International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 552-565 www.ijaem.net ISSN: 2395-5252

Progressive Collapse of an Extradosed Bridge Utilizing Sap2000

Mr. Rohan Bhavsar [1], Prof.Dr. R. K.Jain [2], Prof. Kanchan Pimple [3]

[1]*Research Scholar, JSPM's Rajshri Shahu College of Engineering, Pune-411033, India.*
[2]*Principal, JSPM's Rajshri Shahu College of Engineering, Pune-411033, India.*
[3]*Assistant Professor, Department of Civil Engineering, JSPM's Rajshri Shahu College of Engineering, Pune-411033, India.*

Submitted: 01-08-2022 Revised: 11-08-2022 Accepted: 14-08-2022

ABSTRACT: Progressive collapse is a major threat causes the more demolitions of structure and leads to the loss and damage of lives. The main causes of the progressive collapse are earthquake and severe wind which results in gradual and successive failure of number of elements of the structure. The present paper includes linear static analytical procedures. For linear static analysis loading is considered as per the Post Tensioning Institute (2001) recommendations and GSA (2003) progressive collapse guidelines. Alternate path (AP) method is used for progressive collapse analysis of the extradosed bridge. The extradosed bridges are modeled in SAP 2000 with various cable arrangements and studied the deflection of girder under static loading condition. Also studied the axial forces developed in the cables under the cable loss. The results are taken with respect to the various cable arrangement and number of cable lost.

Keyword: - Extradosed bridge, SAP2000, Progressive collapse

I. INTRODUCTION

Extradosed bridges have been known since the 16th century and cast-off broadly from the 19th. Extradosed 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 extradosed 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 extradosed bridge is optimal for spans longer than cantilever bridges and shorter than suspension bridges.

A. Extradosed bridges

A typical extradosed bridge is a deck with one or two pylons established above the piers in the mid of the span. The cables are close slantways to the girder to arrange for supplementary supports.
Extradosed bridges may look alike to suspension bridges together have roads that hang from cables and together have towers. But both the bridges support the load of the road in very unlike ways. The variance lies in how the cables are linked to the towers.

Cable stayed spans are basic frameworks which are adequately made out of links, primary braces and towers. A scaffold conveys vertical loads mostly by the support. The staying links give transitional backings to the brace with the goal that it can cover a significant distance. The fundamental basic type of a link stayed connect incorporates a progression of covering triangles containing the arch (or the pinnacle), the links, and the brace. Every one of these individuals are under prevalently pivotal powers, with the links under strain and both the arch and the support under pressure. Pivotally stacked individuals are commonly more effective than flexural individuals.

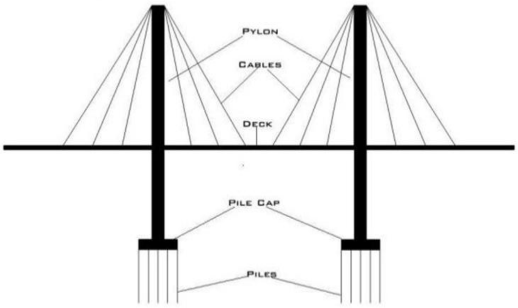


Fig 1. Components of Cable Stayed Bridge

B. Classification based on arrangements of the cables

1. Radial pattern
2. Harp pattern
3. Fan pattern

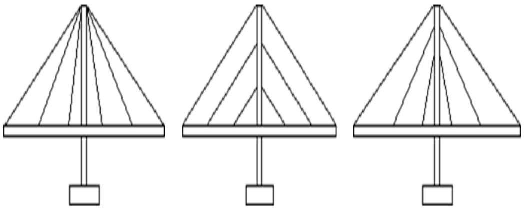


Fig 2 Cable Arrangements a) Radial b) Harp c) Fan

C. Objectives

1. To perform the progressive collapse analysis along with blast load for the extradosed bridge having different cable arrangements and pylon geometry.
2. To compare the absolute displacements of girder and axial cable forces under progressive collapse mechanisms
3. To calculate the demand to capacity ratios for the cables to find out the structural stability against the progressive collapse mechanism
4. To find out the most suitable cable arrangement and pylon geometry against the progressive collapse

II. LITERATURE REVIEW

2.1R. Das et.al (2016)

The authors proposed ‘Progressive Collapse of a Extradosed Bridge’. This study demonstrates modelling and analysis of a typical extradosed bridge through a nonlinear dynamic procedure. The results indicated a decrease in the possibility of failure progression of the extradosed model when the location of the failed cables was closer to the pylon. A definite progressive collapse pattern was also identified along this procedure. The end cables of either side of the bridge are the most vulnerable cables. Rupture in these end cables increases the probability of a failure progression throughout the whole structure. Lesser the distance of the cable from the pylon, lesser will be the chance of failure of the whole structure.

2.2 Bo Sun et al (2016)

This paper presents ‘Probabilistic aero stability capacity models and fragility estimates for extradosed bridge decks based on wind tunnel test data’. Wind resistance design is of vital importance for long flexible structures like extradosed bridges. The developed models are constructed to give balanced estimates of the capacities of interest and properly account of the relevant uncertainties. The measured capacity values from wind tunnel tests are used to determine the subsequent statistics of model parameters through a Bayesian approach.

2.3 Amir Fatollahzadeh et.al (2016)

One of the causes of Progressive collapse is the failure in a number of elements during ultimate events such as earthquake or severe wind. The results show that the mentioned situation during Tabas and Loma Prieta earthquakes will lead to progressive collapse, whereas the structure can withstand two cables removal during the Bam earthquake. To avoid this destruction, six base isolations are installed below the structure.

2.4 S.K. Hashemi et al (2016)

Over the past two decades, blast loads have been recognized as one of the extreme loading events that must be considered in the design of important structures such as extradosed bridges. However, design provisions for blast-resistant bridges are very limited and mostly empirical owing to an inadequate understanding of the local and global dynamic response of the bridge components (piers, deck and cables) subjected to blast loading scenarios. Three different explosive sizes such as small (01W), medium (04W) and large (10W), are considered (W being the TNT equivalent explosive weight index) and placed at different locations above the deck level to determine the influence of the size and location of the blast loads on the global and local response of the bridge components. In certain, the outcomes of the computer recreations are employed to designate the type and extent of harm on the pylon and deck, and also to investigate the likely cable loss circumstances associated with a cost of quay.

