Long-Span Suspension Bridge: A Review

[1]Alay Panchal,[2]Dr.K.B.Parikh,[3]Prof. A.R.Darji
[1]PG Student, Master of Structural Engineering GEC-Dahod,
[2]Head of Department, Applied Mechanics Department, GEC-Dahod,
[3]Assitant Professor, Applied Mechanics Department, Government Engg. College Dahod, Gujarat, India

Abstract— **This paper present a literature review related to Long-span suspension bridge. The main disadvantages of this kind of structure is increased deformability with their complex deformation patterns, aerodynamic stability and dynamic stress fields have led designers adopt conservative methods for analysis & design. Recent literature is on cable-suspension bridges to understand the complex behavior. In the present study an attempt has been made to study the Significance of suspension bridge & type, multiple type loading such as dynamic load, wind load, live load effect, and design parameters. Comparative study of analysis & design of long-span suspension bridge using software sap-2000, Midas civil, ansys with different hanger's configuration has been included.**

Keywords- **Long-span suspension bridge, design parameter, Structural Analysis, modified hangers, dynamic Stress, Torsion, highway loading, etc.…**

I. INTRODUCTION

In the bridge construction history,Suspension bridge has a special place. To meet the social and economic needs of the community for efficient and convenient transportation systems, more and more long suspension bridges have been built throughout the world. Suspension bridge possesses a number of technical and aesthetic advantages, allowing overlapping average and large spans.This type of structures that can be constructed over long spans, and due to the high accuracy, performance, and computing and control system after implementation, they are safe to use. Many long-span suspension bridges have been built around the world, and most of these bridges are steel structures. Research carried out by the American Society of Civil Engineers (ASCE) indicates that 80%–90% of failures in steel structures are related to fatigue and fracture.When long suspension bridges are built in wind-prone regions, it may cause fatigue damage to steel structural members of a long suspension bridge. Fatigue damage accumulation in long-span suspension bridges and the complexity of the dynamic stress responses due to the combined action of multiple loading, a little research has been carried out for fatigue analysis of long-span suspension bridges under multiple loading. Increase in span length combined with shallow or slender decks in suspension bridges has raised concern on their complex behaviors under the service and environmental dynamic loadings such as the traffic, wind and earthquake loadings. The main disadvantage of suspension bridges is increased deformability, especially under the action of local, dynamic,asymmetric or wind loads. The stiffness and stability of suspension bridge structure can be improved by using special structural measures, like combined systems, inclined suspenders and more other. The way to increase the rigidity of a suspension bridge is to transfer a part of stiffening girder rigidity to a suspension cable. The rigid cables successfully resist the action of symmetrical and asymmetrical loads and retain its original form.The effects of some design parameters on the static performance such as structural system, the cable sag, the side span length, the depth, dead load and supporting system of the deck, etc. have been studied. Therefore, the effects of these design parameters on the aerodynamic stability of long-span suspension bridges needs to be further investigated.

II. LITERATURE REVIEW

Xinjun Zhang & Bingnan Sun[1] performed parametric analyses on the aerodynamic stability of the Runyang bridge over the Yangtze River are performed including the structural system which contain single-span & three span systems with span length, the side span length,the cable sag, dead load,the depth and supporting system of the deck. In designing long-span suspension bridges, the aerodynamic stability becomes a governing factor. By analyses they concludethe continuous deck and the three-span system, short side span are more favorable for bridge. They also found aerodynamic stability of bridge can be greatly improved by increasing the deck depth and the cable sag.

Tatjana Grigorjeva & Algirdas Juozapaitis [2]performednumerical experiment by revised engineering method and by FEM under symmetrical load and asymmetrical load.The analysis and design of suspension bridges with the rigid cables successfully resist the action of symmetrical and asymmetrical loads and retain its original form but with flexible cables are rather complex. They conclude by their results that revised engineering method gives possibility to assess the suspension bridge erection process then the displacement in the middle of bridge span under the action of dead load is zero. They performednumerical experiment and compared the results and it shows that the accuracy of revised engineering method is sufficient for conceptual suspension bridge design.

Majid Barghian, Hadi Moghadasi Faridani [3] took Soti Ghat Bridge—a pedestrian suspension bridge in Nepal as a case study and have attempted to present a new model to remove the defects of both vertical and inclined hangers and proposed one modified hangers. Most of pedestrian suspension bridges, vertical hangers have been usually used and a few of these bridges have been built with inclined hangers. They found modification in hangers reduces the tensile forces of inclined hangers significantly and decreases fluctuations in hanger forces therefore, it decreases fracture due to fatigue in hangers. The axial force of towers in the modified model shows improvement considerably comparing with the two other hanger systems.The maximum vertical displacements of the deck for modified hanger system are almost between the maximum vertical displacements of the deck for two other hanger systems.

