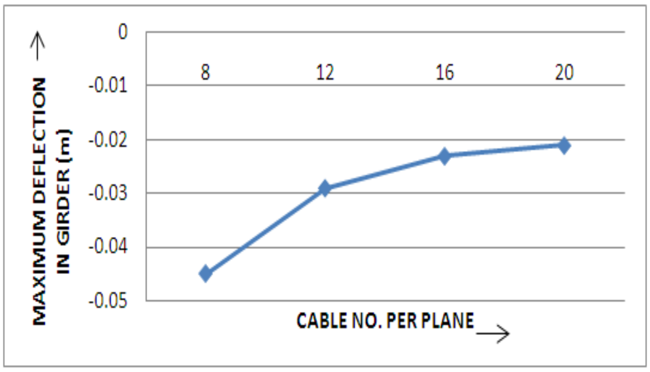
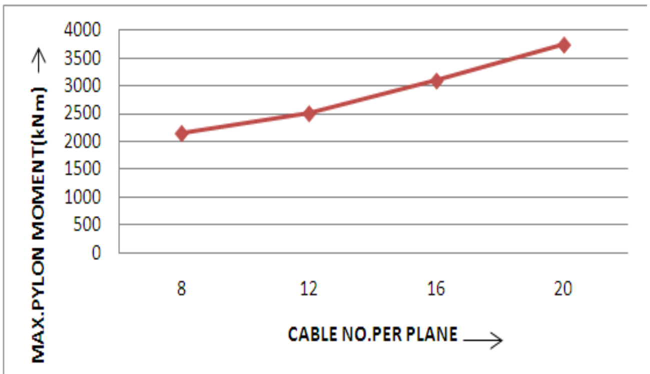


Fig.12 Variation of Max. Cable Force in Girder w.r.t Cable No. per planes

Fig.13 Variation of Max. Deflection in Girder w.r.t Cable No. per planes



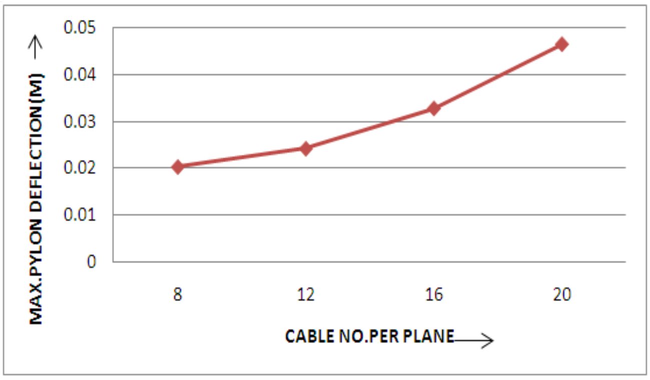


Fig.14 Variation of Max. Pylon Moment in Girder w.r.t Cable No. per planes

Fig.15 Variation of Max. Pylon Deflection in Girder w.r.t Cable No. per planes

Table No.2 Three span cable stayed bridge with varying No. of cables

Cable No	Max. Moment in Girder (M3)kNm	Max.Torsional Moment in Girder (M_T) kNm	Max.Axial force on Girder(P)kN	Max.Shear force in Girder(V_2)kN	Max.Cable force(kN)	Max.Deflection in Girder(m)
8	7284.865	635.953	127.560	415.924	304.670	-0.0455
12	5477.350	619.236	203.856	390.706	221.910	-0.0293
16	4313.222	600.952	269.256	381.438	176.550	-0.0237
20	3806.348	551.362	286.165	316.239	117.380	-0.0214

Table No.3 Pylon moment and deflection for three span cable stayed bridge with varying No. of cables

CABLE NO.	PYLON MOMENT(kNm)	PYLON DEFLECTION(m)
8	2148.577	0.0204
12	2505.395	0.0243
16	3095.939	0.0329
20	3744.310	0.0466

iii) Parameter: Cable Diameter: For analysis of cable stayed bridge girder, parameter considered is cable stiffness. In this different diameters of cable are considered for three span cable stayed bridge. The variable diameter of cable was considered for analysis of 3 span cable stayed bridge girder.5cm,10cm, 15cm, 20cm, 25cm, 30cm was considered for analysis. The results obtained are represented in below figures. From Fig.16, maximum moment decreases smoothly with increase in cable stiffness. It decreases with small amount with increase in cable stiffness**.** By studying Fig.17, Fig.18, Fig.19 torsional moment, maximum axial force, shear force decreases by small amount with increase in cable stiffness.

