A Study on Progressive Collapse Response of Cable Stayed Bridges using Elastomeric Bearing

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Abstract— In recent studies it has been found that the stays in cable stayed bridges are prone to lose their support at the initial stage due to egregious loads such as earthquake loads, thunder strikes, vehicle impact load and wind loads sudden cable losses are generated in the bridge resulting in an incalculable stress reapportionment on the deck towers as well as the span of the bridge. Design of Cable Bridge is essential considering such a sudden loss. these losses being associated geometrical and material discreteness, the synopsis of egregious loading is analyzed by using linear elastic models in design of cable stayed bridges This paper shows, a nonlinear 3D finite element model of an idealized steel cable-stayed bridge are developed and analyzed with use of elastomeric bearing to determine what is behavior of progressive collapse in bridge with use of elastomeric bearing. The deflection which is equal in both the spans of the bridge converts into major deflection in one span after loss of cable in other span. The use of elastomeric bearing in cable stayed bridges must affect the progressive collapse scenario. The percentage reduction in vibrations of triggered event due to introduction of elastomeric bearing is studied.

Key words: Cable-Stayed Bridge, Discreteness, Progressive Collapse, STADD-Pro, Egregious

I. INTRODUCTION

It is known to us that the stays of cable-stayed bridges are perilous components which are subjected to abrasion, corrosion, wind, vehicle impact and malicious actions and these intense scenarios would lead to abrupt damage and loss of cable(s).Such cable loss scenarios would lead to high impulsive dynamic loads in the structure that can potentially trigger progressive collapse of the entire bridge. Consequently, cable-stayed bridges should be designed for potential cable loss scenarios as recommended by the PTI guidelines (2007).

In cable-stayed bridge structures, stays are exposed to abrasion, corrosion and fatigue processes which may reduce their section and a decrease in their resistance capacity. This decrease in their capacity to withstand the forces transferred by the deck and the pylon can cause the fracture of the cable. The characterization of progressive collapse is by a distinct disproportion between cause and effect, i.e., between a triggering event and the resulting widespread collapse. The triggering event can be a local action or a local lack of resistance that leads to an initial local failure. Such failure can remain limited or it can lead to a collapse progression and cause major damage. When the failure remains limited, the structure is called robust, otherwise it is called non-robust. Normal design procedures do not consider initial local failure and, therefore, do not distinguish between robust and non-robust structures. A uniform level of safety can thus not be achieved, at least not without additional considerations concerning a possible collapse progression after an initial local failure In cable-stayed bridges, the anchorage zone of cables is typically exposed to corrosion, abrasion, wind, vehicle impact and even malicious actions that can cause damage to these zones. Subsequently, damage to these highly stressed zones can lead to loss of cables. Accordingly, in cable-stayed bridges, the potential for progressive collapse due to loss of cables should be thoroughly investigated. One of the cost-effective options for collapse assessment of large scale bridges is to use advanced numerical models (e.g. finite element (FE) models) that can properly capture the local and global response of the structure including material and geometrical nonlinearities.

II. METHODOLOGY

- A thorough literature review to understand the basic concept of the topic like seismic evaluation of bridge structures, progressive collapse and nonlinear analysis by referring books, technical papers or research papers.
- Data collection.
- Progressive collapse with successive cable loss.
- Modeling the cable stayed bridge model 200 meters length, 6 meters wide with two spans and two pylon 60 m high at center using STAAD Pro V8i.
- Carry out analysis of bridge with appropriate dead load and moving load and check in results for deflection and axial forces in cables. This is healthy bridge model without elastomeric bearing (M1).
- Preparing another model with loss of one or more cable(s) in healthy bridge and is analyzed and check for deflection and axial forces in results (M2).
- Carry out analysis of bridge by inserting elastomeric bearings and results for deflection and axial forces in cables. This is healthy bridge model with elastomeric bearing (M3).
- Preparing another model by inserting elastomeric bearing and loss of one or more cable(s) is analyzed and check for deflection and axial forces in results (M4).
- All the models are compared and prepared conclusions.

