Analysis & Design of Suspension Bridge by Using SAP 2000

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Abstract:* Among the few basic types of bridges viz., girder bridges, arch bridges, and trussed bridges, Cable stayed bridges have good stability, optimum use of structural materials, aesthetic, relatively low design and maintenance costs, and efficient structural characteristics. Therefore, this type of bridges are becoming more and more popular and are usually preferred for long span crossings compared to suspension bridges. There are many types of cable arrangements among that we chose fan type, semi fan type and harp type arrangements. The bridge is designed and analyzed for these cables arrangement by using SAP2000 software. The objective of this work is to assist the seismic behavior of cable stayed bridge, for determining the design parameters (displacements and base reactions etc). In this work an attempt is made to predict the behaviour of cable stayed bridges under static and dynamic loads. The response of bridges in terms of BMs, SFs is determined under static loading. The dynamic characteristics such as displacement and base reactions are also determined by the non linear time history.

Index Terms: Cable-Stayed Bridge Construction, IRC.

I. INTRODUCTION

During the past decade cable-stayed bridges have found wide applications in large parts of the world. Wide and successful application of cable-stayed systems has been realized only recently, with the introduction of high-strength steel, orthotropic type decks, development of welding techniques and progress in structural analysis. The variety of forms and shapes of cable-stayed bridge intrigue even the most demanding architects as well as common citizens. Engineers have found them technically innovating and challenging. Modern cable-stayed bridges are at present considered to be the most interesting development in bridge design. The increasing popularity of these contemporary bridges among bridge engineers can be attributed to its appealing aesthetics, full and efficient utilization of structural materials, increased stiffness over suspension bridges, efficient and fast mode of construction and the relatively small size of their sub structure. Cable-stayed bridge construction differs from conventional suspension bridges since in the former the girder is supported by individual inclined cable members which are attached directly to the tower, rather than by vertical hangers which are supported by one member as in the case of cable suspended bridges. One of the main difficulties an engineer encounters when faced with the problem of designing a cable-stayed bridge is the lack of experience with this type of structure, predominantly due to its nonlinear behavior under normal design loads. As accurate measurements of seismic responses are scarce in designing these bridges; the need for accurate modeling techniques has arisen. The methods available to the designer for the study of the bridge's dynamic behavior are the forced vibration test of the real structure, model testing and computer analysis. The latter approach is becoming increasingly popular since it offers the widest range of possible parametric studies.

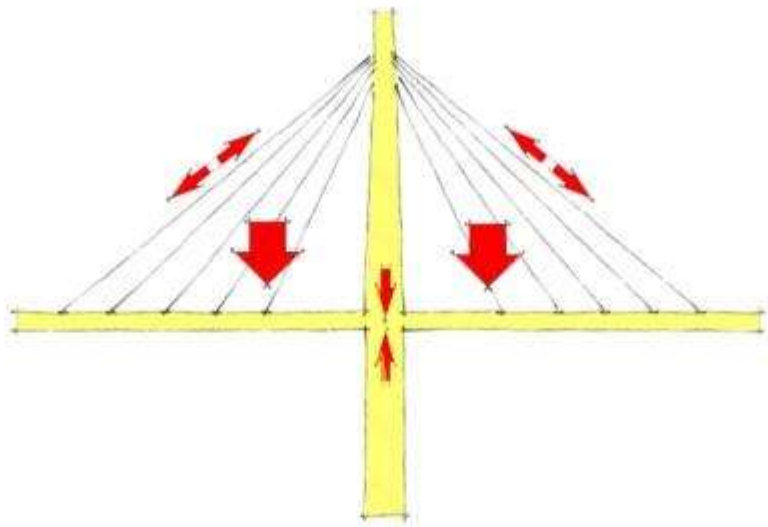

Fig.1. Cable –stayed Bridges.

II. LITERATURE REVIEW

However if cable spacing is increased, dead load moment increases with no significant effect on live load moments (George, 1999). For cable-stayed bridges with concrete decks, the most economical solution having minimum longitudinal moment is always the one having maximum number of cables. After applying both linear and nonlinear procedures for a wide variety of bridge geometries, it has been found (Fleming, 1980) that linear dynamic response, using the stiffness of the structure at the dead load deformed state, considering the nonlinear behavior of the structure during the application of static load and nonlinear dynamic response. Ghaffar (1991) has given general guidelines for seismic analysis and design of cable stayed bridges. He has given different procedures to estimate earthquake loads considering both simplified and elaborate dynamic analysis.

