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Cable Stayed Bridges State of the Art Theoretical Review

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Abstract: Long and short bridges are of different kind, the cable stayed brides are used most commonly. The cable stayed bridges are more stable in case of any danger. The bridge is more stable as structure and has less cost maintenance. Choosing a cable stayed bridge is well structured decision of economical characteristics. This kind of the of the bridges have become popular long span bridges. When compared to suspension bridges the cable stayed bridges are more popular. A cable stayed bridge consists of one or additional tower with cables supporting the upper deck. In terms of cable arrangements, the foremost common sort of cable stayed bridges are a fan, harp, and semi fan bridges. Due to their massive size and nonlinear structural behavior, the psychoanalysis of those sorts of bridges is additional sophisticated than the standard bridges? In these bridges, the cables are the most supply of nonlinearity. Obtaining the optimum distribution of post-tensioning cable forces is a critical job and plays a dangerous part in optimizing the planning of cable stayed bridges. This is an optimum style of a cable-stayed bridge with minimum price, whereas achieving strength and utility necessities could be a hard job. This paper discusses a theoretical review of the state of the art process of cable stayed bridges.

Keywords: Bridge, Cable Stayed Bride, Long Stayed Bridge.

I. INTRODUCTION

Cable-stayed bridges are extremely refined and very efficient structures and they are also architectural landmarks. The compounding of multiple simple systems allows for a structure where the function of each of its elements is easily set. When a cable-stayed bridge is chosen, the initial conception phase is of extreme importance. The characteristics of the social organization and whether if it is primarily constrained by structural or architectural reasons must be fixed at an early point in the conception procedure.

The history of cable stayed bridge dates back to 1595, found in an exceedingly book by the Venetian creator (Bernard et al., 1988). Several suspensions and cable-stayed bridges are designed and developed since 1595 like the Albert Francis Charles Augustus Emmanuel Bridge and therefore the Brooklyn Bridge (Wilson and Gravelle, 1991), (Bernard et al., 1988). Cable-stayed bridges are later created everywhere the globe. The Swedish Stromsund bridge, designed in 1955, is thought because the 1st fashionable cable-stayed bridge (Wilson and Gravelle, 1991). The overall length of the bridge is 332 m, and its main span length is 182 m. It had been opened in 1956, and it had been the most important cable-stayed bridge in the world at that point. This bridge was created by Franz Dischinger, from Deutschland, who was a pioneer in the construction of cable-stayed bridges (Tori et al., 1968). The designers realized that cable stayed style needs less material for cables and deck and can be erected abundant easier than suspension bridges (Bernard et al., 1988), (Tori et al., 1968), (Wilson and Gravelle, 1991), (Simoes and Negrao, 1994), (Ren and Peng, 2005), and (Nieto et al., 2009). This is often primarily because of advances in style and construction methodology and therefore the handiness of high strength steel cables. The outstanding feature of this bridge was the concrete tower, which has the shape of an inverted Y (Bernard et al., 1988). In what follows, the most sorts of long span bridges are reviewed below.

A. Bridge with long Span

Mainly two types of the bridges are most commonly seen with advanced technology and methods. The suspension and the cable stayed bridges.

a. Suspension Bridge

A suspension bridge may be a form of bridge within which the deck, i.e., load bearing half, hangs below suspension cables using vertical suspenders. The vertical suspenders carry the load of the deck.

b. Cable stayed Bridge

A typical cable stayed bridge could be a deck with one or 2 pylons erected higher than the piers in the middle of the span. The cables are connected diagonally to the beam to produce additional supports. Large amounts of compression

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forces are transferred from the deck to the cables to the pylons and into the inspiration. The planning of the bridge is conducted such that the static horizontal forces ensuing from load are virtually balanced to minimize the peak of the pylon. Cable stayed-bridges have a coffee centre of gravity, which makes them economical in resisting earthquakes. Cable stayed bridges offer outstanding study look as a result of their tiny diameter cables and distinctive overhead structure.

The field of dynamic response of cable stayed bridge has increased the attention in recent decades and this type of bridge has become more popular. In most of the research paper dynamic behaviour of cable stayed bridge is studied, but very less research has been performed on hybrid bridges it is alike a compounding of two types of action combine together for more upright purpose. A cable-stayed bridge has one or additional tower (or pylons), from that cables support the span. A special characteristic is the cables that lead directly from the tower to the deck, unremarkably forming a fan-like pattern or a series of parallel communication channels. This can be in distinction to the trendy bridge, wherever the cables holding up the deck are suspended vertically from the most cable, anchored at each terminal of the span and passing between the pillars. [1] The cable-stayed bridge is perfect for spans longer than cantilever bridges and shorter than suspension bridges. This can be the cantilever bridges would quickly grow heavier if the span were prolonged, whereas bridge cabling wouldn't be a lot of economical if the span were shortened.