A. *Model Description*

A cable stayed bridge model for a small river with total length of 200 meters for two lane road traffic is developed. Two Non prismatic steel pylon at centre of two span with deck at 10 meters from bottom. High tension cables connecting pylon and deck. There is no intermediate pier.

Name of parameter	Value	Unit
Length of bridge	200	M
Span	100	M
Single steel Pylon height	60	M
Width of bridge	6	M
Deck stages	40	NOs

Table 1: Key features of the stuctures

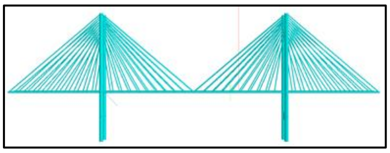

Fig. 1: 2d view of bridge model

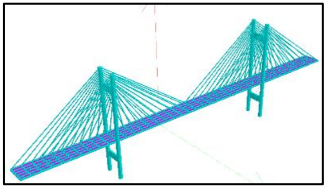

Fig. 2: 3D view of bridge model

B. *Cable Loss Scenario*

Based on PTI (2007) guidelines, for progressive collapse assessment of cable stayed bridges, only the scenarios associated with loss of a single cable are adequate, however, some researchers believe that scenarios in which more than one cable is lost should not be ignored (Wolff & Starossek, 2010). Accordingly, in this paper both symmetrical and unsymmetrical cable loss scenarios with more than one lost cable are considered. The list of considered scenarios including number and location of lost cables, patterns of loading and configurations of the deck is mentioned below.

First unsymmetrical cable number 1 is losses. Then cable 2 and 3. After this, cable symmetrical to 1 loss.

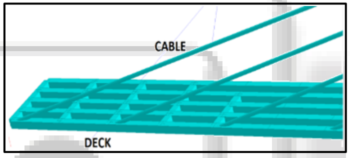

Fig. 3: Bridge Section

III. RESULTS AND DISCUSSION

A. *Healthy bridge (before loss of cables)*

The longitudinal profile of the deck, cable stresses and stress on top surface of the deck obtained from static analysis of healthy bridge subject to symmetrical traffic load pattern and unsymmetrical traffic load pattern.

In Symmetrical Load scenario, the cable stresses for Decks are almost the same whereas for Unsymmetrical Load scenario the cable stresses for Decks are different.

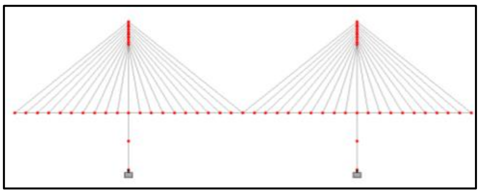

Fig. 4: Node numbers of deck (2D)

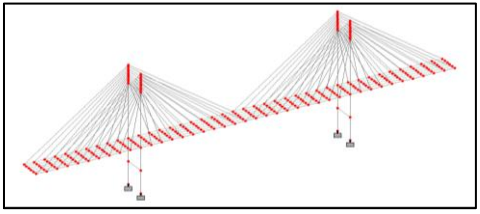

Fig. 5: Node numbers of deck (3D)

