EXAMINING STRUCTURAL INTEGRITY OF CABLE-STAYED BRIDGE THROUGH PROGRESSIVE COLLAPSE ANALYSIS WITH SAP2000

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ABSTRACT

This study presents a comparative analysis of progressive collapse in cable-stayed bridges, focusing on various combinations of cable arrangements and pylon geometries. The analysis is conducted using SAP2000 FEM software under static loading conditions. The study evaluates the deflection of the girder, axial forces in the cables, and the bridge's response to critical cable losses. The findings reveal that the deflection of the girder at the opposite side of the pylon cannot be ignored when external cables are lost, with vertical deflection decreasing as the lost cable's location nears the pylon. Results show that after two critical cable losses, the deflection is minimal on the cable loss side and maximal on the opposite side compared to four and six critical cable losses. The study also indicates that adjacent cables to the ruptured cable do not reach tension yield, and the maximum nodal vertical displacement decreases as lost cables near the pylon. In terms of specific configurations, the study finds that the HARP cable arrangement with an H-type pylon yields the highest deflection, while the FAN cable arrangement with an A-type pylon exhibits the least deflection. Moreover, the FAN cable arrangement with an A-type pylon demonstrates the best resistance against progressive collapse, whereas the HARP cable arrangement with an H-type pylon is the least effective. Additionally, the study notes that axial forces in cables increase in the vicinity of the lost cables up to the pylon location and decrease thereafter. Cables near the pylon experience minimal axial forces, reducing the likelihood of cable loss. The FAN pattern generates the highest axial forces, making it more susceptible to cable losses compared to the Harp pattern, which generates the least axial forces.

Keywords: Cable-stayed bridge, Progressive collapse, SAP2000, FEM, Cable arrangement, Pylon geometry, Deflection, Axial forces, Demand capacity ratio.

1. INTRODUCTION

Cable-stayed bridges have been known since the 16th century and cast-off broadly from the 19th.Cable stayed bridges have only become an established solution for long span structures over the last 60 years. This recent domination is due to the progress of consistent high strength steels for the cables and perhaps more decisively, the beginning and widespread use of computers to analyses the intricate mathematical simulations. A cable-stayed bridge has 1 or more *towers* (or *pylons*), from which cables sustenance the bridge deck. A distinctive feature is the cables which run nonstop from the tower to the deck, generally forming a fan-like shape or a series of parallel lines. This is in distinction to the modern suspension bridge, where the cables backup 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.

1.1 Cable Stayed Bridges in India

1 Vidyasagar Setu

The Second Hooghly Bridge is known as Vidyasagar Setu, A Cable-Stayed toll bridge over the Hooghly River in West Bengal. Vidyasagar Setu is longest cable–stayed bridge in India and one of the longest in Asia.

2 Bandra Worli Sea Link
Rajiv Gandhi Sea Link is one of the most stunning bridges in India that connects Bandra Worli and part of the proposed Western Freeway. The Bandra-Worli Sea Link is a civilengineering marvel with 5.6 km long concrete road 420 ft high towers which crosses the Arabian Sea.

3 New Yamuna Bridge
The New Yamuna Bridge is one of the longest cable-stayed bridge in India, connecting thencity of Allahabad to its neighborhood of Naini in Allahabad. New Yamuna Bridge is Constructed across the Yamuna river.

4 Nivedita Setu
A cable-stayed bridge over Hooghly River next to Vivekananda Setu and marvelous attractions of West Bengal. Nivedita Setu is the first bridge in the country that is a single profile cable-stayed bridge.

5 Akkar Bridge
Akkar Bridge is India's first cable stayed bridge located in Jorethang, Sikkim. The Cable- stayed concrete bridge is build over Rangit River on a single tower.

6 Haridwar Bridge
A Cable-Stayed Bridge is located at Haridwar-Rishikesh Road over Ganges river. Haridwar Cable-Stayed Bridge is Asia's only bridge that suspends on mere Cables.