III. METHODOLOGY

Because of having large dimensions and also great flexibility, cable-stayed bridges have long periods. Therefore, these types of bridges are different than other structures and this matter affects stayed bridges dynamic behavior. One of the items that influence the flexibility and the dynamic characteristics of the stayed bridges is the form of the cable's placement in vertical and horizontal positions. In general, cable-stayed bridges have many degrees of indeterminacy from static and dynamic points of view which are the result of the tension forces in the cables. Economic bridges can be designed using correct and good arrangement of the cables. Thus, in this the seismic behavior of cable-stayed bridges are investigated and compared due to different conditions of cable's placement forms.

A. Finite Element Analysis

In this method the entire structure is divided into small elements and the stiffness of the structures is assembled from the membrane and plate bending stiffness of each element. The method is the only one that is truly general and powerful and can handle all types of structure. It has even been extended to the analysis of structures subject to crackling. Its accuracy depends on the nature and number of elements used. True compatibility of deformation is achieved only at the nodes, and the accuracy of the representation between nodes depends on the suitability of the assumed displacement function for the strain field in question and upon the size of the grid element chosen. Considerable research has been directed recently towards finding the most durable types of elements for box girder work and good agreement between experiment and theory can be obtained. The disadvantages of the method are the large computer storage required and the time consuming input synthesis and output analysis.

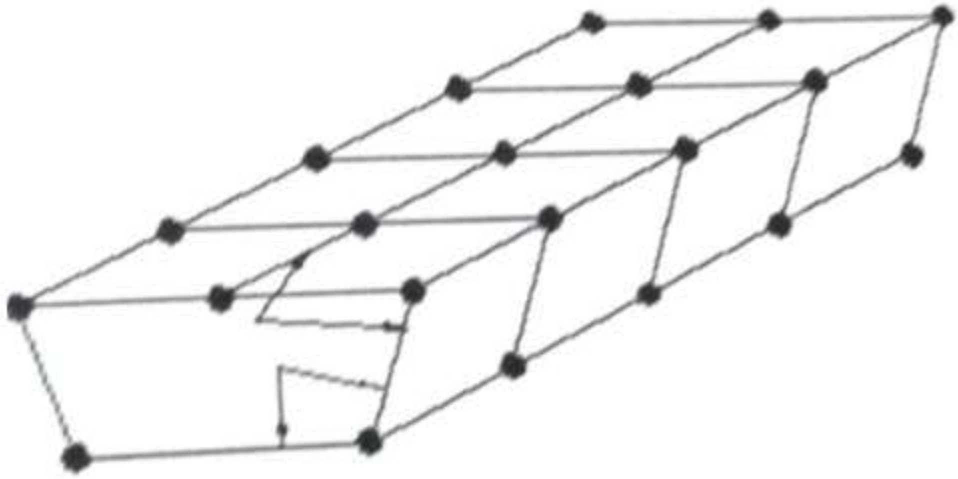

Fig.2. Finite Element Model of Box Girder.

The paramount requirements for box girder construction are the strictest supervision and quality control. Supervision should be directed by experienced engineers acquainted with aspects of the design, and all developments during construction should be examined closely. The formwork and false work for concrete box girder bridges must be of the highest standard. The entire false work must be rigid and almost watertight. Careful curing is essential if shrinkage and thermal cracking of the cross section is to be minimized. All movements of the superstructure during erection should be constantly reviewed to ensure that they fall within anticipated limits and that the final state of stress throughout the structure will be acceptable. Careful supervision of all grouting operations is essentials if the desired durability and ultimate load capacity are to be achieved. In general, superstructure damage is unlikely to be the primary cause of collapse of a span. Instead, damage typically is focused in bearings and substructures. The superstructure may rest on elastomeric pads, pin su.

IV. MODELLING OF CSB

In this study, analysis is made for cable stayed bridge. The total span of the bridge is 160 m. The total width of the deck of the bridge is 8 m. In modelling; firstly edge beams are erected and then followed by deck slab with crossbeams. The total height of bridge is 60 m. The pylon used here is a single tower. The cable stayed bridge is modeled by using SAP 2000. Standard vehicular loading as per IRC is loaded. Bridges with Fan arrangement, Semi fan arrangement and harp arrangement are modelled. The deck is designed as concrete section with steel truss as girder section. The models have been analysed for dead load (static) as well as dynamic loads under the effect of load time histories of Bhuj, El Centro and Uttarkashi earthquakes.