Models	Deflection in mm
M1	278.02
M2	318.85

Table 2: Maximum Deflection in M1 & M2

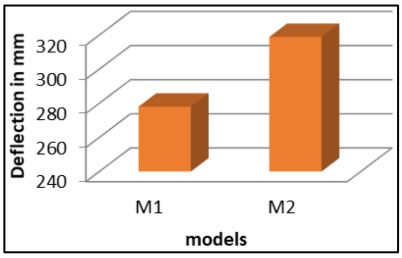

Fig. 6: Maximum Deflection in M1 & M2

Models	Deflection in mm
M1	278.02
M3	312.18

Table 3: Maximum Deflection in M1 & M3

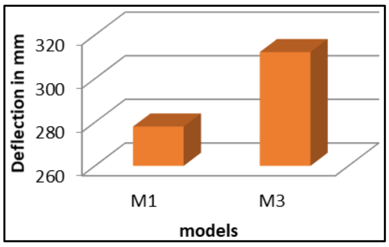

Fig. 7: Maximum Deflection in M1 & M3

Models	Deflection in mm
M1	278.02
M4	303.67

Table 4: Maximum Deflection in M1 & M4

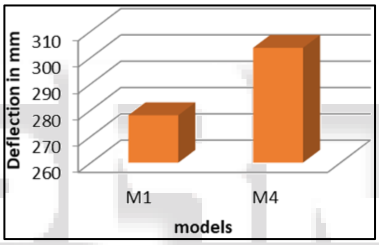

Fig. 8: Maximum Deflection in M1 & M4

Models	Deflection in mm
M1	278.02
M5	299.48

Table 5: Maximum Deflection in M1 & M5

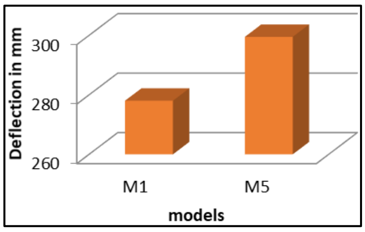

Fig. 9: Maximum Deflection in M1 & M5

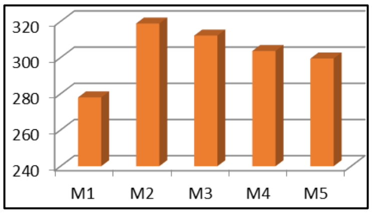

Fig. 10: Deflection in M1, M2, M3, M4, M5

Models	Axial force in KN
M1	1257.74
M2	1425.63

Table 6: Maximum Axial Force in M1 AND M2

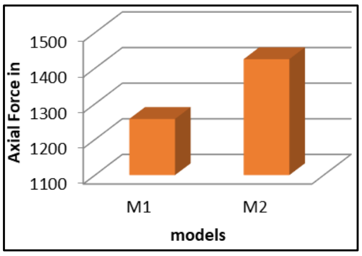

Fig. 11: Maximum Axial Forces in M1 and M2

Models	Axial force in KN
M1	1257.74
M3	1488.05

Table 7: Maximum Axial Forces in M1 and M2

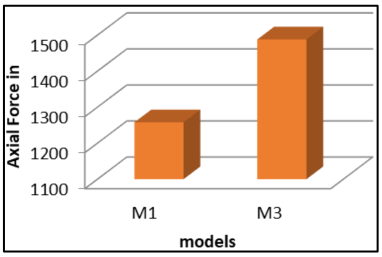

Fig. 12: Maximum Axial Forces in M1 and M3

Models	Axial force in KN
M1	1257.74
M4	1399.8

Table 8: Maximum Axial Force in M1 and M4

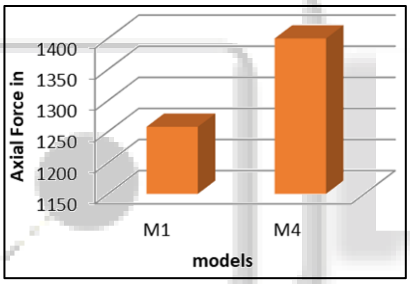

Fig. 13: Maximum Axial Force in M1 and M4

Models	Axial force in KN
M1	1257.74
M5	1378.25

Table 9: Maximum Axial Force in M1 and M5

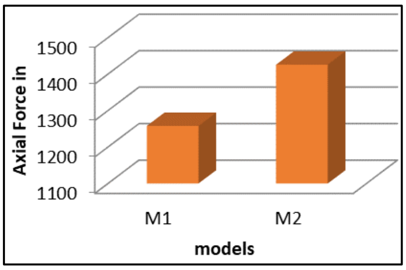

Fig. 14: Maximum Axial Forces in M1 and M2

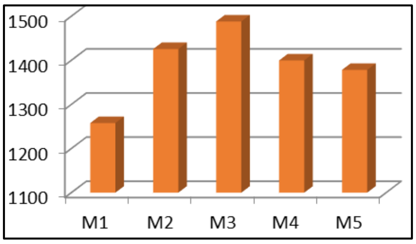

Fig. 15: Axial Forces in M1, M2, M3, M4, M5

B. Cables

Envelop of maximum and minimum tensile stresses in the cables for symmetrical (SL) scenarios are shown in figures. It is seen that the axial stress in the cables is well below the breakage stress of the cables. In addition, the minimum axial stresses in the cables are used for calculating the minimum equivalent modulus of elasticity of cables. It is seen that for the shortest cables connected to the mid-span which would have a minor influence on the response of the bridge. Envelops of the maximum tensile stress in the cables during unsymmetrical scenarios, respectively. It is observable that the axial stress in the cables for the considered unsymmetrical cable loss scenarios is well above the breakage stress of the cables and accordingly in the cable stayed bridge under consideration; progressive collapse is expected to occur due to symmetrical or unsymmetrical loss of two cables. It is seen that for the bridge with Deck subject to unsymmetrical scenario, the minimum E is as low as 0.88E for a cable that can affect the dynamic response and accordingly it should be considered in the progressive collapse assessment of the bridge.

REFERENCES

