Structural components of suspension bridge engineering essay

INTRODUCTION

Suspension bridge is a type of bridge in which the road way or the deck is suspended below the suspension cables. It is a simplest form of bridge which was made of rope and wood in olden days. The modern Suspension bridge developed was in 19th century. In those bridges the cables are carried by using vertical suspender. The two ends of the cables are suspended on towers. The weight of the bridge is transferred to the anchorage system by cables. The anchorage is fixed firmly on concrete blocks or solid rocks . In order to distribute the load evenly and also to protect the cables from breaking, the cables are spread over a large area inside the anchorage.

Historical Background

In early times human beings found it very difficult to cross the stream and a deep gorge to survive. A successful solution found out by early people was to drop a tree between the two banks of the deep flowing stream. This results in the idea of simple beam bridge in early times. Early bridges were made of post and lintel structures, stones or timber or the combination of the both. Later on the use of bamboo or simple rope gave rise to the development of rope suspension bridge. Central and South America and are the first to use rope suspension bridge.

stock-photo-rope-bridge-suspension-bridge-35093119. jpg

Figure: 1 ROPE SUSPENSION BRIDGE

Later on the chain cables were developed when the wrought iron bars became locally available. The first bridge constructed using chain cables were James Finley′s in Westmoreland country, Pennsylvania in 1801. In early

British chain bridges the notable one was Menai bridge with 176m span. One of the longest parbolic arc chain was Clifton Suspension bridge.

menai-bridge. jpg

Figure : 2 MENAI BRIDGE

clifton-suspension-bridge-bristol-gben440. jpg

Figure: 3 CLIFTON SUSPENSION BRIDGE

After the chain cable the wire-cable was developed. Foot â€” bridge at falls of Schuylkill was the first wire-cable suspension cable developed in 1861. The first major bridge constructed using modern methods was Joseph Chaley Grand Pont Suspendu across in Fribourg across the Sarine valley . Its construction was completed in 1834. The first major wire-cable in USA was the Wire â€” bridge at Fairmount in Philadelphia , Pennsylvania, span of 109m and the construction was completed during 1842. A notable bridge was Niagara bridge with250m span in 1855. Later on the American Engineers was constructing Suspension Bridge with higher span length. The notable one among them was are Ambassadar bridge in Detroit with 564m span in 1927, George Washington Bridge in New York with 1006m span in 1931 and Golden Gate Bridge in San Francisco in 1937. Among the parallel wire cables the Otto Beit bridge outside USA was the first Suspension bridge constructed with modern techniques.

golden_gate. jpg

Figure : 4 GOLDEN GATE BRIDGE

STRUCTURAL COMPONENTS OF SUSPENSION BRIDGE

Figure 5 Structural Components of Suspension bridge

The above figure shows the structural components of a three span Suspension bridge. The different parts of a suspension bridge are

Main Cables which support the deck and transfer the loadings to the supporting tower and anchorages.

Deck suspended from the main cables.

Towers to support the main cables.

Hangers which is used to connect main cables and deck

Anchorages to which the ends of the main cables are connected to protect it against any movements.

1. CABLES

The main function of cables is to support the deck which carries the traffic loadings and to transfer these traffic loadings to the towers and anchorages by direct tension forces. Cables are made of high strength steel wires. The tensile strength of the wire is 1550N/mm2. The cables of the Akashi Kaikyo bridge in Japan is made of wires having high strength with minimum tensile strength of 1800 N/mm2. The steel rods from which the wires are manufactured are having higher carbon content. The wire with high tensile strength is obtained by cold drawing the wire. After the final drawing the wire is galvanized for corrosion protection.

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Figure 6 AKASHI KAIKYO BRIDGE

Different types of cables

a. Spiral Bridge Strands

Spiral bridge strands are manufactured by winding several layer of round steel wires in a helical shape onto a straight centre core wire. When layers of wire are laid it should be made sure that an opposite helix to the preceding layer should be laid. Due to twisting of wires spiral strands gets self-compacted under axial loading. As a result of this when the strand is first loaded, non elastic stretch occurs. So in order that the strand should behave elastically, the twisting of wire should be avoided during manufacture. Examples of bridges that have used spiral bridge strand are

Tancarville bridge (france) with span length 608m, Cable size is 56no, Diameter of strand is 72mm. Constuction was completed during 1959

Lillebaelt bridge (Denmark) with span length 600m, Cable size 55no, Diameter of strand is 68. 7mm and 6no 41. 4mm diameter strands. Construction was completed during 1969.