A. Considerations

Bridge Geometry:

- Span length :160 m
- Bridge width :8 m

Deck:

- Outside depth :1m
- Outside width :8m
- Flange Thickness :0.2m
- Web Thickness :0.3m

Edge Beam:

- Material : M45
- Depth :1m
- Width :1m

Pylon:

Pylon Bottom:
- Material : Fe345
- Section type : Tube
- Outside diameter :2.4m
- Wall thickness :0.5m

Pylon Top:
- Material : Fe345
- Section type : Tube
- Outside diameter :1.2m
- Wall thickness :0.5m

Stay Cables:
- Material :Fe345
- Diameter :0.04m

Time History Functions Used:
The Uttarkashi Earthquake

Location : Tehri Region, Himalaya
Year : 20thOct, 1991
Magnitude : 6.6 (on Richter scale)
Duration : 6.22 sec
Excitation type : Short
Number of steps : 1996
Step size : 0.02
Time history type : Modal
Occurrence of maximum acceleration: 1.481 sec

V. RESULTS AND DISCUSSIONS

A. Static Analysis Of Cable Stayed Bridge

The static analysis is done for three types of cable stayed bridges. The table 1 to 3 shows variations in the forces and moments for the models.

TABLE I: Shows Maximum Bending Moment, Shear Forces For Fan Arrangement

Beam No	Shear Force		Bending Moment	
	Max	Min	Max	Min
51	293.2	292.2	1155.6	1147
50	-184.4	-185.4	1472.4	1462.8
49	-322.6	-323.7	1104.7	1095.7
48	-497.7	-498.2	-5122	-5128
47	451.1	-450.1	-2317	-2325.1
46	395.1	393	2291	2282
45	329.3	328.1	3573.5	3563

TABLE II: Shows Maximum Bending Moment, Shear Forces For Semi Fan Arrangement

Beam No	Shear Force		Bending Moment	
	Max	Min	Max	Min
51	294.2	293.2	1163.9	1153.3
50	-184.4	-185.4	1481.4	1471.7
49	-319.1	-320.2	1115.4	1106.1
48	-502.1	-502.6	-5301.2	-5307.4
47	452.9	451.8	-2157.8	-2165.1
46	374.4	373.2	2274.7	2265.1
45	329.3	328.1	3571.3	3560.7

TABLE III: Shows Maximum Bending Moment, Shear Forces For Harp Arrangement

Beam No	Shear Force		Bending Moment	
	Max	Min	Max	Min
51	293.4	292.2	1156.9	1148.2
50	-181.4	-182.4	1486.1	1476.3
49	-319.1	-320.2	1133.9	1124.4
48	-508.6	-509.1	-5442.9	-5449.3
47	464	462.8	-2190.1	-2197.5
46	372.7	371.6	2274.7	2320
45	329.3	328.1	3627	3616.4

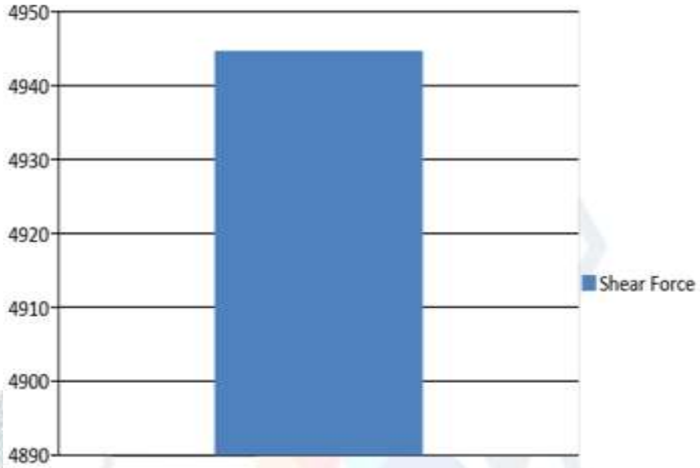

Fig.3. Graph for total Shear force for fan, semi fan and harp type arrangements.