2.5M.A. Bradford et al (2016)

Here one of the extreme loading events that must be considered in the design of important structures such as extradosed bridges. Since design provisions for blast-resistant bridges are very partial and frequently empirical outstanding to an inadequate understanding of the local and global dynamic response of the bridge constituents (piers, deck and cables) subjected to blast loading scenarios. Accordingly, this study develops detailed finite element prototypes of a steel extradosed bridge and it is analyzed using an explicit solver. Three different explosive sizes, i.e. small (01W), middle (04W) and large (10W), are considered (W being the TNT equivalent explosive weight index) and placed at different locations above the deck level to define the influence of the size and location of the blast loads on the global and local response of the bridge components.

2.6 Lubomir Matejicka (2021)

presented the safety of bridge users might be compromised by blocks of ice or snow falling from overhead bridge members following a precipitation icing event occurring under specific atmospheric conditions. Due to the growing number of cable-supported bridges around the world, this type of icing events has been increasingly affecting bridge cables. Numerous ice prevention and removal methods for bridge cables have been tested in the last two decades but none has been widely considered suitable for practical application.

2.7 Lubomir Matejicka (2021)

presented the safety of bridge users might be compromised by blocks of ice or snow falling from overhead bridge members following a precipitation icing event occurring under specific atmospheric conditions. Due to the growing number of cable-supported bridges around the world, this type of icing events has been increasingly affecting bridge cables. Numerous ice prevention and removal methods for bridge cables have been tested in the last two decades but none has been widely considered suitable for practical application.

2.8 Aware Satish1, Gaidhankar Karan2, Kale Vaishnavi3, Fulari Kedar4, Arab Abubakar (2019)

Extra dosed bridges are similar to cable stayed bridges. The stay cables are used for strengthening. This new type of bridges has been constructed in Japan. This concept is introduced by J. Mathivat. This paper shows some example and difference between Extra dosed and cable stayed bridges in structural aspects. The structural behavior of Extra dosed bridge differs from that of cable stayed bridge. The paper shows the free vibration and forced vibration behavior of Extra dosed bridge.

2.9 Rohit Ghorpade1, Dr. M.M. Murudi (2019)

Extradosed Bridge resembles similarity to cable-stayed bridges, the difference lies in the tower height and the depth of the girder. Since the introduction of this new type of bridge by J. Mathivat in 1988, these kinds of bridges supported by cables have been constructed globally. The paper aims at studying the Base reaction variation in the Pier due to varying cable geometry, tower height and pylon type. IRC 6: 2017 has been used for loading. Cable geometry will consist of Radial, Mix and Harp type of cable arrangements.

2.10 Collings, D.,and Gonzalez, A. S (2017)

In their research," Extradosed and cable-stayed bridges, exploring the boundaries" helped in understanding the clear difference between an Extradosed bridge and a Cable stayed bridge. An extradosed bridge is a structure where the permanent loads are shared between the stays and girder, but where the girder carries the majority of the live load (βp is 40 to 80, βv is 10 to 50). The load distribution ratio (β) is defined as, β=100 (Key findings led to the understanding that the load distribution ratio, (β) plays a major distinguishing role and hence has to be studied.

III. PROPOSED CONCEPT

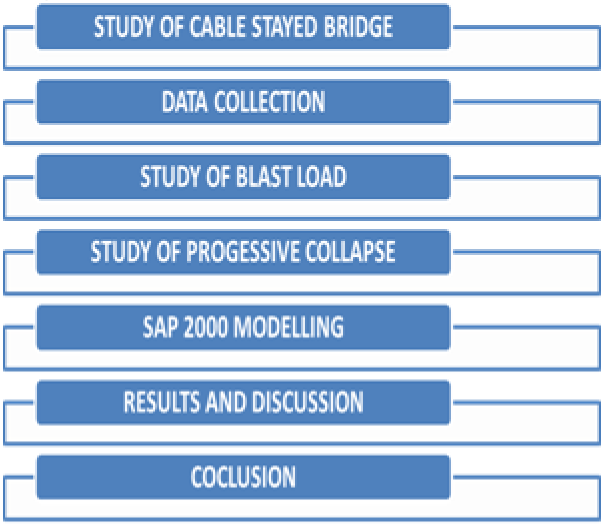
A comparative study of progressive collapse of extradosed bridge using SAP2000 by considering various cable arrangement system and pylon geometry

Table 1. Combinations of cable arrangement and pylon type

Sr.No.	**Cable Arrangements**	**Pylon**
1	Harp Arrangement	A – Type
2		H – Type
3		Y – Type
4	Fan Arrangement	A – Type
5		H – Type
6		Y – Type
7	Radial Arrangement	A – Type
8		H – Type
9		Y – Type

IV. METHODOLOGY

As the bridge with two pylons, three spans i.e. two end spans and one middle span, is quite difficult to analyze. So here bridge with two end spans with single pylon is finalized. The geometrical data is arrived by study of several extradosed bridges built in India and Abroad.



A. Materials Properties.

Ser.No.	Material	Property	Value
1	Structural steel	Yield stress f_{sy}(MPa)	265
		Ultimate strength f_{su}(MPa)	410
		Young's modulus Es(MPa)	205×10^3
		Poisson's ratio μ	0.3
		Ultimate tensile strain e_t	0.25
2	Reinforcing bar	Yield stress f_{sy}(MPa)	250
		Ultimate strengthf_{su} (MPa)	350
		Young's modulus Es(MPa)	200×10^3
		Poisson's ratio μ	0.3
		Ultimate tensile strain e_t	0.25
3	Concrete	Compressive strengthf_{sc}(MPa)	42.5
		Tensile strengthf_{sy}(MPa)	3.553
		Young's modulus E_c(MPa)	32920
		Poisson's ratio μ	0.15
		Ultimate compressive strain e_s	0.045
4	Stud shear connector	Spacing (mm)	110
		Number of rows	2
		Numbers of connectors	68
		Yield stressf_{sy}(MPa)	435
		Ultimate strength f_{su} (MPa)	565
		Young's modulus E_s(MPa)	200×10^3
		Poisson's ratio μ	0.15
		Ultimate strain e	0.045

V. RESULT AND DISCUSSION

A. Modeling of the bridges

SAP2000 is the easiest most productive solution for structural analysis and design needs. It can analyse 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 extradosed bridges. The three types of cable arrangements i.e. Harp, Fan and Radial has modelled by using SAP2000 as shown in following Figures.