Figure 7 Spiral bridge Strand

b. Locked Coil Strand

Locked coil strands is manufactured in the same way as the spiral strands is manufactured. The only difference between the two is that in locked coil strand the final layer of wires are made up of interlocking Z-shaped wires. As a result of this proportion of the cross sectional area of strand to wire area increases, also a smooth exterior surface is obtained . Examples of bridges that have used Locked coil strands are

Tamar bridge (UK) with span length 335m cable size 31no, Diameter of strand is 60mm. Construction was completed during 1961.

Rodenkirchan bridge (Germany) with span length 378m, Cable size 37no, Diameter of strand is 69mm. Construction was completed during 1954.

Askay bridge (Norway) with span length 850m, Cables size 21no, Diameter of strand is 99mm. Construction is completed during 1993.

There are two types of arrangements that can be provided for spiral strands and locked coil strands. One of them is close packed hexagonal formation which has the advantage that the cross-section can be circularized when aluminium or plastic spacer are added and then wrapped properly against corrosion. The other one is an open rectangular array which is rarely used and doesnot have any wrapping operation as in closed packed hexagonal formation. The cable bands are simple fabricated structure. The disadvantage of open rectangular array is that on increasing wind load on the cable it is difficult to conduct inspection and maintenance on the inner strands.

c. Parallel wire cable

In parallel wire cables, several individual wire over the whole cable length is laid straight and parallel. It is constructed in two ways, by aerial insitu spinning of the wires or by prefabricated parallel wire strands.

Insitu span cables : The aerial spinning method was developed during the 19th century and it was mostly used in long span suspension bridge. In this method using the spinning wheel two or four loops of wire are pulled from one anchorage to the other. During each movement of the wheel, required sag is provided to the wire and the cables are assembled.

Prefabricated parallel wire bands: In prefabricated parallel wire strands bundles of wires are bound together by keeping plastic tapes at intervals and are prefabricated into hexagonal shaped strands. At each end sockets are fitted. The Akashi kaikyo bridge was the first bridge to use the longest prefabricated parallel wire strands with 127 wire strands, with average strand length of 4073m.

2. DECK

The main function of deck is to support the load. The deck is suspended on the main cables by using vertical hangers. The most important load that the deck has to carry is the traffic loadings. The self weight of deck should be low because the deck is carried by the cables. Stiffening girders should be provided in the deck to transfer the loads from the deck to hanger.

3. TOWERS

The main function of tower is to support the main cable. The ends of the main cable is connected to the tower which at a sufficient height to provide cable sag. Tower also support the stiffening girder and side span. The initial loadings on the tower will be the vertical load acting at the top of the tower, applied by the main cables, together with the loads acting on cable and bridge deck due to wind load and load acting on stiffening girder. Flexible fixed base are provided for the tower and cable saddles are fixed on the top of the tower. Due to this type of arrangement any movement in the cable saddle due to varying load will result in the longitudinal bending of the tower legs

4. HANGERS

The main function of hangers is to connect the bridge deck and stiffening girder to the main cables . Vertical hangers are used with equal intervals along the span. Based on using one or two parts of rope, there are two types of hangers.

Two part hangers

Two part hanger was used in long span suspension bridges. In this type of hanger the arrangement is in such way that over the main cables the hanger is drapped which is located in the groove of corresponding cable band. Using sockets the bottom ends of the two rope of the hanger are connected to the deck. Hangers are usually made of steel wire rope

Single part hangers

Single part hangers ends on the underneath of the cable and it is connected to the lower part of the corresponding cable band by a socket and pin connections. The lower end of the hanger is connected to the deck using simple bearing socket. This type of hanger is made up of spiral strand or parallel wires

5. ANCHORAGES

The main function of anchorage is to support the ends of the main cable and to prevents any movements in the main cable by transferring the force from the main cable to the ground. Since the anchorage has to resist a large force the design of anchorages is very tough unless the ground on which the anchorage is to be positioned is good and also if sound rock is available in the ground.

Avantages and Disadvantages of Suspension bridges

Avantages

1. When compared to other bridges, higher spans can be provided for the main span in suspension bridge.

2. Construction cost can be reduced in Suspension bridge due to less material used when compared to other bridges

3. No access is required below during construction of suspension bridge when compared to other bridges. Only for the installation of initial temporary cables the access is required.

4. Suspension bridge can prevent earthquake movements than other bridges.

5. Suspension bridge can be constructed at heights above the waterways to allow the passage of tall ships.

Disadvantage

Bridge deck vibrating due to heavy wind is prevented using aerodynamic profiling.

The deck stiffness of suspension bridge when compared to other bridges is very low. Due to this it makes the bridge very difficult to carry heavy rail traffic.