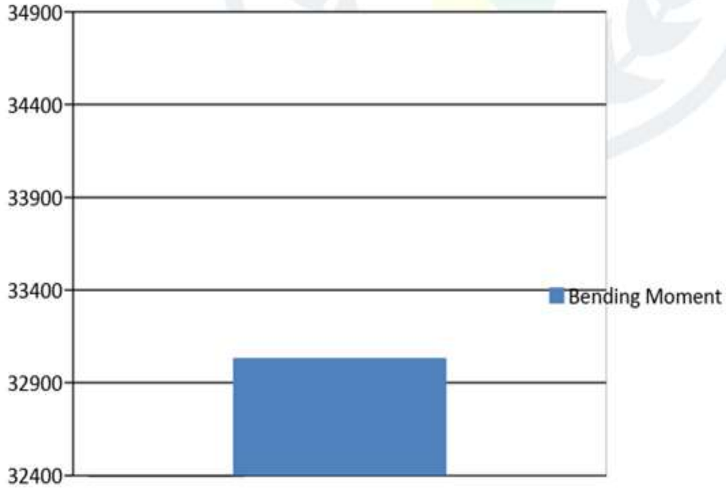

Fig.4. Graph for total Bending moment for fan, semi fan and harp type arrangements.

B. Joint Displacements

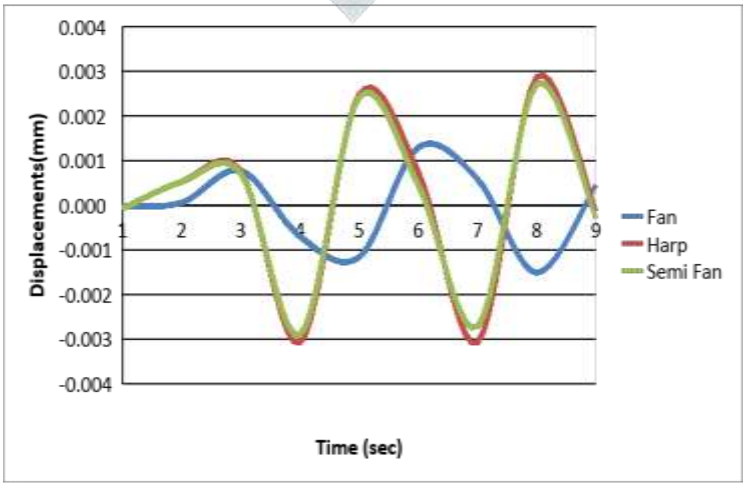

Fig.5. Time Vs Displacement Longitudinal Displacement at joint 56.

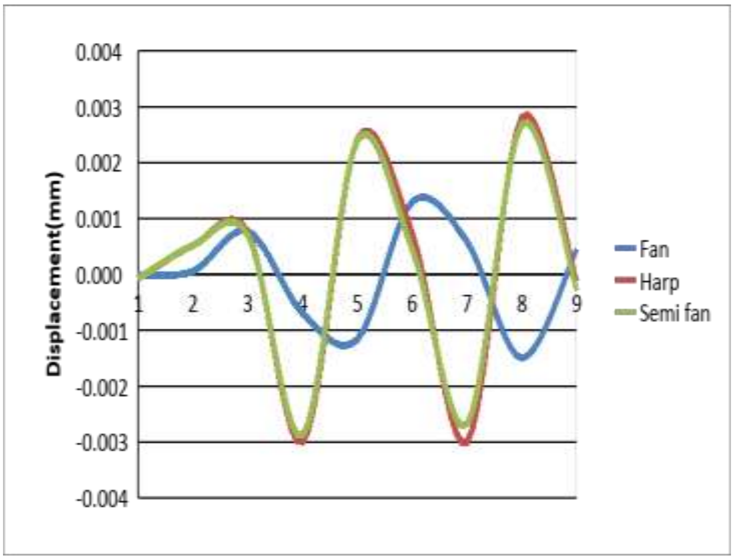

Fig.6. Time Vs Displacement Longitudinal Displacement at joint 45.

The response has been plotted with zero end at the roller supports and the 160 m at other end of the roller supports of the girder. From the following graphs, it can be ascertained that the edge beam displacements is minimum at the ends and maximum displacements are seen at the middle span for the 3 cable type arrangements.

C. Maximum Displacements

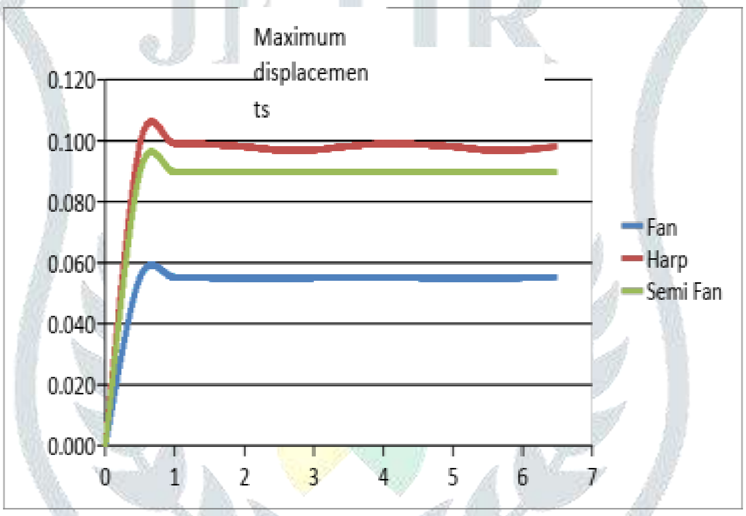

Fig.7. Overall maximum displacements.