7 Raja Bhoj Cable Stay Bridge
Raja Bhoj Cable Stay Bridge was inaugurated on 26 May 2017, Connecting Kamla Park to VIP Road Crossing. The 220-meter-long cable stay bridge is Madhya Pradesh's first cable stay bridge on the Upper Lake of Bhopal.

Figure.1.1 a) Vidyasagar Setu b) Bandra Worli Sea Link

Figure.1.2 a) New Yamuna Bridge b) Nivedita Setu

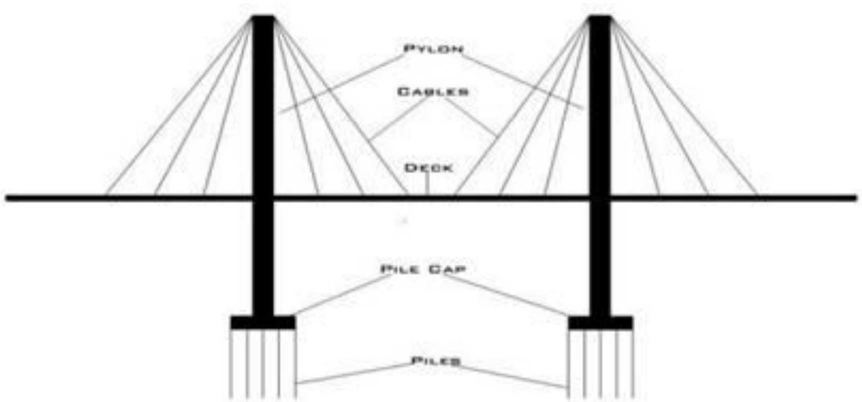

Figure 1.3 Components of Cable Stayed Bridge

2 MODELING OF THE BRIDGES
SAP2000 is the easiest most productive solution for structural analysis and design needs. It can analyses simple 2D frames as well as the complex 3D structures. It is the most suitable finite element tool for modelling and

progressive collapse analysis of cable- stayed bridges. The three types of cable arrangements i.e. Harp, Fan and Radial has modelled by using SAP2000.

3 RESULT AND DISCUSSION

The analysis of deflection of girder and axial cable forces for various combinations of cable arrangements and geometry of pylon are discussed below.

5.1Analysis of Deflection of Girder

The analysis of deflection or the vertical displacement of girder is one of the most significant criteria while the analysis of bridges is considered. The analysis is done for the various cable arrangements with different types of pylons and the maximum deflection of girder is calculated subjected to blast load.

