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Comparison and Study of Cable Stayed Bridges using STAAD Pro

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***Abstract*: Long span Bridges are constructed to cross obstacles. Bridges are structures which are built to provide a passage over lake, river, valley, road or any other obstruction. During the past twenty years cable stayed bridged has occurred as the most structurally dominant system for the long spans. Long span bridge could be achieved with use of high strength materials and innovative techniques. The requirement of long span bridge is increase with development of infrastructure facility in every nation. Long span bridge could be achieved with use of high strength materials and innovative techniques for analysis of bridge. Generally, cable supported bridges comprise both suspension and cable-stayed bridge. Cable supported bridges are very flexible in behavior. Live load acting on the bridge is transferred to the bridge deck, which in turn both the dead load of the superstructure (self-weight of the bridge deck) and live load of the bridge is balanced by tension cables which is anchored to the tower. The tower of the bridge carries the total working load. Innovative efforts has been taken to reduce the depth of girders of large span bridges resulting in the development of cable stayed bridge decks in which the deck system is suspended by steel cables. The objective of this is to study and analysis in detail the cable stayed bridge which his continuously evolving as an efficient structure.**

***Keywords*: Bridges, Suspension Bridge, Cable Stayed Bridges, Structures, STAAD Pro.**

1. Introduction

The cable-stayed bridges are aesthetically appealing lifeline structures. More and more cable-stayed bridges are built worldwide because of their elegant shapes and smaller cost of construction. Cable-stayed bridges, which are very popular nowadays, are susceptible to strong earthquake motions because of the associated low damping and high flexibility. Cable stayed bridges are constructed along a structural system which comprises of a deck and continuous girders which are supported by stays in the form of cables attached to tower located at the main piers. Stiffness of the overall structure can be provided by stiff towers or can be stiffened by taking backstays to individual or by employing intermediate tension piers or combination of the stiffness of the main span, the tower and the back span, credited to several advantages over suspension bridges, predominantly being associated with the relaxed foundation requirements, with the introduction of high-strength steel, development of welding technology and progress in structural analysis and new construction technique which is very much in vogue.

2. Types of bridges

A. Suspension bridges

A suspension bridge is a type of bridge in which the deck i.e. the load-bearing portion is hung below suspension cables on vertical suspenders. This type of bridge has cables suspended between towers, plus vertical suspender cables that carry the weight of the deck below, upon which traffic crosses. This arrangement allows the deck to be level or to arc upward for additional clearance.

The suspension cables must be anchored at each end of the bridge, since any load applied to the bridge is transformed into a tension in these main cables. The main cables continue beyond the pillars to deck-level supports, and further continue to connections with anchors in the ground. The roadway is supported by vertical suspender cables or rods, called hangers. In some circumstances, the towers may sit on a bluff or canyon edge where the road may proceed directly to the main span, otherwise the bridge will usually have two smaller spans, running between either pair of pillars and the highway, which may be supported by suspender cables or may use a truss bridge to make this connection. In the latter case there will be very little arc in the outboard main cables.

As an outcome, optimization techniques are frequently employed with the purpose to identify the structural behavior of the bridge with respect more complex external loads such as aero elastic and seismic phenomena. However, most of the methodologies are typically concerned to evaluate optimum post-tensioning forces in the dead load configuration, without achieving the complete optimization of the geometry, the stiffness of the structural elements and thus cost of construction [2].

Fig. 1. A typical suspension bridge

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B. Cable-stayed bridges

A cable-stayed bridge has one or more towers (or pylons), from which cables support the bridge deck. A distinctive feature are the cables or stays, which run directly from the tower to the deck, normally forming a fan-like pattern or a series of parallel lines. This is in contrast to the modern suspension bridge, where the cables supporting the deck are suspended vertically from the main cable, anchored at both ends of the bridge and running between the towers. The cable-stayed bridge is optimal for spans longer than cantilever bridges and shorter than suspension bridges. This is the range within which cantilever bridges would rapidly grow heavier, and suspension bridge cabling would be more costly.

The structural action is simple in concept; the cables carry the deck loads to the towers and from there to the foundation. The primary forces in the structure are tension in the cable-stays and axial compression in the towers and deck; the effect of bending and shear in deck is less influential. In cable-stayed bridges a cable-stays are making variable angles with horizontal axis, so the forces in the cable-stays are incompatible at different locations [1].