Cable-stayed bridges are renowned since the sixteenth century and used wide since the nineteenth. Early examples usually combined options from each the cable-stayed and suspension styles, in concert with the famed Brooklyn Bridge. The planning fell from favour through the twentieth century as larger gaps were bridged with pure suspension styles, and shorter ones using varied systems designed of reinforced concrete. [1] It yet again rose to prominence within the later twentieth century once the mix of latest materials, larger construction machinery, and also the have to be compelled to replace older bridges all lowered the relative worth of those styles.

B. General Design of Cable Stayed-Bridges

The primary structural parts of a cable stayed bridges are the upper deck, docks, and towers therefore it remains. The deck supports the weight and transfers them to the stays and to the piers through bending and compression. [2] The stays transfer the powers to the towers that transmit them by compression to the foundation. The suspension is typically one among 2 main varieties, with the stays anchored in the highest of the tower (Fan) or the anchors are distributed on the length of the tower (Semi-Fan and Harp). This technique directly affects the amount of axial load and hence the elastic support given to the deck and to the tower. The cable-stayed bridge's static system will change based on the conditional support of the deck at the abutments and also the weather there are peers within the aspect spans. The affiliation between the deck and therefore the tower is additionally of nice importance. This technique primarily affects however, effectively the structure carries live masses. The longitudinal system is characterized by the quantitative relation of the peak of the towers to the central span, the connection between the central span with the facet spans, the association of the deck to the approach span, and therefore the magnitude relation of stiffness of the deck and therefore the towers. The geometry of the tower depends on the sort of the suspension (Fan, Semi-Fan, or Harp), the shape of suspension at the deck (with centre or facet anchors), whether or not the deck rests directly on the tower, and therefore the obtainable area for anchoring and tension of the stays within the tower.[1,2]

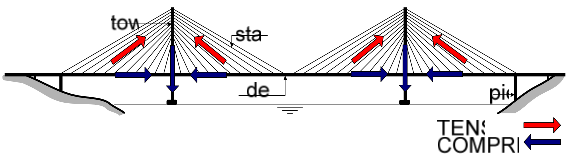

Figure II.1: Cable Stayed Bridge tension and compression

The material chosen for the tower depends on the characteristics of the foundation soil, the development speed, and therefore the construction method. The cross section of the deck influences the entire structure of a cable-stayed bridge owing to its characteristics of self-weight and mechanics. Most cable-stayed bridges typically adopts a 1 method concrete block. Once a central suspension is adopted the deck should offer torsional support. In those cases the stiffening beam of the cable stayed bridges are going to be in an exceedingly cellular box theme. [2]

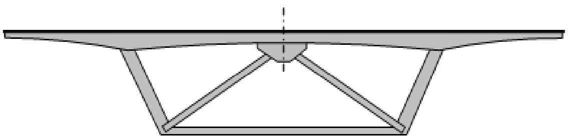
Figure II.2: Box section Bridge Deck

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When a multi-cable arrangement is accepted (usually aspect supported) the deck is an open beam cross section. Bridges with terribly long spans ought to use cross sections with high torsional stiffness.

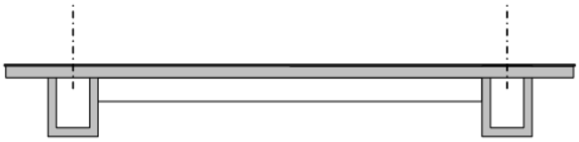

Figure II.3: Open Grinder Cross section of Bridge Deck

The anchoring of the stays in the deck is usually made by embedment of the anchors in the concrete stiffening girders. In composite bridges the anchors can be aligned with the stiffening girder or placed in an exterior position (under or in the slab plan). The construct of a cable-stayed bridge is straightforward. A bridge carries primarily vertical hundreds functioning on the beam. They keep cables give intermediate supports for the beam so it will span a protracted distance. The fundamental structural variety of a cable-stayed bridge may be a series of overlapping triangles comprising the pylon, or the tower, the cables, and also the beam. Of these members are underneath preponderantly axial forces, with the cables underneath tension and each the pylon and also the beam underneath compression. Axially loaded members are usually additional more economical than flexural members. This contributes to the economy of a cable-stayed bridge. At the last count, there square measure concerning 600 cable-stayed bridges within the world and the variety is also increasing quickly. The span length additionally magnified considerably. [4, 5]