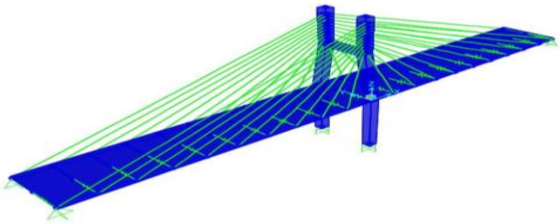


Fig 3. Fan Cable arrangement with H-type pylon

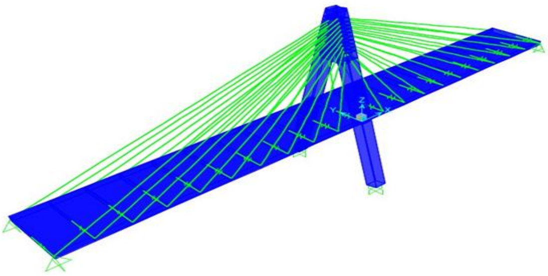


Fig 4. Fan Cable arrangement with A-type pylon

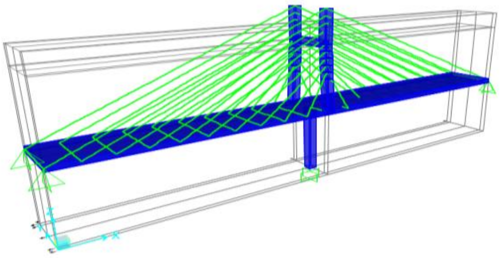


Fig 5 Fan Cable arrangement with Y-type pylon

B. Deflection of Girder for FAN cable arrangement with A- type pylon

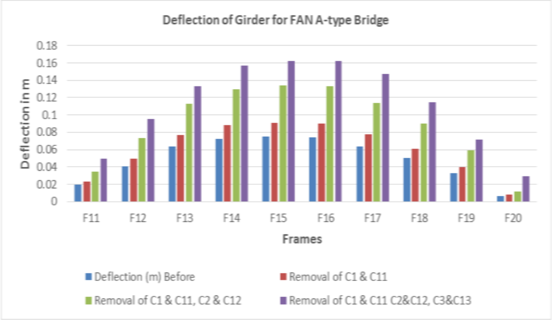


Fig 6 Deflection of Girder for FAN A-Type Bridge

C. Deflection of Girder for FAN cable arrangement with H- type pylon

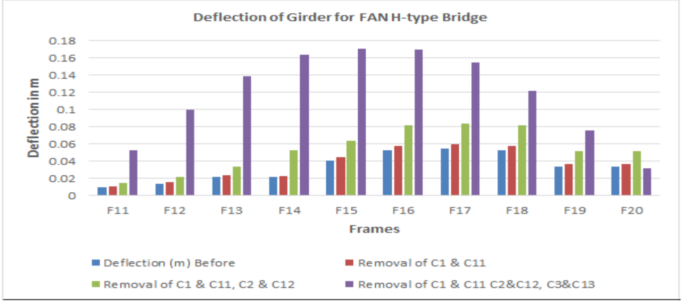


Fig 7 Deflection of Girder for FAN H-type Bridge

D. Deflection of Girder for FAN cable arrangement with Y- type pylon

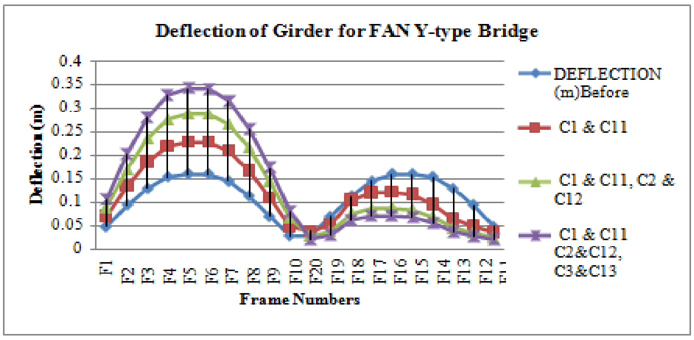


