Analysis of Progressive Collapse of a Cable Stayed Bridge

Sourabh Gautam , Rashmi Sakalle

P.G. Scholar, Department of civil engineering
Truba institute of engineering & information technology,
Bhopal India
HOD, Department of civil engineering
Truba institute of engineering & information technology,
Bhopal India

Abstract: *Cable stayed bridge works on the precept that deck of the bridge can be supported by way of the inclined individuals which might be stretched from the tower and acts as the tension members to carry the load coming over the bridge and transfer the load into the sub structure through the towers. Because of their large size and nonlinear structural behaviour, the analysis of these types of bridges is more complicated than conventional bridges. In these bridges, the cables are the main source of nonlinearity. In our work, cable stayed bridge is analysed by changing the cables arrangement each time, to obtain the results for bending moment, forces, deflection. In this analysis, we investigate the performance of the Cable Stayed Bridge with four types of common arrangement of cables i.e., fan type arrangement, star arrangement, radial arrangement and harp arrangement with different arrangement of phylon "A" shape, "Y" shape, "H" shape. Thecomparison is made for the theses arrangement types in respect to shear force, bending moment and displacement. All the analysis will be done on STAAD Pro software. With respect to shape of tower we noticed that H shape pylon shows low amount of sag and moment in the cables and the deck because it have more number of joints comes under non homogeneity so that the concentration of stress and tension carrying capacity of the cables was not effectively to the other parts of the cable which may lead to maximum concentration in some cables, when compared to circular which has homogeneous member.*

Keywords: Cable stayed bridge, conventional bridges, bending moment, displacement, radial arrangement, harp arrangement, STAAD Pro.

1. Introduction

Progressive collapse is a persistent spread and enlargement of initial local failure of structures characterized by a discrepancy between the initial failure and its resulting extensive collapse. Although great efforts have been contributed to the progressive collapse of building structures, comparably small attention has been paid to the bridge structures, especially the cable-stayed bridges. Progressive collapse, a structural failure, is triggered by a localized structural injury and eventually develops a chain reaction resulting in breakdown of a major portion of the structural system. It is a dynamic event initiated by a release of internal energy due to the instantaneous loss of a structural affiliate disturbing the

initial load equilibrium and thus, the structure vibrates until either a new equilibrium position is found or it collapses. Recent events, such as the collapse of Haeng-Ju Grand Bridge in Seoul in 1992 during its construction highlighted the need to incorporate progressive collapse into the design of major bridges. Bridges are primarily horizontally aligned structures with one main axis of extension. Hence, the possible mechanisms of collapse are different as compared to buildings. In case of Cable-stayed bridges, the loss of cables should be measured as a possible local failure since the cross sections of cables are usually small, and therefore provide low resistances against accidental lateral loads stemming from vehicle impact or accidental actions. The loss of cables can lead to overloading and rupture of adjacent cables. In addition, the stiffening girder shows compressive behaviourand a cable loss reduces its bracing against buckling.

In recent years, with the rapid development of bridges construction, bridge collapse accidents were often reported in the last few years. The causes of bridges collapse are various that can be divided into two categories: human factors and natural factors [1, 2]. Human factors mainly include the unreasonable design and construction, improper management, ships impact, and cars' impact. Natural factors mainly are made up of earthquake, flood, wind, rain and debris (ice) impact, and so on. The bridge collapse accidents caused by earthquake account for the largest proportion among all the factors with the proportion of 20% [2]. Forty- two bridge structures were significantly damaged during the San Fernando earthquake in 1971 (countingtwin freeway bridges as single structures), including five that collapsed [3]. The most dramatic damage occurred to overpass structures at three major interchanges. These three interchanges are all in the region of strong shaking. This earthquake was the primary reason for the US congress to establish the National Earthquake Hazard Reduction Program (NEHRP) in 1977. During the Kobe earthquake in 1995, according to the Japan road association (JRA) earthquake damage investigation results, there were 320 bridges damaged, of which about 27 bridge suffered serious damage [4].

2. CABLE-STAYED BRIDGE

It is just like suspended bridge i.e. it has towers and a deck that is held by using cables, but itscables keep the deck through connecting it immediately to the towers as a substitute via suspender cables. It normally carries pedestrians, bicycles, cars, vans, and mild rail. It's far usedin locations where spans want to be longer than cantilever bridge can gain (due to its weight), however the span is brief sufficient so a suspension bridge is not realistic there

economically. It has more than one tower also called pylons, through which cables guide the bridge deck. A one-of-a-kind feature is the cables which run immediately from the tower to the deck, generally forming a fan-like pattern or a chain of parallel strains. That is in evaluation to the modern-daysuspension bridge, wherein the cables assisting the deck are suspended vertically from the principle cable, anchored at both ends of the bridge and running between the towers. The cable-stayed bridge is most useful for spans longer than cantilever bridges and shorter than suspension bridges. However it is the range where cantilever bridges would hastily develop heavier if the span has been lengthened; at the same time as suspension bridge cabling might not be more in economical aspect if the span had been shortened.