a. Layout of Cable Stayed Bridge

At the first stage, the concept of a cable-stayed bridge was to use cable suspension to switch the piers as intermediate supports for the beam in order that it might span an extended distance. Therefore, an early cable stayed bridges placed cables so much aside from one another supported the utmost strength of the beam. This resulted in rather stiff girders that had to span the big spacing between cables, additionally to resisting the world forces. The behaviour of a cable-stayed beam may be or so simulated by an elastically supported beam. The bending moment within the beam below a particular load may be thought of as consisting of a local element and a worldwide element. The native bending moment between the cables is proportional to the square of the spacing. The world bending moment of an elastically supported beam is or so. [3,4]

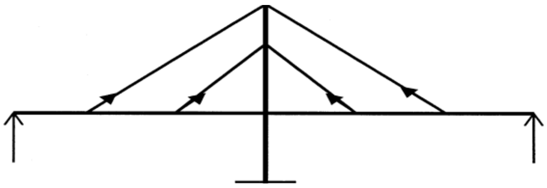

Figure II.4: Conceptual layout of the cable stayed bridge

The elastic support bending can be approximately be determined as:

$$M = c * p * \sqrt{I/_{k}}$$

Equation 1: Bending Moment of Elasticity

The equation above can be explained as c is the coefficient of the type of the load, p is the load applied to the bridge. I is the moment of inertia of the beam, where the k is the support constant with elastic nature. The support constant is derived based on the stiffness of the cable. The overall bending moment M is directly proportional to the moment of Inertia I, i.e. when the moment of Inertia decreases there is a decrease in the overall moment.

Features	**Bridge Name**	**Country**	**Span (m)**	**Year of Completion**
First successfully built cable-stayed bridge	Stromsunde	Sweden	183	1955
First bridge with closely spaced cables	Bonn–Nord	Germany	280	1967
All-steel open-deck plate girder	Knie	Germany	320	1969
Center spine, single plane, all steel	Neuenkamp	Germany	350	1971
First major concrete span, box spine girder	Hoescht	Germany	148	1972

Table II-1: World's 5 earliest cable Stayed Bridges

The table above details about the bridges constructed around the world which are structured with cables. The duration of construction and the year of completion is been given in the table. Cable stayed bridges with first of its kinds are been constructed only after 1955. Not more than six decades this modern structure is been designed and successfully constructed.

II. LITERATURE REVIEW

In this section, we review the previous works on style of cable stayed bridges offered within the literature is given. Simoes and Negrao (1994) planned an entropy-based theme for value optimization of cable stayed bridges. During this technique, the post-tension cable forces don't seem to be included during this analysis and therefore the variety of keep cables additionally because the length of the span is assumed to be constant. Long et al. (1999), has used an economical algorithmic rule supported internal penalty algorithm to optimize the value of cable-stayed bridges. The same as the theme given by Simoes and Negrao (1994), the pylon height, span length, and therefore the range of keep cables received a pre-assigned worth. Also, during this work the result of posttensioning forces of cable stays has not been thought-about within the optimisation technique. A protrusive scalar perform has been utilized to optimize the cost of the deck in cable-stayed bridges by:

A. Simoes and Negrao (2000)

During this time, post-tensioning forces of keeping cables also are thought-about. The convex scalar operates combines the dimensions of the bridge and therefore the post-tensioning cable forces. Note that during this scheme pylon height and span length aren't thought-about as style variables during this optimization technique.

B. ShideHu and Aijun Ye (2000) Seismic Conceptual Design of Long-Span Cable-Stayed Bridge.

For a long-span cable-stayed bridge, the seismic performances highly dependent on the seismic conceptual design instead of numerical design. In the paper, based on the seismic response analysis of more threaten long-span cable-stayed bridges, the seismic conceptual design is discussed in the following four aspects:

1. A Choice of deck type: Composite deck, hybrid deck composed of composite deck in the main span and concrete deck in side spans, are compared from a seismic design viewpoint.

2. Choice of deck-tower connection manner: Three connection manner no connection, elastic connection and rigid connection are discussed. The effect of elastic stiffness on the seismic response of cable-stayed bridges is analysed, and suitable stiffness are proposed.