[1] Mozos, C.M. and Aparicio, A.C. (2010). “Parametric study on the dynamic response of cable stayed bridges to the sudden failure of a stay, Part II: Bending moment acting on the pylons and stress on the stays”, Engineering Structures, Vol. 32, No. 10.

[2] Wolff, M. &Starossek, U. 2010, “Cable-loss analyses and collapse behavior of cable-stayed bridges”, IABMAS2010, The Fifth International Conference on Bridge Maintenance, Safety and Management. Philadelphia, USA.

[3] Yukari Aoki1, Hamid Valipour, BijanSamali and Ali Saleh (2012) A Study on Potential Progressive Collapse Responses of Cable-Stayed Bridges, Advances in Structural Engineering Vol. 16 No. 4 2013

[4] Shankar Nair, R. 2006. Preventing Disproportionate Collapse Journal of Performance of Constructed Facilities, 20(4), 309-314, November 2006.

[5] Wolff, M. &Starossek, U. 2009. Cable loss and progressive collapse in cable-stayed bridges. Bridge Structures, 5:1,17 – 28, March 2009

[6] B Samali, Y Aoki, A Saleh & H Valipour (2015) Effect of Loading Pattern and Deck Configuration on the Progressive Collapse Response of Cable-Stayed Bridges, Australian Journal of Structural Engineering, 16:1, 17-34

[7] Starossek, U. 2011, “Progressive Collapse and Bridge Dynamics”, National Scientific Seminar on Dynamics and Progressive Collapse in Cable-Stayed Bridges, Hanoi, Vietnam.

[8] Starossek U. 2007. Typology of progressive collapse. Engineering Structures, 29(9), 2302-2307, September 2007.

[9] Mozos, C.M. and Aparicio, A.C. (2010). “Parametric study on the dynamic response of cable stayed bridges to the sudden failure of a stay, Part II: Bending moment acting on the pylons and stress on the stays”, Engineering Structures, Vol. 32, No. 10.

[10] Wolff, M. &Starossek, U. 2010, “Cable-loss analyses and collapse behavior of cable-stayed bridges”, IABMAS2010, The Fifth International Conference on

Bridge Maintenance, Safety and Management. Philadelphia, USA.

[11] Yukari Aoki1, Hamid Valipour, BijanSamali and Ali Saleh (2012) A Study on Potential Progressive Collapse Responses of Cable-Stayed Bridges, Advances in Structural Engineering Vol. 16 No. 4 2013

[12] Shankar Nair, R. 2006. Preventing Disproportionate Collapse Journal of Performance of Constructed Facilities, 20(4), 309-314, November 2006.

[13] Wolff, M. &Starossek, U. 2009. Cable loss and progressive collapse in cable-stayed bridges. Bridge Structures, 5:1,17 – 28, March 2009

[14] B Samali, Y Aoki, A Saleh & H Valipour (2015) Effect of Loading Pattern and Deck Configuration on the Progressive Collapse Response of Cable-Stayed Bridges, Australian Journal of Structural Engineering, 16:1, 17-34

[15] Starossek, U. 2011, “Progressive Collapse and Bridge Dynamics”, National Scientific Seminar on Dynamics and Progressive Collapse in Cable-Stayed Bridges, Hanoi, Vietnam.

[16] Starossek U. 2007. Typology of progressive collapse. Engineering Structures, 29(9), 2302-2307, September 2007.