Z.W. Chen, Y.L. Xu, Y. Xia, Q. Li, K.Y. Wong[4] proposed a framework for fatigue analysis of a long-span suspension bridge under multiple loading by integrating computer simulation with structural health monitoring system. By taking the example of Tsing Ma Bridge in Hong Kong,first proposed for dynamic stress analysis of the bridge under railway, highway and wind loading and then stress time histories due to the combined action of multiple loading are also compiled. Finally, fatigue analysis is performed to compute the cumulative fatigue damage over the design life of 120 years. The results shows that the railway loading plays the dominant role in the fatigue damage of the bridge. The damage induced by highway loading is greater than that due to wind loading at some locations. Furthermore, it is necessary to consider the combined effect of multiple types of loading in the fatigue analysis of long-span suspension bridges.

Y.L. Xu, T.T. Liu, W.S. Zhang[5] present a systematic framework for assessing long-term buffeting-induced fatigue damage to a long suspension bridge by integrating a few important wind/structural components with the CDM-based fatigue damage assessment method. By taking the Tsing Ma Bridge as an example, they identify stress characteristics at hot spots of critical steel members at different levels of wind speed and direction and accumulative fatigue damage to the critical member during the bridge design life and evaluated by using a CDM-based fatigue damage model by consideration of long-term effects of buffeting forces.The results show that the proposed procedure can well assess the long term buffeting-induced fatigue damage to a long suspension bridge and also show that monsoon wind-induced fatigue damage to the bridge is not significant.

Huu-Tai Thai, Dong-Ho Choi[6]proposed an efficient analysis method for predicting the behavior and ultimate strength of multi-span suspension bridges by taking example of four-span suspension bridge which has two main 3000 m spans with steel box girder and tower and considering geometric nonlinearities of the cable members due to sag effects are captured using the catenary element, while the geometric nonlinearities of the beam-column members due to second-order effects are captured using the stability functions. They performed analyses by taking six different load cases and found the proposed method is of capable tool for predicting ultimate strength as well as behavior of suspension bridge of very large scale structure.

Chin-Sheng Kao, Chang-Huan Kou, Wen-Liang Qiu, and Jeng-Lin Tsai[7]presents a method of reduced stiffness used to analyze the ultimate loadbearing capacity and the failure process of a self-anchored suspension bridge and also investigated were the effects on the load-bearing capacity due to variations in the strength and stiffness of the four substructures and due to broken hangers. The whole suspension bridge failed when the stress in the hanger at the mid-span reached its ultimate stress, stiffness reduced by half, the main cable affected the ultimate load-bearing capacity of the whole bridge most seriously. They found the effect was most prominent when the hangers on either side of the mid-span hanger broke subsequently and hangers broke when the ultimate loadbearing coefficient of the bridge was less than 1.0 and the bridge failed immediately under its own weight. They conclude that the variation in the material strength and structural stiffness of substructures can lead to different degree of influence on ultimate load-bearing capacity of bridge.

Nurdan Memisoglu Apaydin, SelcukBas, Ebru Harmandar [8] investigatedthestructuralbehavior of theFatihSultanMehmetSuspensionBridge. As a consequence of Izmit (1999) and Duzce earthquakes with Mw=7.4, there has been an increased awareness about seismic vulnerabilities of the transportation systems in Turkey, especially in Istanbul. They carried spatially varying ground motions in triple direction were produced for each support of the bridge considering the Mw=7.4 scenario earthquakes on the main Marmara Fault. In order to simulate the ground motions into account, non-linear time-history analysis was carried out, and the results obtained from the analysis were compared to those from uniform support earthquake excitation to identify the effects of multi-point earthquake excitations on the seismic performance of the bridge. They compared to the results obtained from simple-point earthquake excitation, noticeable axial force increase in the cable elements was obtained under multi-point earthquake excitation and cable elements led to increase in axial force at the towers and in shear force at the base section of the tower column. They concluded that the spatially varying ground motions has to be considered for long span suspension bridges, and the multi-support earthquake analysis should be carried out for better understanding of bridge.

Seung-Eock Kim, Huu-Tai Thai [9]proposed efficient numerical procedure for the nonlinear inelastic time history analysis of suspension bridges subjected to earthquake excitations.The geometric nonlinearities of tower and girder members are taken into account by the use of stability functions, while the geometric nonlinearities of cable members are considered using exact analytical expressions of an elastic catenary. A computer program utilizing Newmark's average acceleration algorithm with Newton–Raphson iteration is developed and results are compared with those generated using the commercial package SAP2000.they showed that the good results obtained in a short analysis time prove that the proposed program can effectively be used in predicting the nonlinear seismic behavior of suspension bridges instead of using the time-consuming and costly commercial structural software and they promises to be an accurate and efficient tool for daily use in office engineering design.