3. Arrangement of sidebars: Considering that several sidebars are often adopted in hybrid cable stayed bridges, the effect of derangement of side piers on dynamic behaviour is analysed.

4. Choice of deck-side pier connection manner: The deck-side pier connection manner in the transvers direction is discussed from a seismic design viewpoint. For a cable stayed bridge with several side piers, the best connection manner is analysed and discussed. The conclusions of topper will provide guidance and reference for the seismic design of long span cobblestoned bridges.

C. Jajnic et al. (2003)

Given an economical idea to look out best tensioning strategy for the development of cable-stayed bridges during which 3 main sources of non-linearity are thought of. Also, bending moment distribution at the deck connections is used to search out the optimum cable forces.

D. Paolo Clemente Et Al (2004) SeismicAnalysis of the Indiano Cable-Stayed Bridge.

This paper presents result of observed and analytics of the dynamic response of the Indian Cable-Stayed Bridge influence, Italy. The observed part is based on traffic-induced vibration tests, which allowed extracting the dynamic characteristics of destructor in terms of resonance frequencies, mode shapes and damping. These areas compared with those obtained from finite element model for which the geometrical characteristics and the mechanical properties of the materials used in structural design of the bridge have been adopted. To supplement these analyses, equivalent static analyses were performed to yield amplitudes of response and stressing structural elements. This version of analysis was performed by response spectrum technique using uniform response spectra expressed in terms of pseudo-velocities as input. The response spectra were obtained from contemporary, seismic hazard studies performed in Florence site.

E. Sung et al. (2006)

Studied optimum post-tensioning cable forces for cable-stayed bridges. It's shown that the higher limits on cable forces for the cable-stayed bridges are because of a burden. During this work, post-tensioning forces of keep cables ar taken into account. The Mau-Lo Hsi cable-stayed bridge situated in Taiwan is taken into account as a case study.

F. Lee et al. (2008)

Planned an improvement of tensioning strategy for uneven cable-stayed bridge and its result on the development method. Unit load technique (ULM) into consideration because it will take into account the particular construction method whereas other approaches are supported configuration of the ultimate structure solely. The numerical results are given to indicate the validity of the planned approach.

The current method is the optimized methods from the above given methods and optimization. The methods we use in this research and deployment is a hybrid methods using elastic fittings with spring / rubber on the deck. The methods are combination of cable stayed and in case of damage the spring retrofitting play and stable role.

G. Shinae Jang et al. (2010)

Structural Health Monitoring of A Cable-Stayed Bridge Using Smart Sensor Technology: Deployment And Evaluation.Structural health monitoring (SHM) of civil infrastructure using wireless smart sensor networks (WSSNs) ah as received significant publication in recent years. The benefits ofaWSSNs are that they are low-cost, easy to install, and provide effective data management via on-board computation. This paper reports on the deployment undervaluation of a state-of-the-art WSSN on the new Jindo Bridge, a cable-stayed bridge in South Korea with a 344-m main span and two 70-m side spans. The central components of the WSSN deployment are the Imote2 smart sensor platforms, a custom-designed multi metric sensor boards, base stations, and software provided by the Illinois Structural Health Monitoring Project (ISHMP) Services Toolasuite. In total, a70 sensor nodes and two base stations have been deployed to monitor the bridge using an autonomous SHM application with excessive wind and vibration triggering the system timesheet monitoring. Additionally, the performance of the system is evaluated in terms of hardware durability, software stability, and power consumption energy harvesting capabilities. TheaJindo Bridge SHM system constitutes the largest deployment of wireless smart sensors for civil infrastructure monitoring to date. This deployment demonstrates the strong potential of WSSNs for monitoring of large-scale civil infrastructure.

H. Hyejin Yoon et al (2013) Conceptual Design of Hybrid Cable-Stayed Bridge with Central Span of 1000 m Using UHPC.

Ultra-high performance concrete (UHPC) is featured by compressive strength 5 times higher than that of ordinary concrete and by high durability owing to the control of the chloride penetration speed by its dense structure. The high strength characteristics of UHPC offer numerous advantages like the reduction of the quantities of cables and foundation base design of lightweight super structure in focus of the long-span bridge preserving its structural performance through axial forces and structures governed by compression. This study, conducted the conceptual design of a hybrid cable-stayed bridge with central span of 1000 m and exploitinga200 MPa-class UHPC. The economic efficiency of the conceptual design results of the hybrid cable-stayed bridge with central span ofa1000 m and of Sutong Bridge, the longest cobblestoned bridge in the world, was analysed.