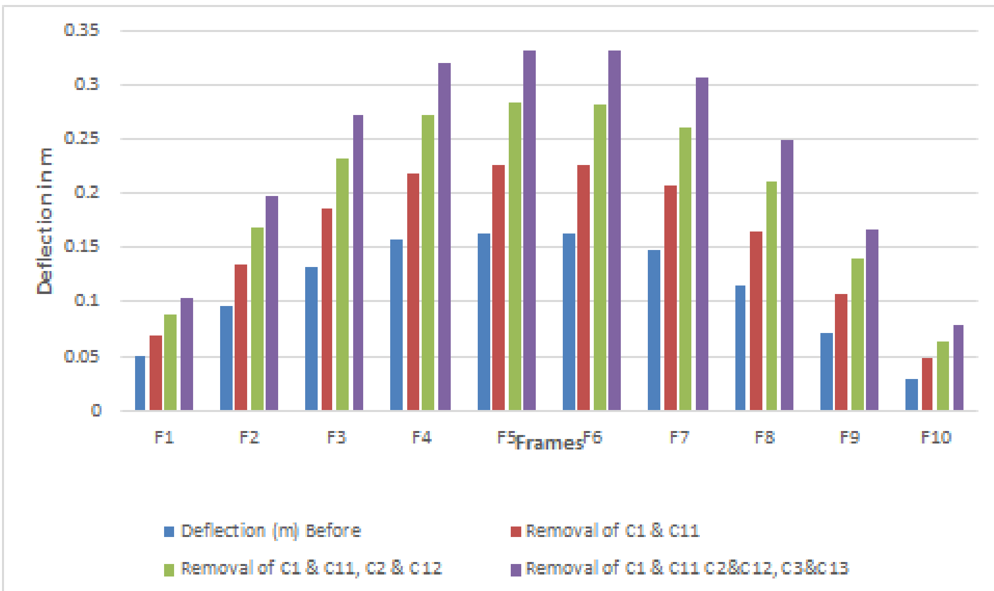

Figure 1.4 a) Deflection of Girder for FAN A-type Bridge

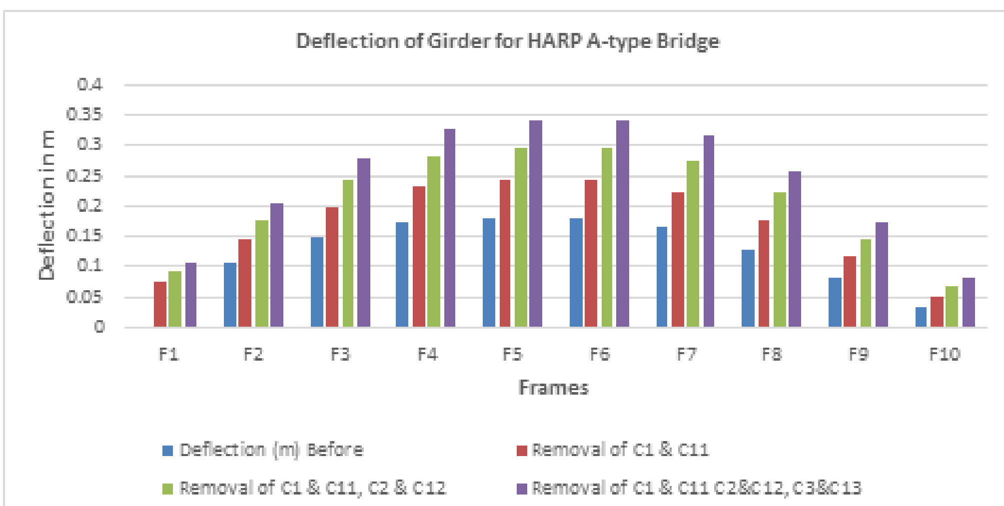

Figure 1.5 b) Deflection of Girder for HARP A-type Bridge

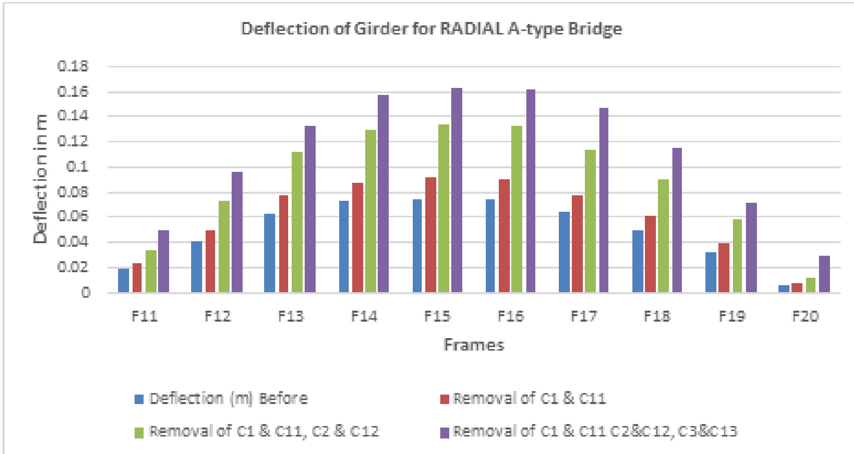