The requirement of incredible long span bridges is increased day by day with increase in inhabitants and their needs. To achieve a very long span bridge, use of high strength material along with novel structural system is essential. To achieve longer span bridges and good structural system the cable stayed bridges are used, in which the cable-stayed bridge has better structural stiffness than suspension bridges.

Fig. 2. Cable Stayed bridge

3. Components of cable stayed bridges

The various structural components of a cable stayed bridge are:

I. Towers
II. Types of cables
III. Cable arrangement

Typical different types of towers include:

a) Single
b) Double
c) Portal
d) A-shaped

- The single arrangement uses a single column for cable support, normally projecting through the center of the deck, but in some cases located on one side or the other.
- The double arrangement places pairs of columns on both sides of the deck.
- The portal is similar to the double arrangement but has a third member connecting the tops of the two columns to form a door-like shape or portal. This offers additional strength, especially against traverse loads.
- The A-shaped design is similar in concept to the portal but achieves the same goal by angling the two columns towards each other to meet at the top, eliminating the need for the third member. The inverted Y design combines the A-shaped on the bottom with the single on top.

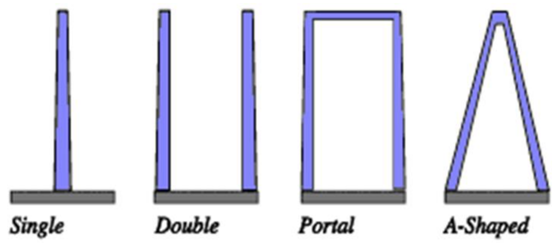

Fig. 3. Different shapes

A. Cables

In cable stayed bridges the cables are the most important element as it transfers the load from the super structure to the tower and to the anchorages.

Different types of cables are as follows:

a) Parallel Bars strands
b) Parallel wires strands
c) Parallel strands
d) Helical coil strands

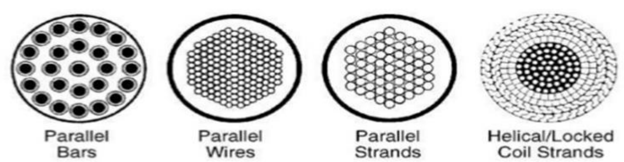

Fig. 4. Cables

In the construction of cable stayed bridges, the cables are chosen on the basis of high and constant value of modulus of elasticity, therefore the parallel wire strands is the most commonly used cable type. The arrangement of cables depends upon factors like clear span, tower height and level of roads. There are four types of cables used and they are classified as:

a) Mono type

This type of system consists of bridges with one single stayed cable along the longitudinal axis of superstructure.

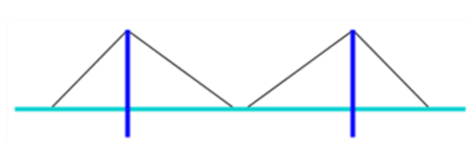

Fig. 5. Mono design

b) Harp type

In Harp type the cables are connected to the tower at different heights and are parallel to each other. The compression is higher in this kind of pattern.

Fig. 6. Harp design

c) Fan type

In this system, the cables are connected at the same distance from the top of the tower it is the most economical arrangement of cables.

Fig. 7. Fan design

d) Star type

In star type cables are connected to two opposite points on the pier.

Fig. 8. Star design

4. Some Important Cable Stayed Bridges

- *France Sky Bridge:* This bridge spanning the Fraser River between New Westminster and Surrey, BC, Canada. Tallest and Longest cable-stayed bridge in the World named as Millau Viaduct or France Sky Bridge it has 4 lanes tallest pier is of 336.4m and shortest pier is of 77m and total length of roadway is 2460m its pylon, cables and deck slab is made of Steel and concrete.

Fig. 9. France Sky Bridge

- *Sundial bridge:* It is the award winning single span pedestrian bridge spanning the sacramento River in California. It is set at a 42-degree angle and loaded by cable stays on only one side its pylon height is of 66m and total length of 700m the deck is made up of 200 tons of glass and granite and is supported by 4300feet of cable.