Fig 8 Deflection of Girder for FAN Y- type pylon

Deflection of Girder for FAN cable arrangement with Y- type pylon

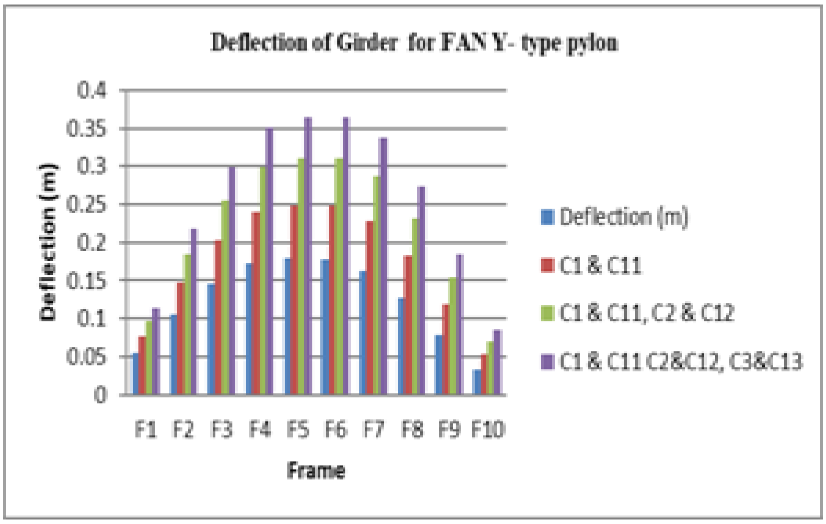


Figure 9 a) Deflection of Girder for FAN Y-type Bridge

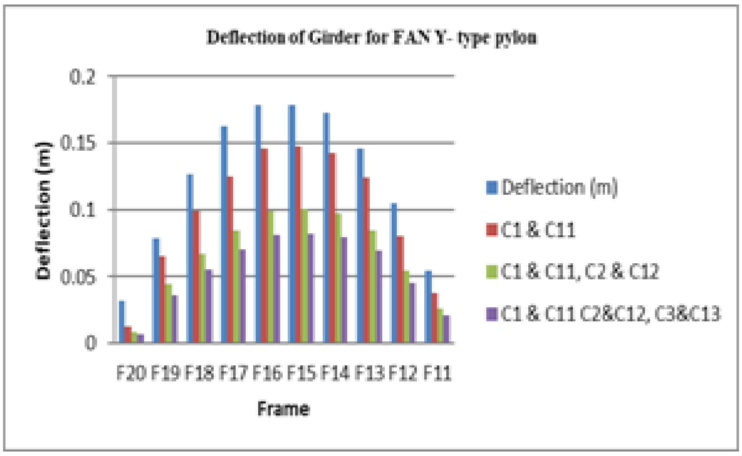


Figure 10 b) Deflection of Girder for FAN Y-type Bridge

Deflection of Girder for HARP cable arrangement with Y- type pylon

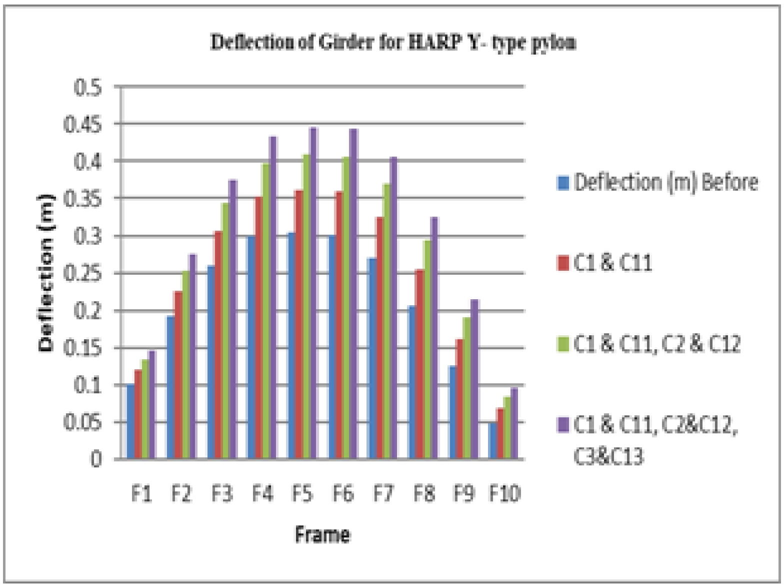


Figure 11 a) Deflection of Girder for HARP Y-type Bridge

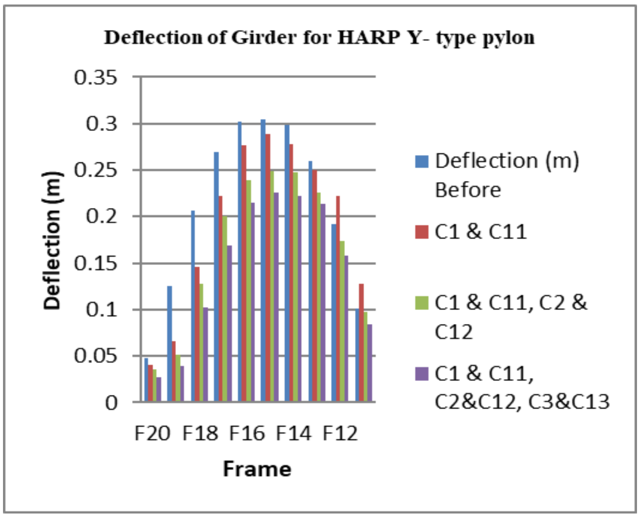


Figure 12 b) Deflection of Girder for HARP Y-type Bridge

Deflection of Girder for RADIAL cable arrangement with Y- type pylon

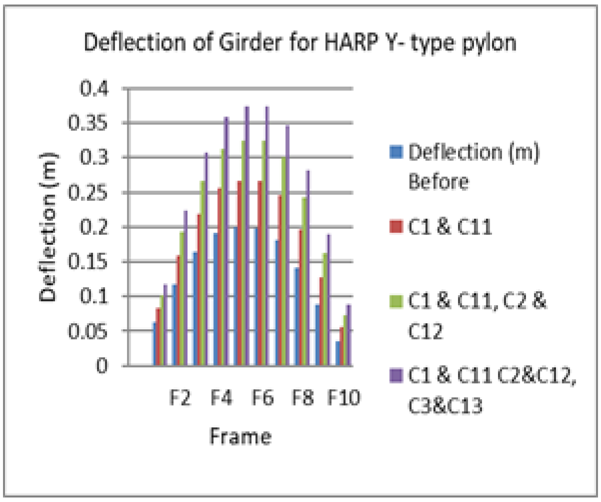