The foundation work is costly and requires more area to combat the effect of heavy load on foundation towers , when Suspension bridge is constructed on soft ground.

NON LINEAR ANALYSIS OF SUSPENSION BRIDGE

Suspension bridges was considered as the most efficient and remarkable in architectural appearance when compared to other structural systems. But suspension bridge has more tendency to get deformed due to the asymmetrical loadings. This kind of displacement is called as kinematical diaplacements. There are many ways to reduce the kinematical displacements in suspension bridges. One of the method is, if flexible cables are used in suspension bridges the local bending stiffness is taken into account while analyzing the stress-strain state. Other method to reduce kinematical displacement is to use rigid cables instead of flexible cables.

Standard hot rolled or welded sections are used to make the structural elements. Also by using rigid cables it provides the required stiffness for the suspension bridge. The technique is not accurate but can be used or rough calculation.

For analysing the suspension bridge made of flexible cables or rigid cables there are some numerical methods. The analysis of suspension bridge made of flexible cable is very difficult when the non-linear behavior is concerned. So it is analyzed based on the assumption that the main cables are made of flexible cables , when only dead load is acting on the bridge its shape is parabola, all other structural elements are made of ideally elastic material, through out the span of the bridge the bending stiffness of the girder is assumed to be constant, the displacements in the hanger is neglected and the load acting on the cable is considered to be uniform. The loading is in such a way that dead load acts on the cable, the stiffening girder and cable supports the live load. By using these assumption the non-linear analysis is done using certain equations. But while analysisng suspension cables with rigid cables these assumptions are not applicable. In rigid cables there is always some bending stiffness. Also the cables are made up of standard welded or steel sections for the suspension bridge to be initially a stabilized. Grigorjevaet al. (2006) proposed a technique for the analysis of suspension bridge with rigid cables.

CASE STUDY

Dynamic Response of the Suspension Span of the SAN FRANSICO-OAKLAND BAY BRIDGE

The dynamic seismic analysis of the suspension span of San Fransico-Oakland bay bridge was modelled to make astudy on the effects on suspension bridge due to ground motions. Due to the combined effect of motions due to tectonic displacements and seismic waves , ground motions are developed near-fault regions for along period. In olden days the seismic design codes for the structures were used based on the past experiences and the historical ground motion instrument and signal processing methods were not accurate. So it was very difficult to measure the ground motions. But the development of Modern broad-band, digital instruments helped in measuring the near-fault motions. The effect of long period motion is different for flexible and rigid structures. Rigid bodies will have a natural frequency higher than 0. 2Hz and for longer wavelength seismic waves it behaves as a rigid body. But for flexible bodies the natural frequency will be low.

Using a finite-element modeling software the structure is modeled. The deck model is a combination of truss, membrane and sway stiffness elements. The steel braced tower is represented by fibre bending elements and the bridge cable is represented by tension-only cable element. The advantage of modelling the structure in this way helps to reduce the degree of freedom which is an essential aspect in the repose of suspension bridge. After the gravity initialization is completed as described in detil by McCallen and Astaneh, 2000 , the explicit integration scheme for non-linear analysis of earthquake motion is done. The ground motions in the near by areas will be affected by various reasons like the superposition of seismic waves, site geological response etc. The effect of these parameters may vary for different ruptures happening in future and these rupture may cause changes displacement in ground, velocities and accelarations.

In this study the effect of rupture and wave propagation were studied by providing a parallel and finite difference in computational simulation of the rupture, a three dimensional finite difference calculation, empirical Green function and at seven points in San Fransico-Oakland Bay Bridge the ground motion is computed. By doing the above said it was found out that the far field in the near source can result in fault with periods of 0. 2 to 0. 5s due to directivity effects and the near field arrivals can result in fault with periods of 0. 2 to 0. 1 s due to tectonic movements. There are chances for these long period arrivals to accur along with the future earthquakes along the Hayward or San Andreas faults which is nearby San Franciso-Oakland bay Bridge and it will affect the long span bridges in San Fransico bridge. Along the Hayward fault , five locations along the suspension span of western San Fransico two rupture model were synthesized for a ground motion of Mw = 7. 25. These were considered as mean and other one as standard deviation models. They were represented as HAY06 and HAY31. The ground displacements at the bridge generated was greater for the mean fault than the standard deviation but the standard deviation produced more acceleration and long durations. Analysis of the model has shown that the mean model produced more stress than the standard deviation. The response of Bay bridge is computed against the ground motion from the rupture model HAY06. Due to this displacements occur which indicates that the flexible deck cannot respond as fast as the towers when large displacement occurs. The tower motion lags and then the deck starts to respond when the tower returns with the ground.