3. REVIEW OF PAST RESEARCH

Mycherla Chaitanya (2018) modelled Girder Bridge and Cable stayed bridge and investigate its performance under dynamic loading conditions. They consider dead load, live load and combined load for analysis purposes. At last author made comparative analysis with reference to internal forces, stresses and deformation of structure under various load effects.

Krunali Mavani (2017) performed the modelling of Cable Stayed Bridges with different pylonarrangement. Author realised that there is a need of examination of dynamic response on the effect of shape of pylon. Also in there research work the bridge specifications and other performance parameters were kept constant and the only variation is he made changes in pylonshape with variation in height of the pylon for assessment purpose.

Pravin Malwiya (2017) did linear static and nonlinear static analysis using this software SAP2000. He also investigates cable tension, deck deflection, and base shear and made comparison for the study of behaviour of cable-stayed bridge.

Pawan Patidar and Sunil Harne (2017) checked the economic status of Plate Girder Bridge (Railway) on various spans keeping one parameter constant and other parameters varying.

Praveen kumar M et al (2017) calculated the displacements of the cable stayed bridge deck and pylon with the traffic loads and seismic loads. Later this load is transferred to the foundation below the pylons. Author also selects the shape of the pylons and arrangement

of cables carefully in such a way that they carry all the different types of loads.

G. Lakshmi Poornima and R. Bharath (2017) have done research work on analysis of cable stayed bridge with different cable configuration. Author considered the different shapes of pylon and estimates the most appropriate configuration of the cable and the tower by using FEM software. The pylons shape are “A” shape, ”Y” shape, ”H” shape and one axial layer of stays i.e. circular shape pylon. All pylon have different cross sectional area and shape. Authorin his investigation take different cable configurations are mainly of four types which are basedon the connection of cables to the deck and the tower.

Guru prasad D (2016) made assessment of two bridges and author find out the most economical and suitability of bridge for the six traffic lanes. He noticed that three plane cable configuration of cable stayed bridge is more economical with more width as compared to thatof two plane cable configuration.

Shivanshi and Pinaki (2016) considered most common arrangements such as fan type, semi fan type and harp type cable. Author designed the bridge and analysed by using these cables arrangement on STAAD Pro software. After that author suggest the utmost effective arrangement after analysis of all bridge models. The results indicated that the fan arrangementis more efficient then two other arrangement.

G. M. Savaliya (2015) performed the nonlinear static and modal time history analysis of cable-stayed suspension Hybrid Bridge. Author also validates their results. All the analysis was carried out in SAP2000 software. After analysis the time period of bridge for different mode shape is obtainable to associate the result of research paper with Sap 2000 software.

Deep Gupta et al (2016) in their research work author design a bridge at the intersection of NH-58 and Kaliyar road. Author said that it will eliminate completely traffic jamming and delay at the highway and also eliminate clashes between pedestrians and motor vehicles. In recent years, the interest in solar energy has risen due to environmental concern and also to support green building initiative of College, a solar power generation system also incorporatesin the design.

Mohammed Yakub Ali & Gugulothu Swarna (2016) designed bridge because at aurora’s engineering college where students and other people cross the road and heavy jams and also for the elimination of conflicts between pedestrians and motor vehicles. He

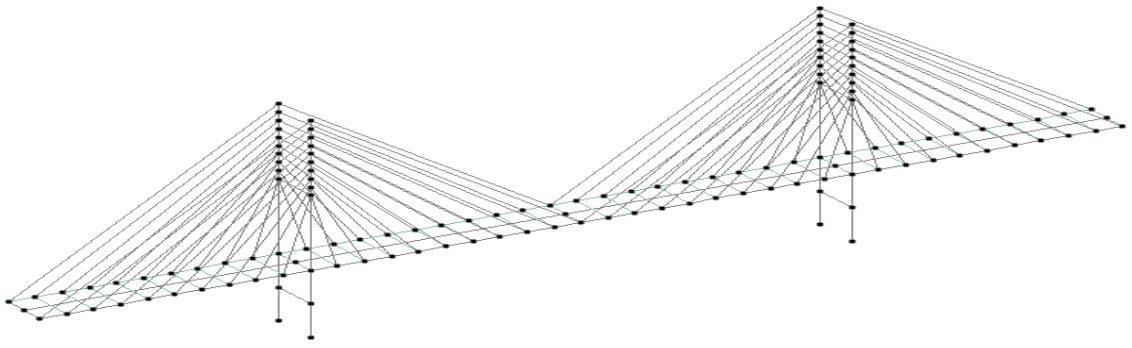
found that vehicles in front of aurora are engineering college where students and other people cross the road, an average hourly traffic of more than 2500 vehicles. With this high average hourly traffic value,crossing the road by foot can not only be challenging, but can be dangerous too. With regard to this, he design bridge at the intersection of roads in front of college building. This will minimize traffic jams and delay at the highway as well as eliminate engagements between pedestrians and motor vehicles.