Figure 1.6 b) Deflection of Girder for RADIAL A-type Bridge

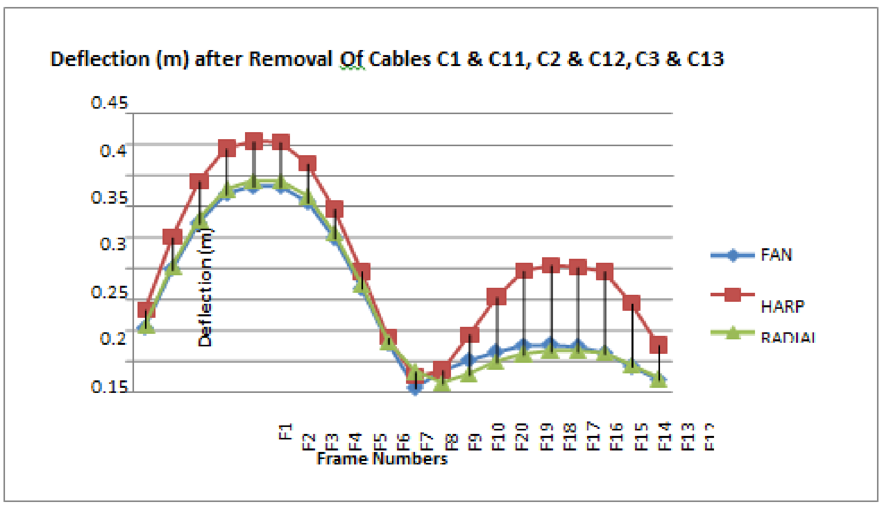

Figure 1.7 Comparison of Deflection of girder for various cable arrangements with cable loss of C1 and C11, C2 and C12, C3 and C13 A-type pylon.