A. Romero, M.Solı´s, J.Domı´nguez, P.Galvı´n [10] studied the dynamic soil-bridge interaction in high speed railway lines. In railway bridges, resonance occurs when the load frequency is equal to a multiple of the natural frequency of the structure.Therefore, the dynamic behavior of railway bridges is an important design issue.The vehicle was modelled as a multi-body system, the track and the bridge were modelled using finite elementsandthesoilwasconsideredasahalf-spacebytheboundaryelementmethod.Soil–structure interaction was taken into account by coupling finite elements and boundary elements. They presents the results obtained for a simply supported short span bridge in a resonant regime under different soil stiffness conditions. They found the fundamental periods and damping ratios of the response were higher,resonant train speeds were lower when soil–bridge interaction was considered. Therefore, dynamic effects on railway bridges considering soil–structure interaction are an important issue in structure design.

III. CONCLUSION FROM LITERATURE REVIEW

1. For ultimate strength and behavior of multi-span suspension bridge under the effect of live load we must analyze the structure by taking various live load cases as symmetry and nonsymmetrical through varying span length.
2. By adding some structural measures such as three-span system with continuous deck, increasing stiffness by adding members the aerodynamic stability of bridge can be improved.
3. If long span suspension bridges are subjected of multiple load such as rail load, highway load, wind load then fatigue analysis are must considered by taking combine effect of multiple loading.
4. To improve the aerodynamic stability of structure, use some modified hangers in such a way that they act like bracing.
5. To find ultimate load bearing capacity of substructure the strength should kept reduced by the half while designing the structure.
6. To determine the effect of earthquake load the entirely structure should excited under uniform and spatially varying ground motion at every point.
7. While designing the railway bridges the dynamic effect must check by considering the soil-structure interaction.
8. Some computer program or efficient numerical method should developed which gives an accurate results with the time saving function.
9. Aerodynamic stability of bridge can be greatly improved by increasing the cable sag and the deck depth.

REFERENCES

[1] Xinjun Zhanga, Bingnan Sunb, (January-2004) Parametric study on the aerodynamic stability of a long-span suspension bridge, ELSEVIER, Journal of Wind Engineering and Industrial Aerodynamics Vol.92, Pg. 431–439
[2] Tatjana Grigorjeva & Algirdas Juozapaitis,(2013)Revised Engineering Method for Analysis of Behavior of Suspension Bridge with Rigid Cables and Some Aspects of Numerical Modeling, ELSEVIER, Procedia Engineering Vol.57, Pg. 364 – 371
[3] Majid Barghian, Hadi Moghadasi Faridani, (April-2011) Proposing a New Model of Hangers in Pedestrian Suspension Bridges to Solve Hangers Slackness Problem, scientific research, Engineering Vol.3, Pg. 322-330
[4] Z.W. Chen, Y.L. Xu, Y. Xia, Q. Li, K.Y. Wong, (August-2011) Fatigue analysis of long-span suspension bridges under multiple loading: Case study, ELSEVIER, Engineering Structures Vol.33, Pg.3246–3256
[5] Y.L. Xu, T.T. Liu, W.S. Zhang, (March 2008) Buffeting-induced fatigue damage assessment of a long suspension bridge, ELSEVIER, International Journal of Fatigue, Vol.31, Pg.575–586
[6] Huu-Tai Thai, Dong-Ho Choi, (July 2013) Advanced analysis of multi-span suspension bridges, ELSEVIER, Journal of Constructional Steel Research, Vol.90, Pg.29–41
[7] Chin-Sheng Kao, Chang-Huan Kou, Wen-Liang Qiu, and Jeng-Lin Tsai,(2012) Ultimate load bearing capacity of self-anchored suspension bridges, Journal of Marine Science and Technology, Vol. 20, No. 1, Pg.18-25
[8] Nurdan Memisoglu Apaydin, SelcukBas, Ebru Harmandar, (January2016) Response of the Fatih Sultan Mehmet Suspension Bridge under spatially varying multi-point earthquake excitations, ELSEVIER, Soil DynamicsandEarthquakeEngineering, Vol.84, Pg.44–54
[9] Seung-Eock Kim, Huu-Tai Thai, (August 2010)Nonlinear inelastic dynamic analysis of suspension bridges, ELSEVIER, Engineering Structures, Vol.32, Pg.3845–3856
[10] A. Romero, M.Solı´s, J.Domı´nguez, P.Galvı´n, (July-2012) Soil-structureinteractioninresonantrailwaybridges, ELSEVIER, Soil DynamicsandEarthquakeEngineering, Vol.47, Pg.108–116