D. Minimum Displacements

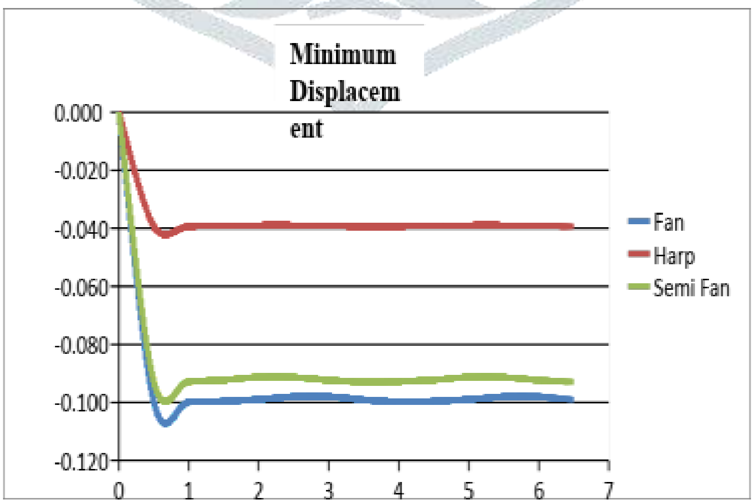

Fig.8. Overall minimum displacements.

From the above graphs the maximum and minimum displacements are observed under Uttarkashi earthquake. Hence the displacement is more in fan than semi fan and least in Harp arrangement.

E. Axial Forces In Cables

The models were also checked for axial forces present in the stay cables. The response has been plotted with the outermost cable at the roller support end of the girder numbered one and subsequently increasing as we move towards the other end. The total number of cables in one plane is 12 with equal spacing of 10m throughout the length of the deck.

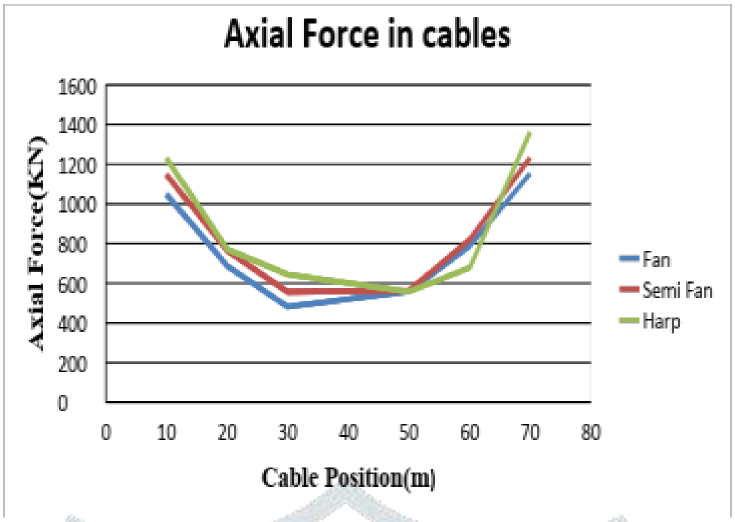

Fig.9. Axial Forces of three types of Cable arrangement.

VI. CONCLUSIONS

Seismic behaviour of cable stayed bridges with cable arrangements is a complicated subject study and requires extensive investigation. However, based on the limited study conducted in this work, the following conclusions could be drawn. Under static loads, fan type cabled bridges were superior to the other models from the point of bending moment and shear force. In the result of non-linear dynamic loads the smallest displacement on edge beams was in fan type models and the biggest one was in harp type models. In three cases, the maximum displacement is occurred at the mid-span of the structure. Total axial forces happened in cables of fan type model was 2% less than semi fan type model and 3% less than harp type. Hence Cables of different lengths experience varying axial forces depending upon their relative positions. From the results, we can infer that, the most efficient out of all these three arrangements indicated that the fan arrangement is more efficient then two other arrangements i.e. Semi fan type and harp type.

VII. REFERENCES

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