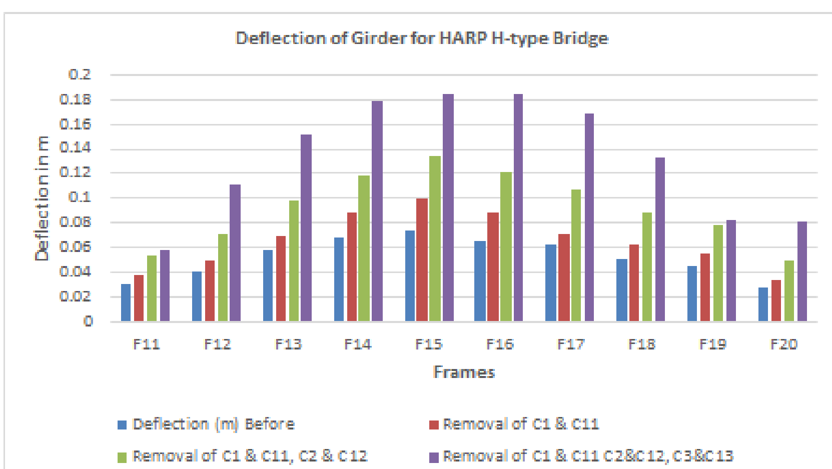

Figure 1.8 b) Deflection of Girder for HARP H-type Bridge

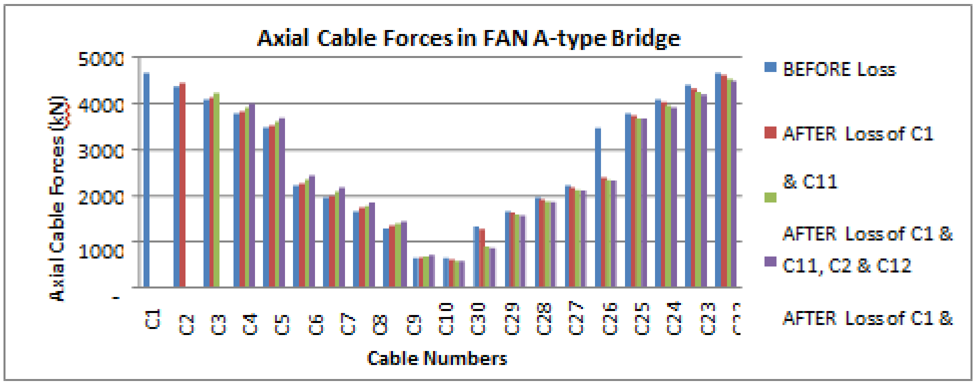

Figure 1.9 Axial force comparison after loss of cables in FAN A- type Bridge

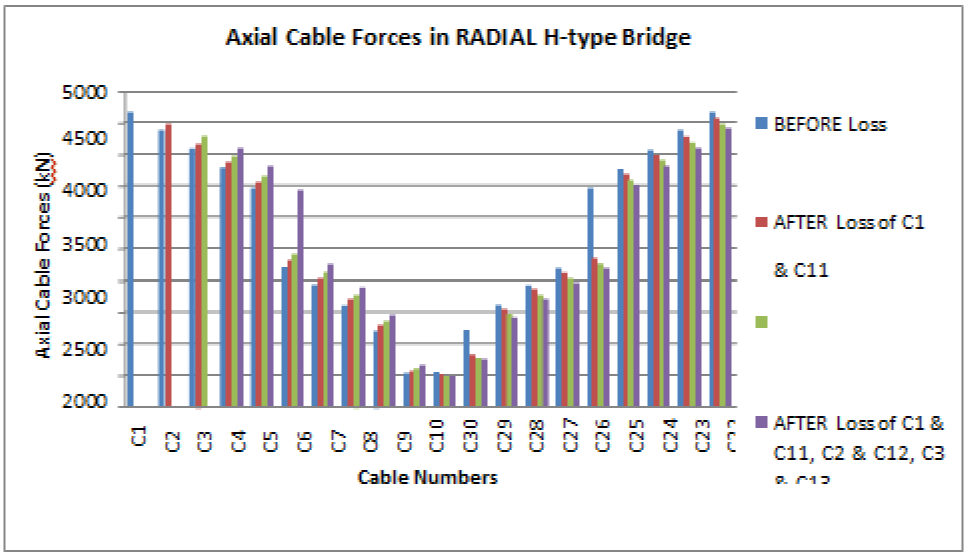

Figure 1.10 Axial force comparison after loss of cables in Radial H- type Bridge

CONCLUSIONS

A Comparative study of Progressive Collapse of Cable-Stayed Bridge having various combinations as per the cable arrangement and pylon geometry is done by using SAP2000 FEM programmer. The static loading condition is considered and the analysis of bridges is done. Based on comparison of the results for the various combinations of cable stayed bridges after the two critical cable loss, four critical cable loss and six critical cable loss, it can be observed that

1. The deflection of girder at the other side of the pylon cannot be considered as negligible under the loss of outside cables. The vertical deflection at the other side of the pylon decreases as the location of the lost cable approaches the pylon.
2. After two critical cable loss deflection obtained is minimum on the cable loss side and maximum deflection on the other side as compared to the four and six critical cable losses. For six cable losses the deflection on the cable loss side is maximum and the deflection on the other side is minimum.
3. The cables adjacent to the ruptured cable do not reach the tension yield and the maximum nodal vertical displacement decreases when the lost cables are near the pylon.

4. When only Cable arrangement is considered the maximum deflection obtained is 0.4714m in HARP cable arrangement with H-type pylon whereas the FAN cable arrangement with A-type pylon gives least deflection0.3317m.
5. In case of cable arrangement with pylon geometry, the FAN cable arrangement with A-type pylon gives best results against progressive collapse. HARP cable arrangement with H-type pylon gives worst results progressive collapse.
6. The axial forces in the cables start increasing in the adjacent of the lost cables up to the location of the pylon, after the pylon, the axial forces in cables starts decreasing.
7. The cables which are in the vicinity of the pylon have very less axial forces, so they have very less possibility of cable loss.
8. The axial cable forces are generated more in the Fan pattern. And least axial forces generated in the Harp pattern. So as per the demand capacity ratio the Fan pattern cables are more susceptible to the cable losses.
9. In case of axial cable forces, maximum percentage increase occurred as 9.049% in FAN cable arrangement with H- type Pylon Bridge.
10. As per the DCR values it can be concluded that the pylon geometry has less significance in the variation of cable forces. These values are very close.
11. FAN cable arrangement with A-type Pylon can be considered as the best possible combination against the progressive collapse.