Fig. 9. Sundial bridge

- *Vidyasagar Setu:* Over river Hooghly, Kolkata it was completed in 1991, since then it is the longest span cable span bridge in India. Its pylon height is of 131m longest span is of 457.2m and total length is of 823m. It is two way with 3-general purpose lanes in each direction However it secure 24 place in the longest span cable stayed bridge in India.

Fig. 10. Vidyasagar Setu

- *Bandra worli sea link (BWSL):* This is also called as Rajiv Gandhi Sea Link. It is 8 lanes of road traffic (including 2 lanes dedicated for buses) with a total length of 29.6 kilometer, and cable-stayed with 50m-50m-150m-50m-50m span arrangement.

Fig. 11. Bandra worli sea link (BWSL)

5. Advantages of Cable-Stayed Bridges

- A great advantage of the cable stayed bridge is that it is essentially made of cantilevers, and can be constructed by building out from the towers.

- In a cable stayed bridge cables are anchored to the deck and tower, whereas in a suspension bridge cables are anchored in a massive anchored blocks, which are quite expensive.
- The main girder can be very shallow with respect to span.
- They are more economical for spans ranging from 200m to 1600m according to the literature till date.
- Horizontal component of stay forces, which causes compression in deck, favor a concrete deck structure. This stay force component is utilized to prestress the concrete.
- Erection of the super structure and the stays are relatively easier with technology of prestressing, prefabrication and segmental construction procedure.
- They have charming aesthetics.
- Cables are of small diameter as compared to suspension bridges. The tower are taller, however it is geometrical unchanged under any load position on the bridge and the cable is always in state of tension.
- The important characteristics of this bridge are that full participation of transverse structural part in work of the main structure in longitudinal direction. This means considerable increase in moment of inertia in construction, which permits a reduction of depth of girder and consequent saving in steel.

6. Dimensions of Member Property of Cable Stayed Bridge

The dimensions of various sections are considered for the purpose of Design and Analysis of Simple Model of Cable Stayed Bridge as follows:

- Column Sizes = 3.50 m X 1.50 m
- Cross Section of Longitudinal Girder = 1.80 m X 0.45 m
- Cross Section of Cross Girder = 1.80 m X 0.30 m
- Total Length of Bridge = 112 m
- Width of Bridge = 20 m
- Cable thickness = 0.15 m
- Number of Cables = 16
- Thickness of RCC Slab = 0.6 m
- Total Span = 56 m
- Panel length = 7 m

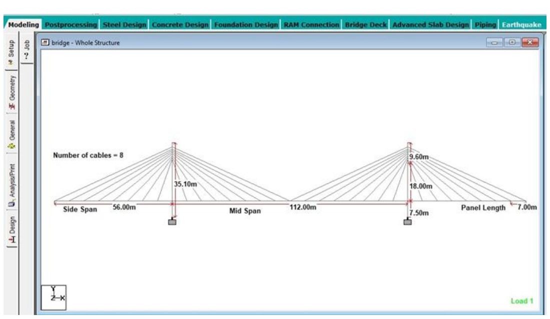

Fig. 12. Dimensions

7. Analysis using STAAD-PRO

The following is the fundamental considerations for the effective use of STAAD-PRO (i.e. Structural Analysis & Design Program software) for the analysis of structures. It must be mentioned however that since STAAD is a computer program. It is therefore recommended that experience of continually using STAAD is obtained, and for important structures parallel hand calculations for the analysis of the structure be done as well [4].

8. Conclusion

- The cable stayed bridges has much greater stiffness than the suspension bridges, so that deformation of deck are reduced.
- Cable stayed bridges were highly statically indeterminate structures and in order to find out exact solution of these highly indeterminate systems and analyze the cable stayed bridge.
- Cable stayed bridges have much greater stiffness since the cables can handle more pressure.
- Here different cables, towers and cable arrangements are considered for the study.
- The difference between cable stayed bridge and suspension bridge lies in how the cables are connected to the towers.
- In cable stayed bridge cables are directly connected to an incline to bridge tower.
- Loading is transmitted to the foundation in sequence as
- To the deck
- To the stay cable
- To the bridge tower
- And lastly to the foundation.
- In suspension bridge the cable rides freely across the tower transmitting the load to the anchorages at either end.

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