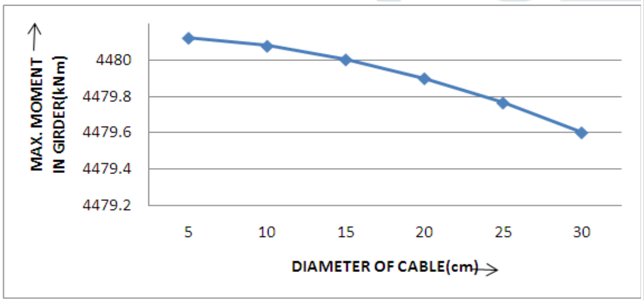


Fig.16 Variation of Max.Moment in Girder w.r.t. cable diameter

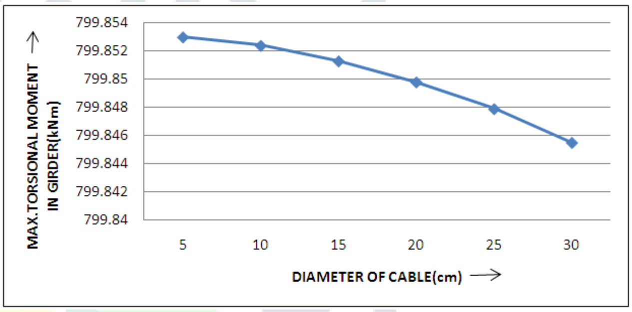


Fig.17 Variation of Max.Torsional Moment in Girder w.r.t. Cable diameter

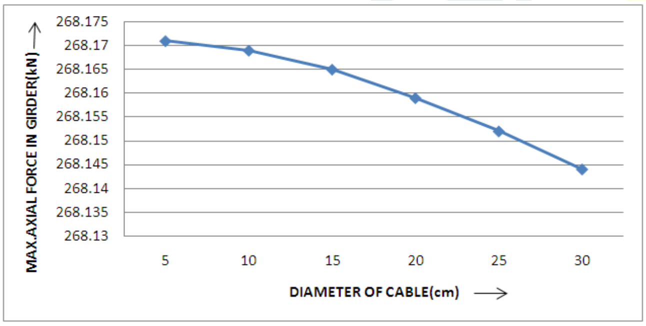


Fig.18 Variation of Max.Axial Force in Girder w.r.t. cable diameter

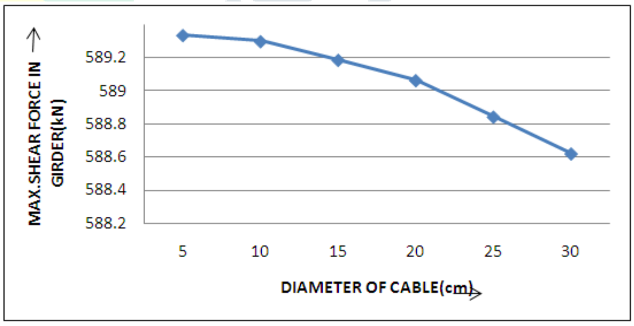
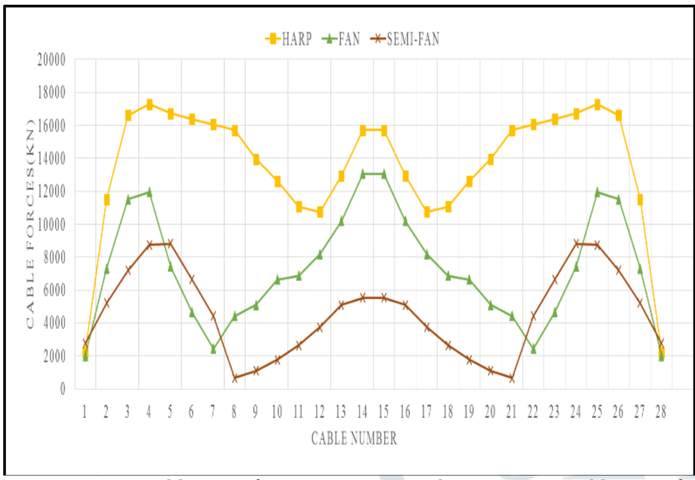


Fig.19 Variation of Max. Shear Force in Girder w.r.t. Cable diameter

Table No.4: Three span CSB with diameter of cables as variable

Cable Dia.(Cm)	Max. Moment in Girder (kNm)	Max.Torsional Moment (kNm)	Max.Axial force in Girder (kN)	Max.Shear force in Girder(kN)
05	4481.123	799.9530	268.2711	589.4382
10	4481.0780	799.9524	268.2693	589.4013
15	4481.0032	799.9513	268.2650	589.2880
20	4480.8993	799.9498	268.2591	589.1651
25	4480.7650	799.9479	268.2522	588.9440
30	4480.6011	799.9455	268.2445	588.7213

iv) Parameter: Upper Strut Height: For optimum cable stay force in cable stayed bridge parameter considered is upper strut height. In this at different heights 20m,40m,60m upper strut is in three span cable stayed bridge for Fan, Harp & Semi fan system. No. of cables=7,Mid span=316 upper strut height h=20m,40m,60m.The results obtained are represented in below figures.
From Fig.20,For Upper strut height 20m maximum post tensioning cable stay force in Harp arrangement and Minimum in semi fan arrangement is observed.
For upper strut height 40m,60m post tensioning cable force is shown in fig.21,Fig.22 shown respectively. Comparison For all the system is done and it shows that Minimum Post tensioning cable force is possible to achieve when upper strut height is increases(Fig.23).