REFERENCES

1. Allan Larsen and Guy L. Larose (2015), “Dynamic wind effects on suspension and cable-stayed bridges”, Elsevier Journals, Journal of Sound andVibration334.
2. Bo Sun, Paolo Gardoni and Rucheng Xiao (2016), “Probabilistic aerostability capacity models and fragility estimates for cable-stayed bridge decks based on wind tunnel test data”, Elsevier Journals, Engineering Structures 126106–120.
3. Cai J.G, Xu Y.X, Zhuang L.P,(2012) “Comparison of various procedures for progressive collapse analysis of cable-stayed bridges”,Journal of Zhejiang University-Science A.
4. Cheng J. and Jiang J. (2003),“Aerostatic Stability of Long Span Cable-Stayed Bridges:Parametric Study”, Tsingua Science and technology, ISSN 1007-0214, 16/21 pp201-205 Volume, Number2.
5. Das R., Pandey A.D.(2015), “Progrssive Collapse of a Cable-stayed Bridge”, 12th international conference on vibration problems, Elsevier Journals,ICOVP.
6. Fatollahzadeh A. ,Naghipour M (2016), “Analysis of Progressive Collapse in Cable- Stayed Bridges due to Cable Failure during Earthquake”, International Journal of Bridge Engineering (IJBE), Vol. 4, No. 2, pp.63-72
7. General Service Administration, (2003), "Progressive Collapse Analysis and Design Guidelines".
8. Hashemi S.K., Bradford M.A., Valipour H.R. (2016), “Dynamic response of cable- stayed bridge under blast load”, Elsevier Journals , Engineering Structures 127, 719– 736.
9. Kaiming Bi , Wei-XinRen , Pi-Fu Cheng , Hong Hao (2015), “Domino-type progressive collapse analysis of a multi-span simply-supported bridge: A case study”, Elsevier Journals, Engineering Structures Volume 90, Pages172-182.

10. Khan R.A. Datta T.K and Ahmad S. (2006), “Seismic risk analysis of modified fan type cable stayed bridges”, Elsevier Journals, Engineering Structures 28,1275–1285.

11. Kuihua Mei, Yajuan Li and Zhitao Lu (2015), “Application study on the first cable- stayed bridge with CFRP cables in China”, Elsevier Journals, Journal of traffic and transportationengineering.

12. Lonetti P. and Pascuzzo A. (2014), “Optimum design analysis of hybrid cable-stayed suspension bridges”, Advances in Engineering Software 73 (2014)53–66.

13. Liu Y., Han B., Ma Xiao (2011), “Advances in Progressive Collapse of Bridge Structures”, Pacific ScienceReview.

14. Martins A.M.B., Simoes L.M.C., Negrao J.H.J.O. (2015), “Optimization of cable forces on concrete cable-stayed bridges including geometrical nonlinearities”, Elsevier Journals, Computers andStructure.

15. Post Tensioning Institute, (2001). Recommendations for Stay Cable Design, Testing and Installation. Cable-Stayed Bridges Committee,USA.

16. Robin S.H. and Tom A. Wyatt (2016), “Construction aerodynamics of cable-stayed bridges for record spans:Stonecutters Bridge”, Elsevier Journals,ISTRUC-00143.

17. UweStarossek,“Typology of progressive collapse”, Elsevier Engineering Structures 29 (2007)2302–2307

18. Vikas A C, Prashanth M H, IndraniGogoi, Channappa T M. (2013), “Effect of Cable Degradation on Dynamic Behavior of Cable Stayed Bridges”, Journal of Civil Engineering Research, 3(1):35-45.

19. Wolff M. and U. Starossek (2010), “Cable-loss analyses and collapse behavior of cable-stayed bridges”, in Proceedings of the 5th International Conference on Bridge Maintenance, Safety and Management.

20. Yufen Zhou ,Suren Chen (2015), “Numerical investigation of cable breakage events on long-span cable-stayed bridges under stochastic traffic and wind”,Elsevier Journals Engineering Structures 105299–315.

21. Zoli, T.P., Steinhouse J (June 2010), “Some Considerations in the Design of Long Span Bridges against ProgressiveCollapse.