Figure 13 a) Deflection of Girder for HARP Y-type Bridge

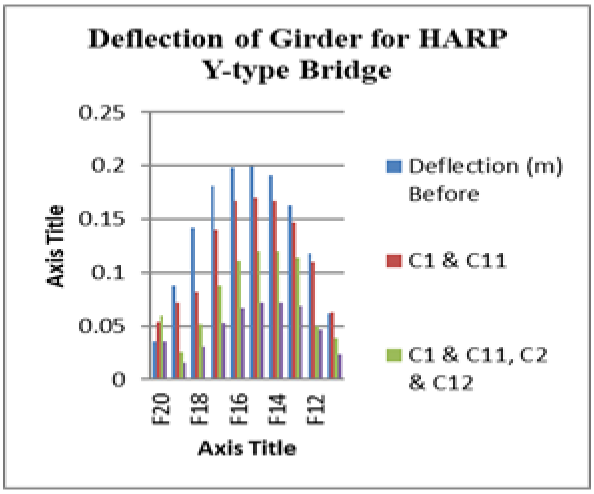


Figure 14 b) Deflection of Girder for HARP Y-type Bridge

Deflection of Girder for FAN cable arrangement with A- type pylon

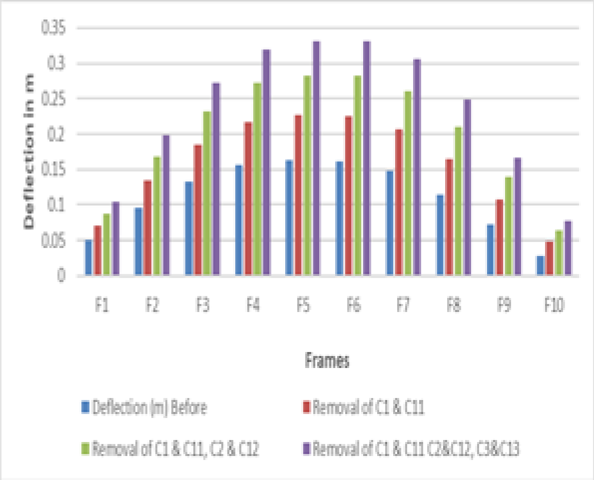


Figure 15 a) Deflection of Girder for FAN A-type Bridge

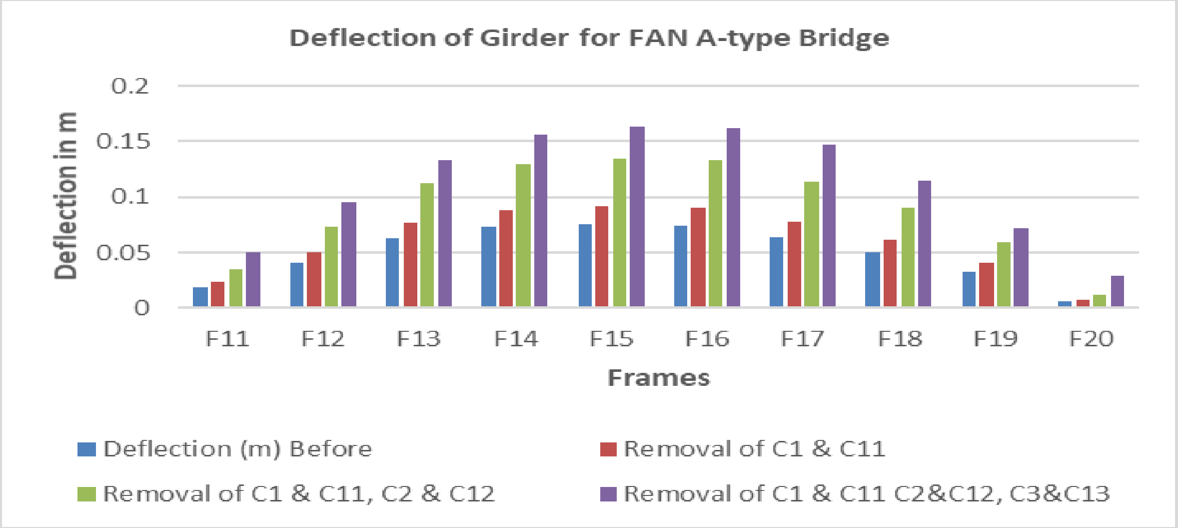


Figure 16 b) Deflection of Girder for FAN A-type Bridge

Deflection of Girder for HARP cable arrangement with A- type pylon

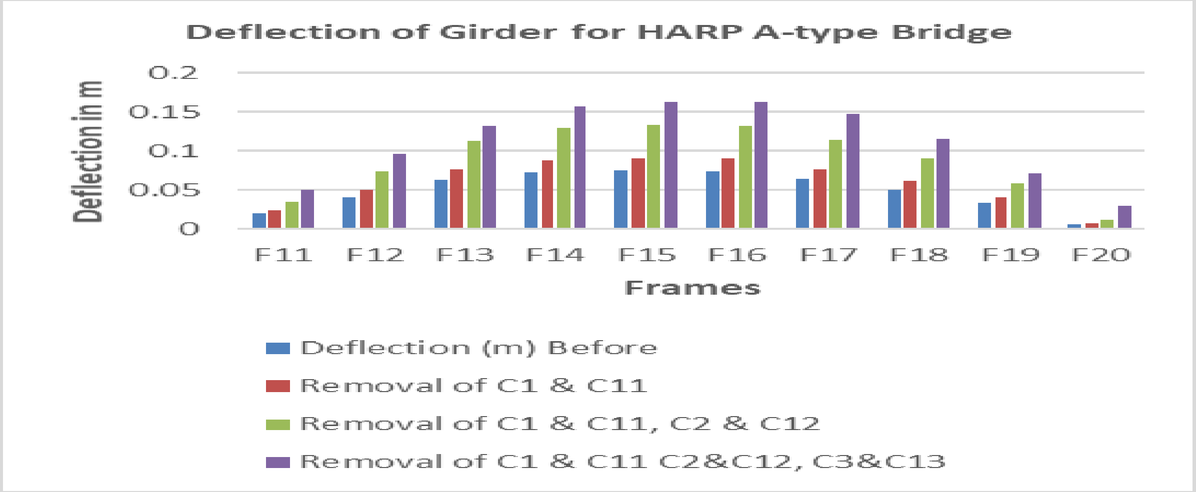


Figure 17 a) Deflection of Girder for HARP A-type Bridge

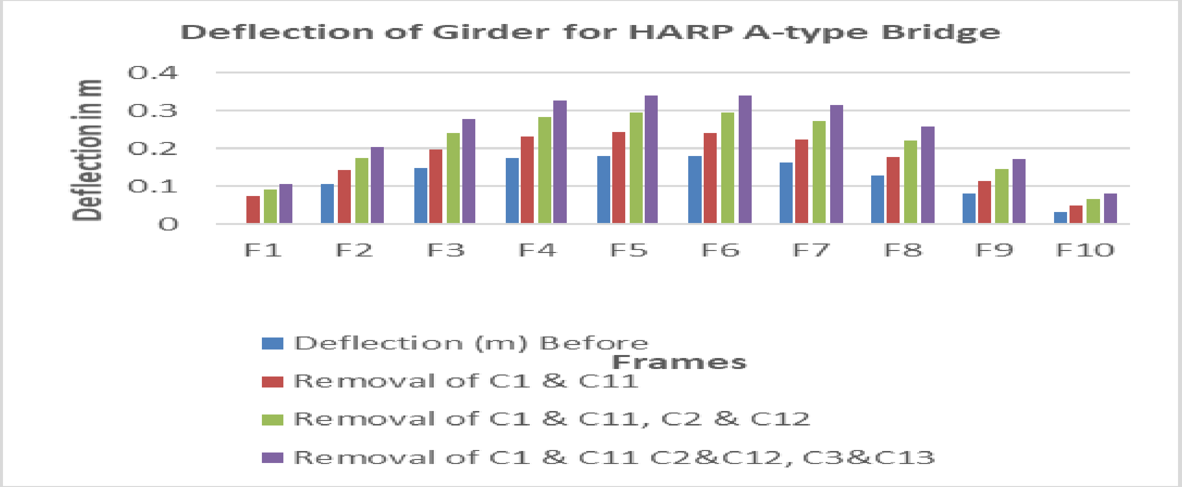


Figure 18 b) Deflection of Girder for HARP A-type Bridge