4. DESCRIPTION OF BRIDGE

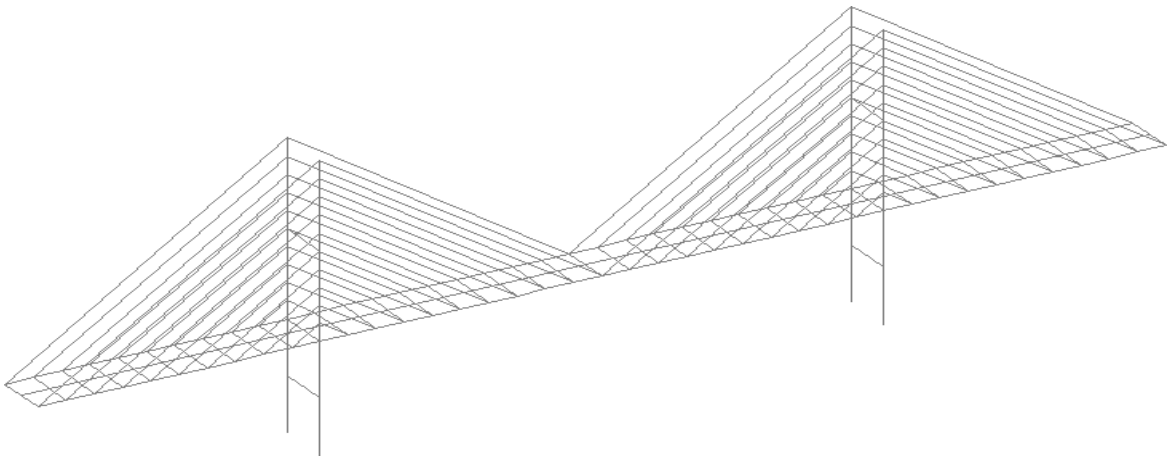
Analysis is made for cable stayed bridge. The span of the bridge is 200 m. The deck width is 10 m. The total height of bridge is 65 m. The pylon used here of different shape. Bridges with Fan arrangement, Radial arrangement, Star arrangement and harp arrangement are as shown innext chapter.

5. STRUCTURAL MODELING AND ANALYSIS

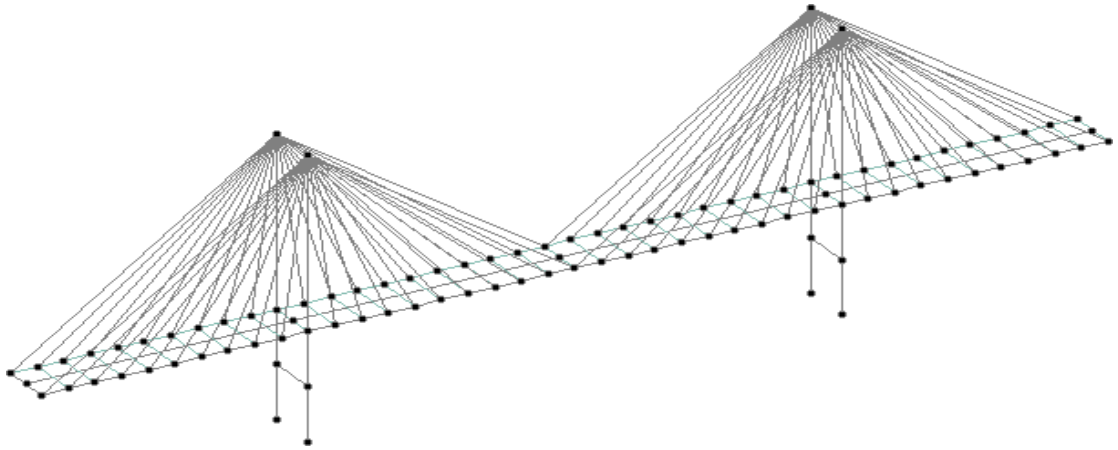
It interconnects with the STAAD analysis engine through the STD input file. It is a text file comprising of a series of instructions which are performed chronologically. The guidelines contain either commands or data concerning to analysis and/or design. The STAAD input file can be formed through a text editor or the GUI Modelling capability. All-purpose, any text editor may be employed to edit/create the STD input file. The GUI Modelling capability creates the input file through a collaborating menu-driven graphics concerned with procedure.