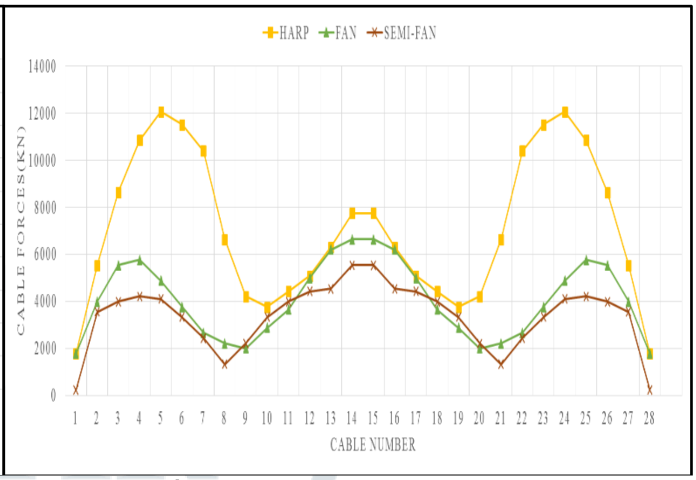
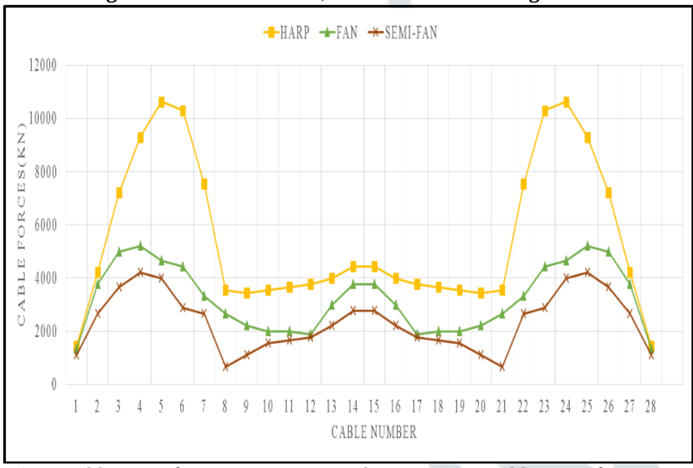


Fig.20 Cable Force for N=7,M=316 m & h=20 m **Fig.21**Cable Force for N=7,M=316 m & h=40 m



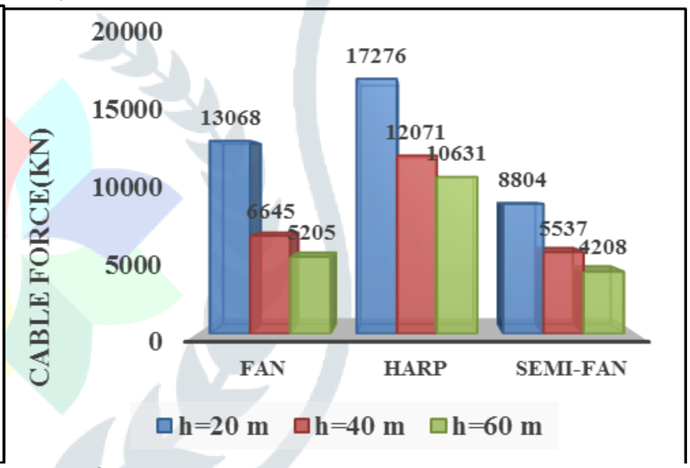


Fig.22 Cable Force for N=7,M=316 m & h=60 m**Fig.23**Cable Force for N=7,M=316 m & h=20,40,60 m

CONCLUSION

For the "Parametric study of cable stayed bridge girder" using MIDAS CIVIL software the results were obtained as given in previous chapter.

From these results and discussion we have come to following conclusion:

1)For total span of 600m two plane cable stayed bridge economical side span to main span ratio is in between 0.45to 0.55.

2) As we increases number of cables for total span of 600m, two plane cable stayed bridge with box girder deck, there is decrease in the maximum moment in the girder. But pylon moment increases with increase in the number of cables per planes.

3) There is decrease in the maximum deflection in the girder as we increase number of cables per plane for total span of 600m of radial type, double plane cable stayed bridge with box girder deck. But there is increase in the pylon moment.

4) It is found that 16 cables per plane will be economical as it gives least deflection in the girder also it produces less moment in the girder and it does not significantly increases moment in the pylon.

5) With increase in cable Diameter maximum moment, axial force, shear force decreases but there is no significant change in these values for total span of 600m two plane cable stayed bridge with box girder deck.

6) For Fan cable system With increase in height of Upper Strut From h=20m to h=60m Maximum cable force decreases 60.16%.

7) For Harp cable system With increase in height of Upper Strut From h=20m to h=60m Maximum cable force decreases 38.46%.

8) For Semi-Fan cable system With increase in height of Upper Strut From h=20m to h=60m Maximum cable force decreases 52.20%.

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