Deflection of Girder for RADIAL cable arrangement with A- type pylon

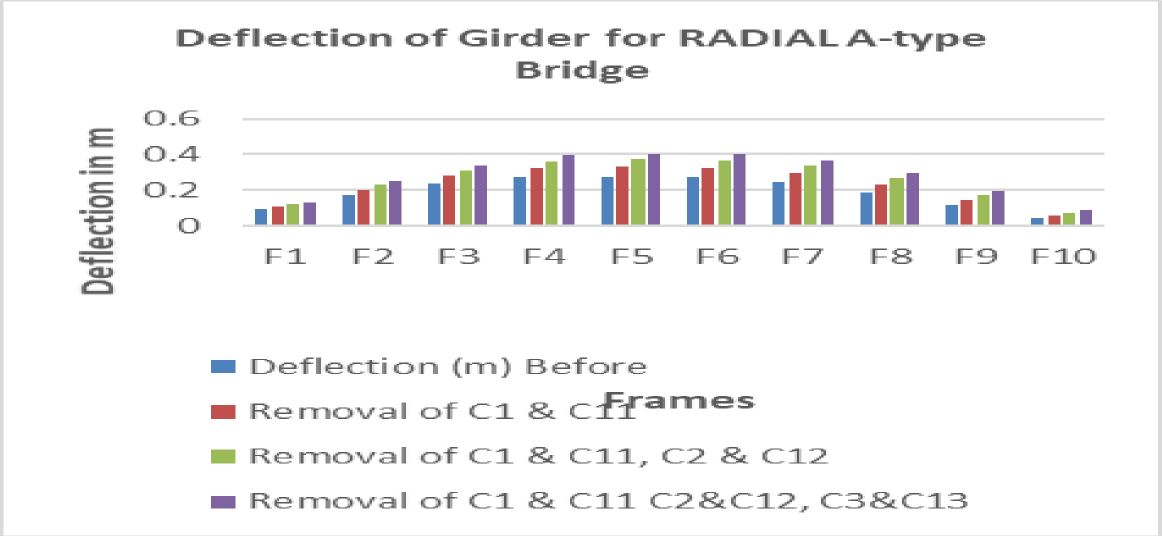


Figure 19 a) Deflection of Girder for RADIAL A-type Bridge

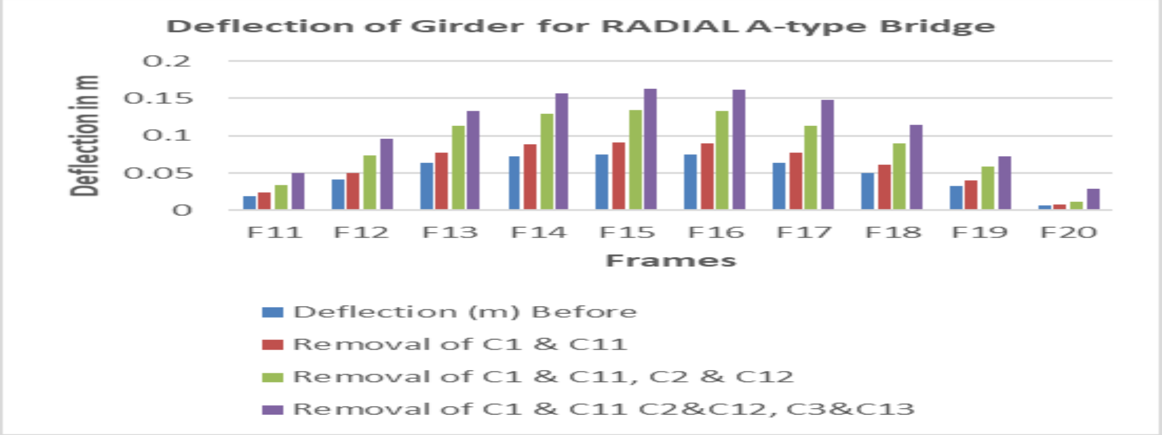


Figure 20 b) Deflection of Girder for RADIAL A-type Bridge

Deflection of Girder for FAN cable arrangement with H- type pylon

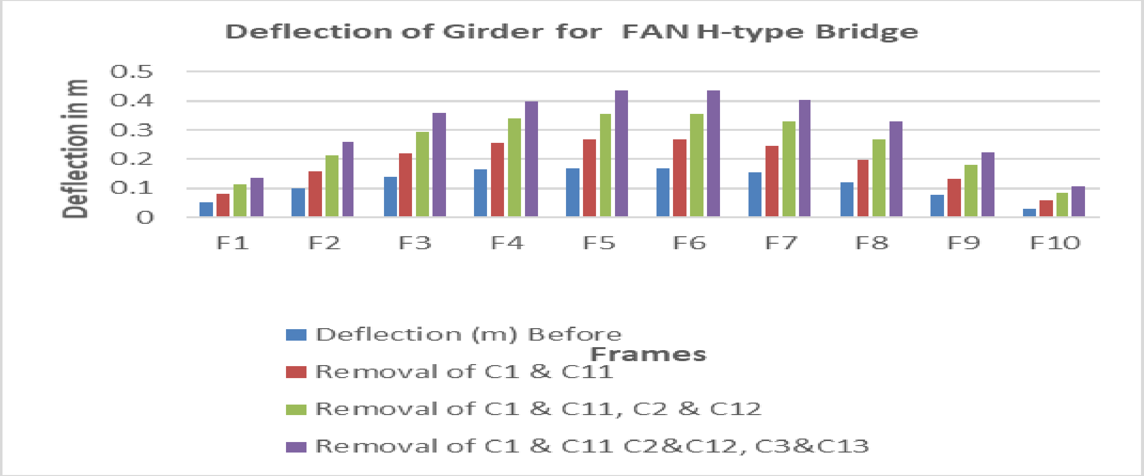


Figure 21 a) Deflection of Girder for FAN H-type Bridge

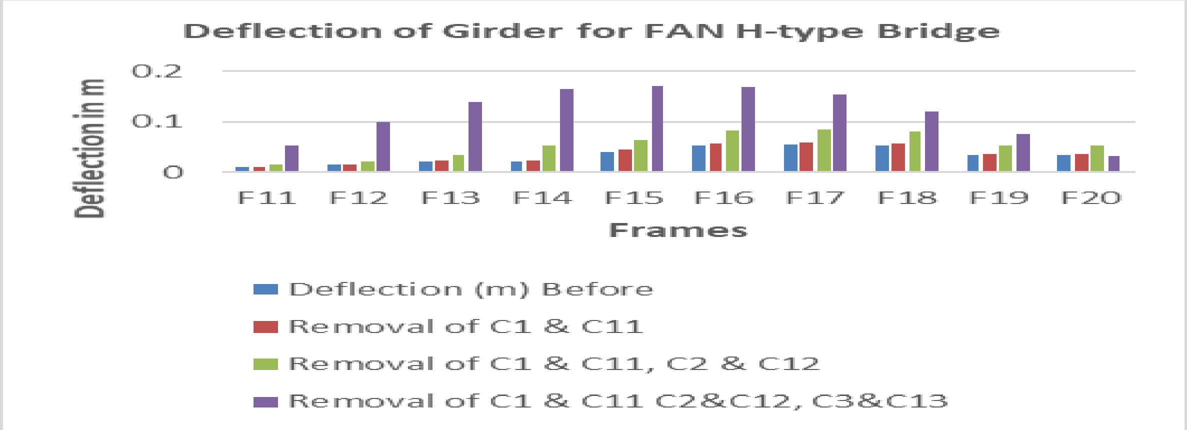


Figure 22 b) Deflection of Girder for FAN H-type Bridge

Deflection of Girder for HARP cable arrangement with H- type pylon

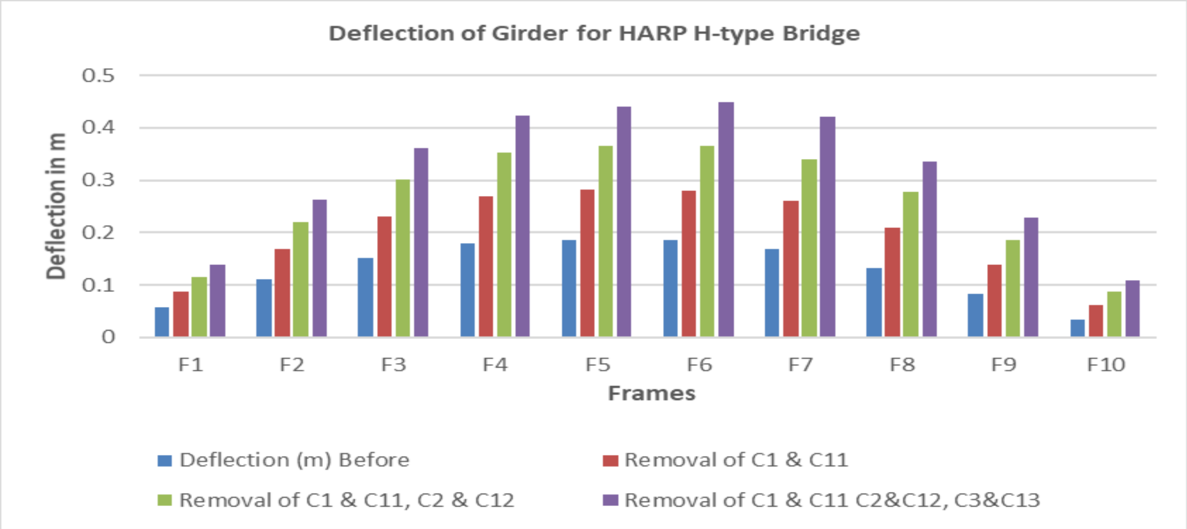


Figure 23 a) Deflection of Girder for HARP H-type Bridge