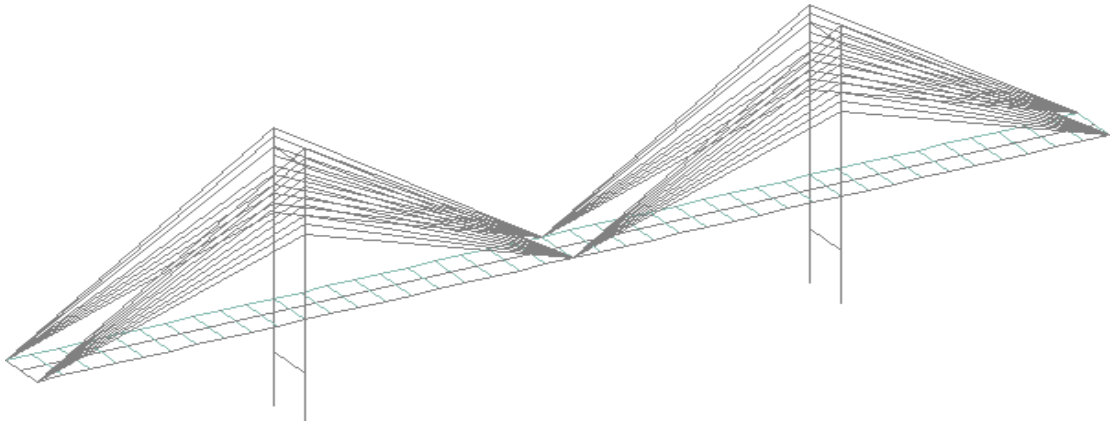
(a) Fan arrangement of cables



(b) Harp arrangement of cables



(c) Radial arrangement of cables



(d) Star arrangement of cables

Fig 1: H-shape tower with different cable arrangement

6. RESULTS AND DISCUSSION

In this section, the results for the efficient design of the four arrangements of cable-stayed brides including star, fan, radial and harp arrangements are presented. Magnitude of maximum shear force and bending moment for various cable arrangements has been plotted in figure number 5.1 – 5.6, it is observed that in this comparative study maximum shear force and max. Bending moment is in star arrangement whereas harp type arrangement shows minimum shear force and min. bending moment value which results in balanced section.