I. Nitin P Kataria, RS Jangid (2016) Seismic protection of the horizontally curved bridge with semi-active variable stiffness damper and isolation system

Seismic vibration because of earthquake will injure the incurvate bridges that are the most interconnecting element for traffic separation structures of the urban transit. Failure of bridges throughout and once an unstable event is vulnerable as bridges are lifeline structures. This work investigates the appliance of semi-active variable stiffness will damp for an unstable management of the horizontally incurvate bridge isolated with completely different passive devices. The most objectives of the study are to research the effectiveness of the hybrid system and to search out the optimum hybrid system for the unstable management of the incurvate bridge with completely different management laws of a damper. The chosen bridge could be a three-span continuous concrete beam supported on piers and rigid abutment. The upper deck is sculptural as one spine beam and therefore supporting the pier is sculptural as linear lumped mass system. The bridge is worked up with four completely different ground motions having different ground motion characteristics with all three-ground motion parts (horizontal still as vertical). The results of the analysis demonstrate that the utilization of semi-active variable stiffness damper with completely different Isolators is extremely effective in dominant the response of the incurvate bridge. The mixture of semi-active variable stiffness damper and lead rubber bearing will offer an efficient means for overall unstable management of the incurvate bridge. The utilization of changes shift management law for damper is as effective as shift management, law with less variety of sensors.

J. Camara, A. (2017). Seismic Behaviour of Cable-Stayed Bridges: A Review. Medcrave Online Journal of Civil Engineering.

The seismic style of cable-stayed bridges follows 2 main approaches: (1) capability style, during which the damage is focused at bound plastic hinges distributed on the structure and designed to accommodate the desired rotation capability, and (2) mitigation style, during which special-purpose devices are installed to concentrate the seismic harm and to stay the most structure within the elastic vary. Nowadays, seismic mitigation looks to be the popular possibility within the style of cable-stayed bridges set in earthquake-prone areas as a result of the towers will stay basically elastic. This can be powerfully judicious considering the key role of the towers within the structural integrity of a cable-stayed bridge and therefore the advanced reparation of their massive sections. What is more, vital displacements are assumed and expected in cable stayed bridges as a result of their massive flexibility, therefore, the increment of the displacement demand by using anti-seismic devices isn't commonly problematic. Moreover, cable-stayed bridges, gift terribly low damping values and it's recommendable to feature auxiliary sources of energy dissipation.

K. Ahad Javanmardi, et. Al, (2017) Seismic response characteristics of a base isolated cable-stayed bridge under moderate and strong ground motions

A summarized comparison of most unstable responses of the cable-stayed bridge. The performance comparison of the first configuration (non-isolated) and isolated cable-stayed bridge showed that the isolation system is absolutely able to mitigate the unwanted response of the structure below harmful unstable loads. In alternative words, the general unstable performance of the cable-stayed bridge is remarkably improved by utilizing the bottom Isolators at the deck-tower connections and also the supports. To boot, the isolates are able to minimize the transmission of unstable forces from substructure to structure, and hence, mitigate the harm to the structure. Following this, because the bridge is an existing structure that is found in high unstable zone and suffered damages attributable to earlier, unstable excitations, the bottom isolation system is often thought of as a potential alternative resolution for unstable retrofitting strategy.

In this study, the unstable behaviour of an existing steel cable stayed bridge equipped with LRBs has been investigated. The insulators are designed for the strongest earthquake and enforced at abutments and deck-tower affiliation of the cable-stayed bridge. The bridge unstable responses in longitudinal and crosswise directions are evaluated through bi-directional moderate and powerful earthquakes. In line with this purpose, a 3D Fe model of the bridge has been developed and also the nonlinear dynamic time-history analysis of the bridge has been performed. Nonlinearities sources and abutments elevation distinction of the cable-stayed bridge are taken into thought within the numerical modelling.

III. CONCLUSION & FUTURE SCOPE

The theoretical review explains that cable stayed bridges are more stable when compared to any other long or short stayed bridge. The reviews discuss the structural imbalances and balances during earthquakes and other damaging conditions.

The future scope of the paper is to study the retrofitting’s in the case of damages. The types of retrofitting’s used in cable stayed bridges. Designing the bridges with and without retrofitting’s.

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