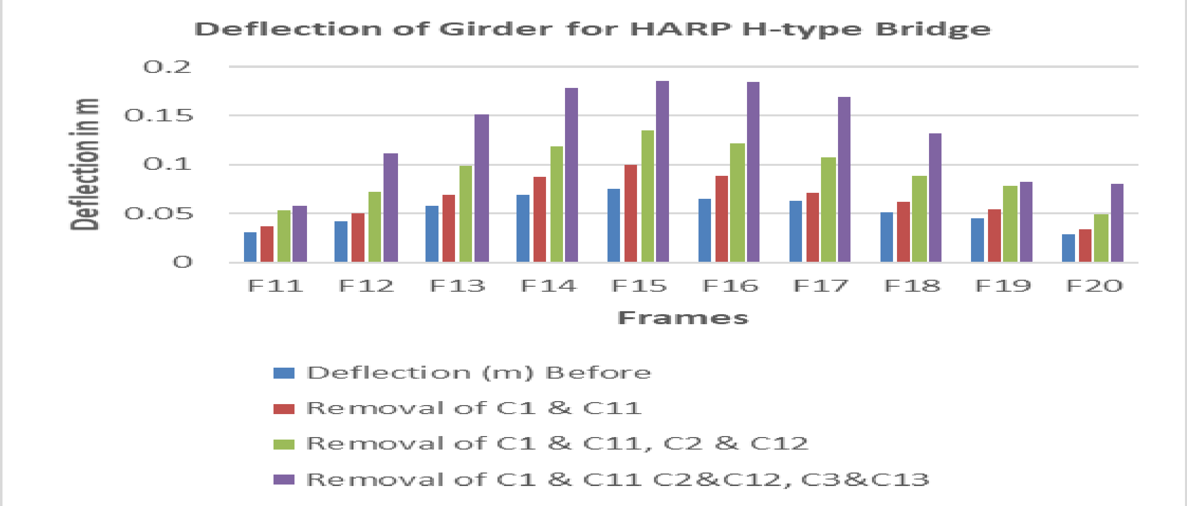


Figure 24 b) Deflection of Girder for HARP H-type Bridge

Deflection of Girder for RADIAL cable arrangement with H- type pylon

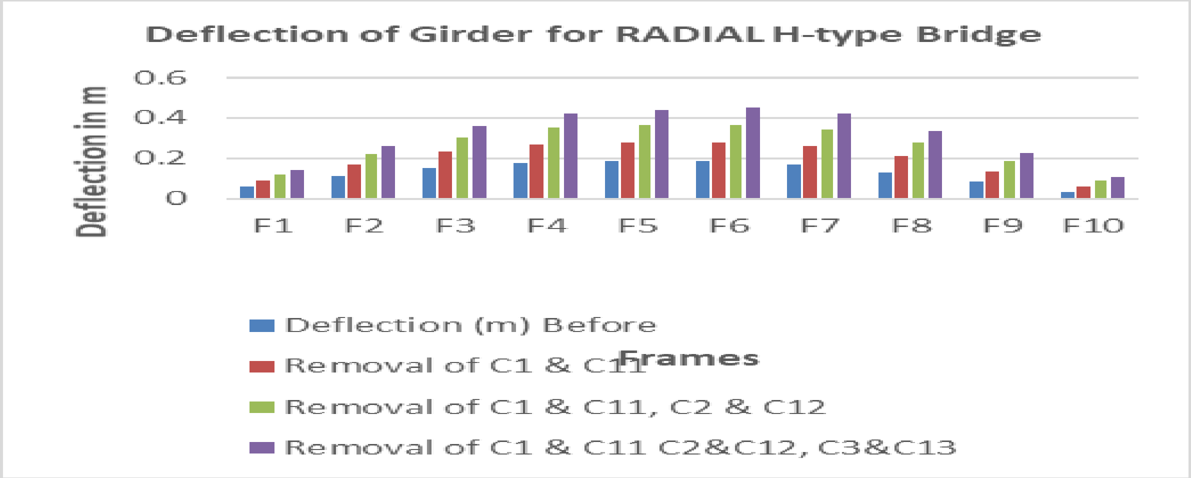


Figure 25 a) Deflection of Girder for RADIAL H-type Bridge

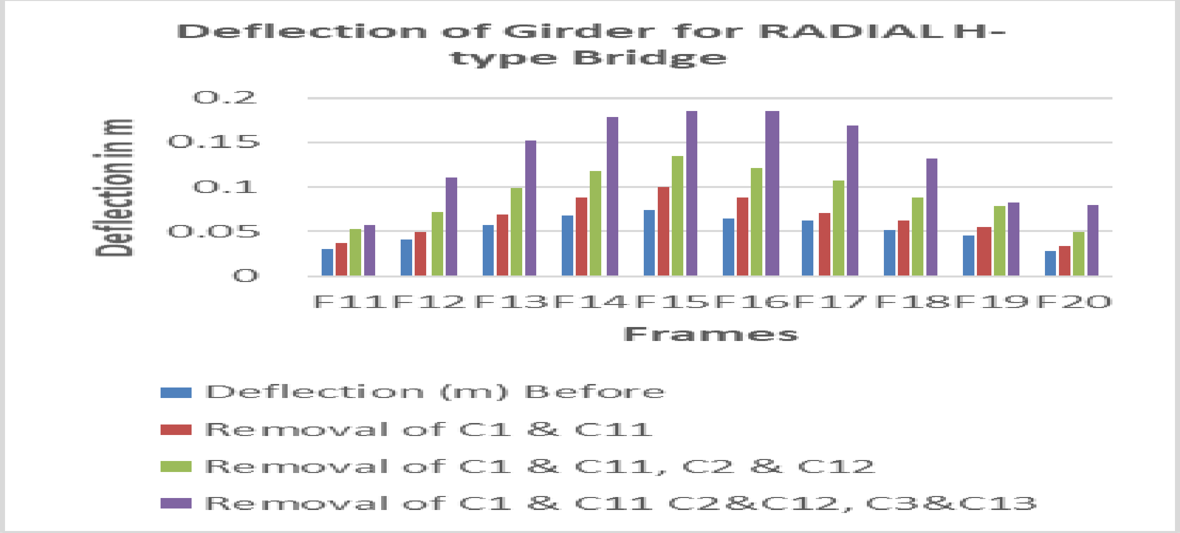


Figure 26 b) Deflection of Girder for RADIAL H-type Bridge

VI. CONCLUSION

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.

1. After two critical cable losses 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
2. 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.
3. 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.
4. 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.

REFERENCES

[1]. Allan Larsen and Guy L. Larose (2015), “Dynamic wind effects on suspension and extradosed bridges”,Elsevier Journals, Journal of Sound andVibration334.

[2]. Bo Sun, Paolo Gardoni and Rucheng Xiao (2016), “Probabilistic aerostability capacity models and fragility estimates for extradosed 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 extradosed bridges”,Journal of Zhejiang University-Science A.

[4]. Cheng J. and Jiang J. (2003),“Aerostatic Stability of Long Span Extradosed 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 Extradosed 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. 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