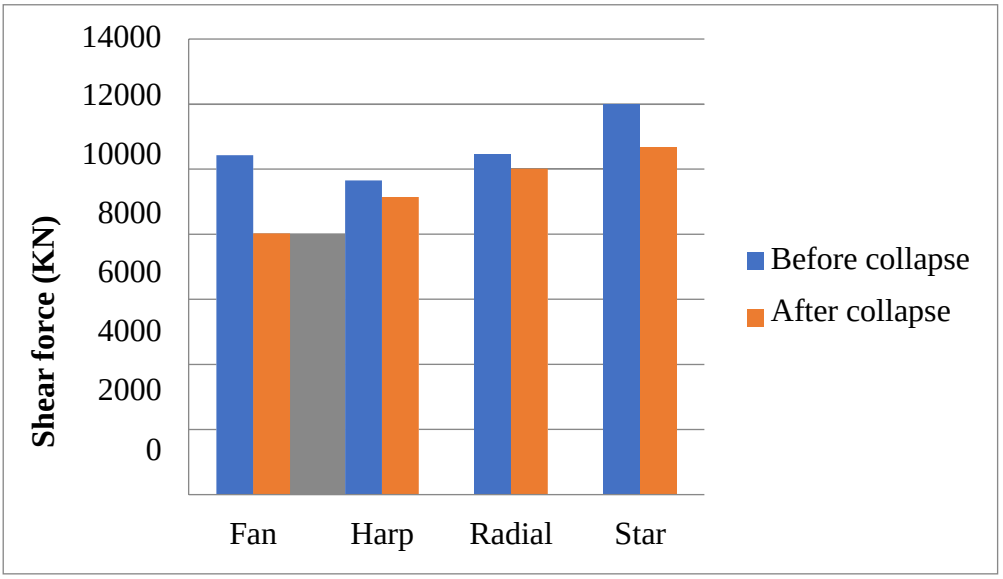


Fig 2: Shear force for H shape tower

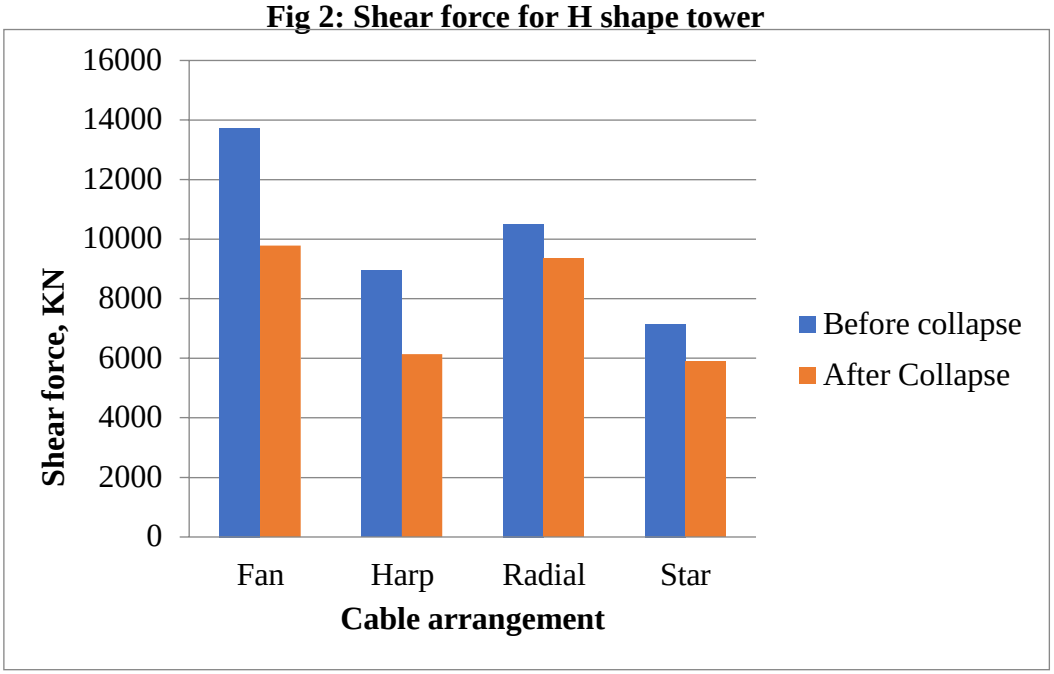


Fig 3: Shear force for A shape tower

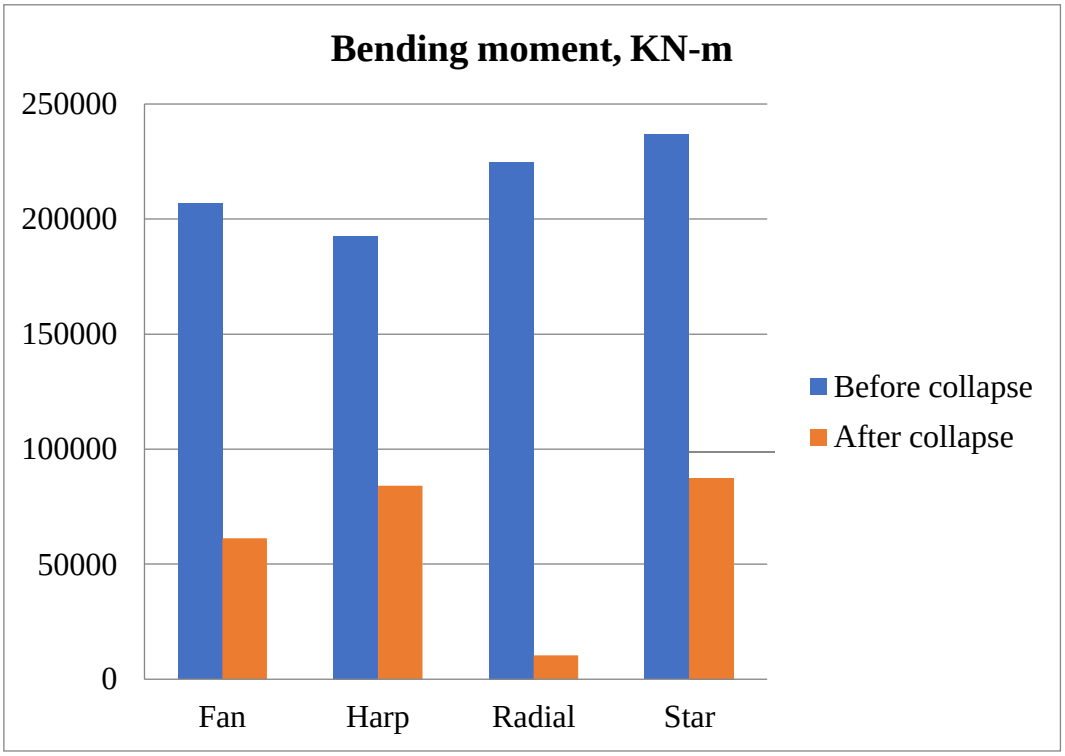


Fig 4: Bending moment for H shape tower

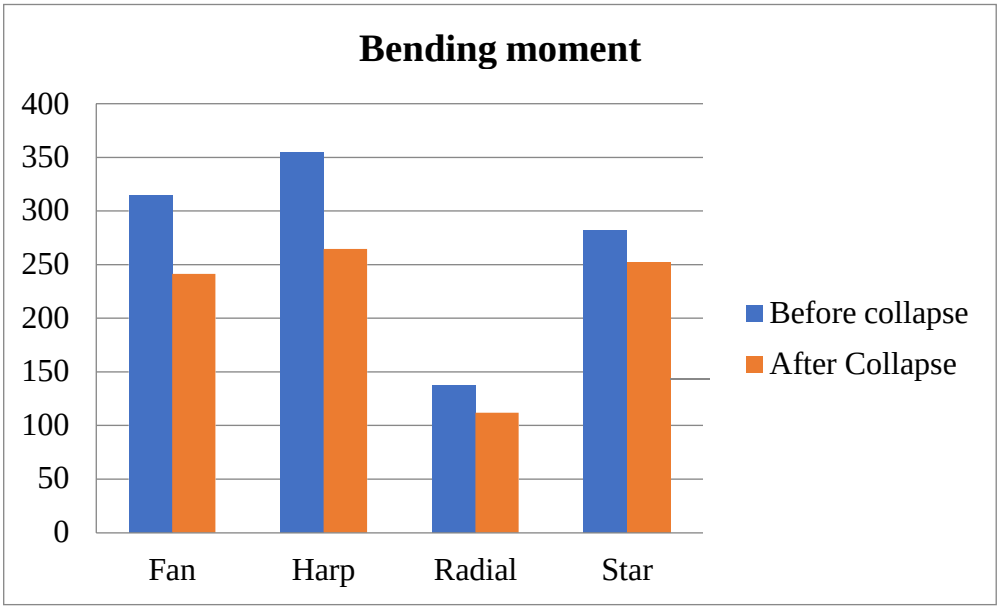


Fig 5: Bending moment for A shape tower

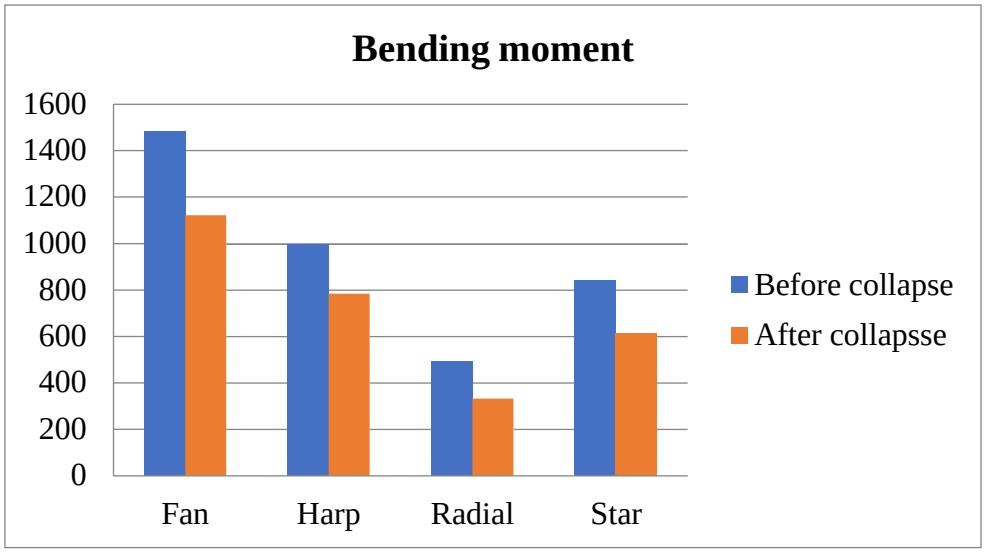


Fig 6: Bending moment for Y shape tower

Magnitude of maximum displacement for various forms of truss has been plotted in figure number 16, below it is determined that deflection is maximum in star cable arrangement whereas minimum in harp cable arrangement which indicates that star cable arrangement willrequire more supports as compared to other cases.

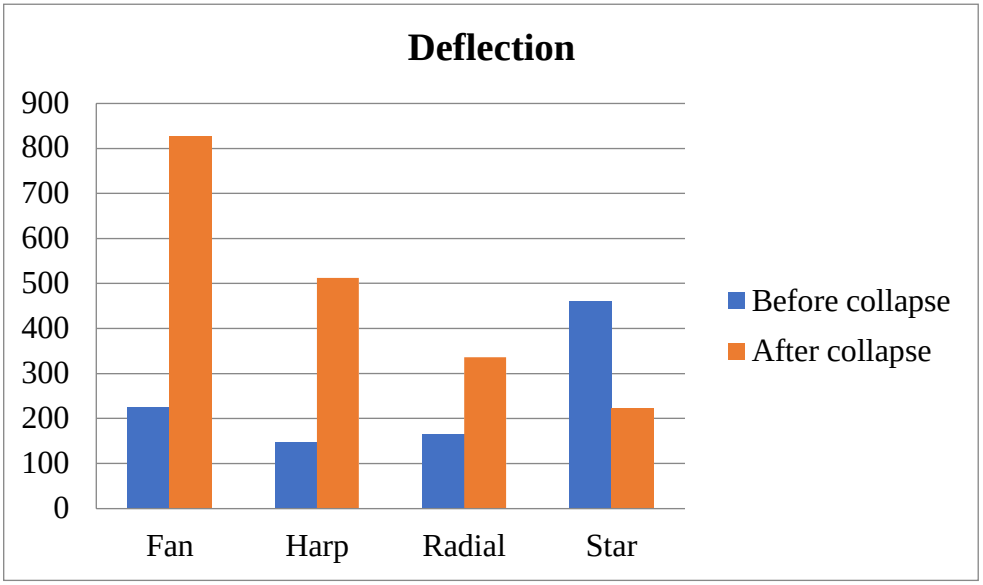


Fig 7: Deflection with different cable arrangement for H shape tower

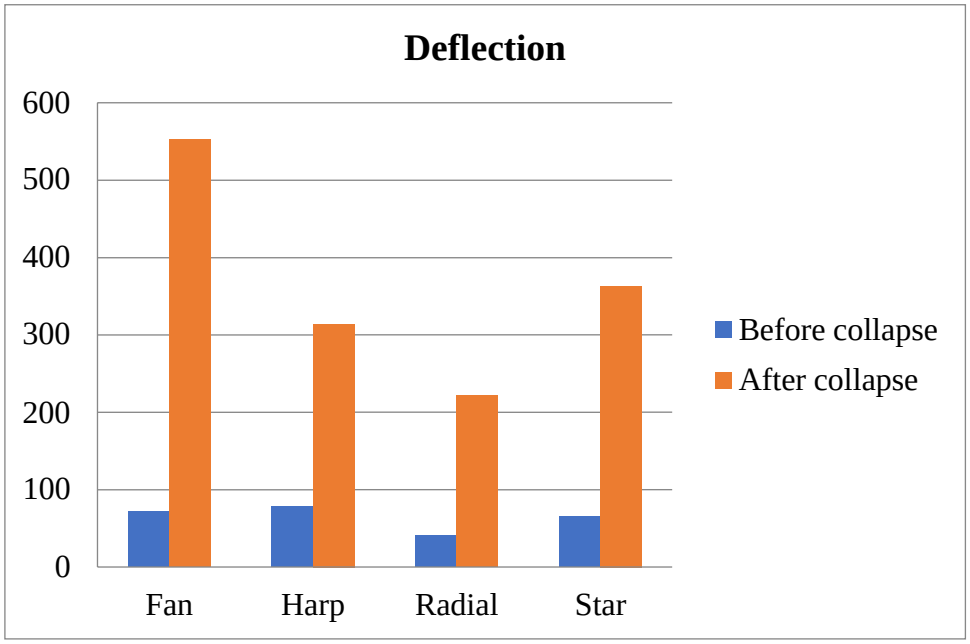


Fig 8: Deflection with different cable arrangement for A shape tower

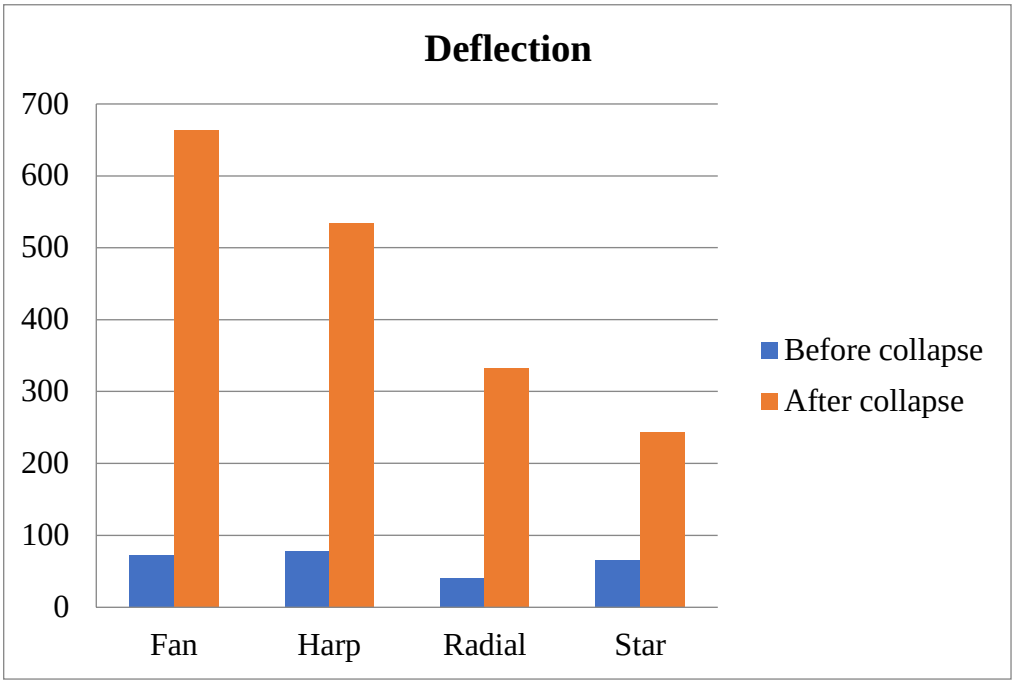


Fig 9: Deflection with different cable arrangement for Y shape tower

7. FINDINGS

We have considered various cases along with dead load & live load for the different cable

arrangement with H, A and Y shape tower for analysis by using Staad-Pro software. Followingare the conclusions of this study-

H shape tower

1. The shear force is more in star and least in harp arrangement under collapse scenario
2. The bending moment is more in star and least in harp arrangement under collapse scenario
3. Deflection is more in star and least in harp arrangement under collapse scenario
4. The results indicated that the harp arrangement is more efficient then three other arrangementunder collapse scenario

A shape tower

1. The shear force is more in Fan and least in radial arrangement under collapse scenario
2. The bending moment is more in harp and least in radial arrangement under collapse scenario
3. Deflection is more in harp and least in radial arrangement under collapse scenario
4. The results indicated that the radial arrangement is more efficient then three other arrangement under collapse scenario

Y shape tower

1. The shear force is more in Fan and least in star arrangement under collapse scenario
2. The bending moment is more in Fan and least in radial arrangement under collapse scenario
3. Deflection is more in harp and least in radial arrangement under collapse scenario
4. The results indicated that the radial arrangement is more efficient then three other arrangement under collapse scenario

References

1. *Pawan Patidar, Sunil Harne (2017), "Parametric Study of Plate Girder Bridge", Journal of Mechanical and Civil Engineering, Volume 14, Issue 6, PP: 01-08.*
2. *Shivanshi, Pinaki (2016), "Analysis of the behaviour of Cable stayed bridge with different types of cables arrangement", International Journal of Innovative and Emerging Research in Engineering Volume 3, Issue 5, PP: 125-134.*
3. *Guruprasad D (2016), "Comparison of Two Planes and Three Planes Cable Configuration Of Cable Stayed Bridge", International Research Journal of Engineering and Technology, Volume: 03 Issue: 09, PP: 1029-1031.*

4. *Atul K. Desai (2013), "Seismic Time History Analysis for Cable-Stayed Bridge Considering Different Geometrical Configuration For Near Field Earthquakes", International Journal of Engineering and Technology, 5(2), 1-10.*
5. *G. M. Savaliya, A. K. Desai, S. A. Vasanwala (2016), "Static And Dynamic Analysis Of Cable-stayed Suspension Hybrid Bridge & Validation ", International Journal of Advanced Research in Engineering and Technology , Volume 6, Issue 11, PP: 91-98.*
6. *Mohammed Yakub Ali, Gugulothu Swarna (2016), "Design and Analysis of Pedestrian Bridge", International Journal of Advance Technology in Engineering and Science, Volume 4, Issue 10, PP: 323–331.*
7. *Aishwarya Kulkarni, Priyanka Kumbhar, Pooja Mandge, Sarita Khot (2016), "Materials for Footover Bridges", International Research Journal of Engineering and Technology, Volume: 03 Issue: 04, PP: 2701-2703.*
8. *T. Pramod Kumar and G. Phani Ram (2015), "Analysis and Design Of Super Structure of Road Cum Railway Bridge Across Krishna River", International Journal of Engineering & Science Research, Vol-5, Issue-7, PP: 830-838.*