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Study of Effect of Rise-Span Ratio and Study of Different Hanger Configuration in the Analysis of Bowstring Arch Bridge

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***Abstract*:- Bowstring arch bridges have significant advantages in economical and atheistic appearance which provide suitable option for bridges of longer spans. Though bowstring arch bridges have different design parameters which effect the performance of bridges. Parameters such as rise-span ratio, various hanger arrangements affect the economy of the bridge. The purpose of this paper is to investigate the influence of different parameters and determining the most suitable solution for a railway bridge. The hangers are significantly prone to premature failure or harm because of fatigue as they endure continual loading with giant variations and ample load cycles. The rise-span ratio has comparatively large effect on stability of structure. Excessively large or small rise-span ratio is drawback for structural stability. The work focuses on comparing the results of different rise-span ratio with each other and the response of the tensile stresses when different hanger arrangements are used. The work focuses on decreasing fatigue stress without increasing bending moments in arch and tie.**

INTRODUCTION

Tied arch bridges have been designed and constructed since the late 19th century. Tied arch bridges are both aesthetic and economical alternates to long span bridges holding a place in the hierarchy of major bridges. They fit in a niche between viable and economical plate girder spans and short cable stayed bridge spans. There are several variations of the tied arch with the most common form being those having vertical hangers, stiff tie girders and the tie are strongly influenced by the hanger arrangement. Vertical, fan and network arrangements are the most commonly adopted schemes for hangers. Hanger arrangement is the key issue in determining the structural behavior. Many parameters should be taken into consideration to optimize the design of a tied arch bridge: the bending moment in the arch and tie, the axial force in the hangers, the variation of bending moment in the arch and tie, and the variation of axial force in the hangers. The hangers are significantly prone to premature failure or harm because of fatigue as they endure continual loading with giant variations and ample load cycles. The rise-span ratio has comparatively large effect on stability of structure. Excessively large or small rise-span ratio is drawback for structural stability.

HANGER ARRANGEMENT

Depending on the inclination of hangers for tied arch bridges, in the analysis we considered different arrangements, as follows:

1. *Langer system or vertical hanger system*- as in Fig. 1 which requires a deck with high rigidity, who plays the role of a tie for the flexible arches. The deck is suspended by vertical hangers.

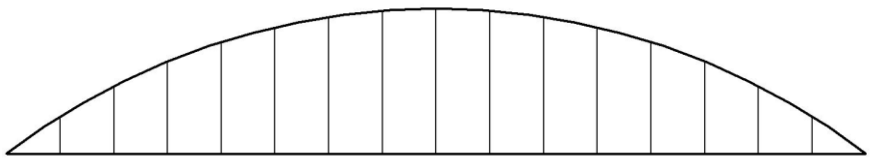

Fig. 1 – Tied arch bridge with vertical configuration of hangers

2. *Nielsen system or network hanger system*- as in Fig. 2 which consists of a single rigid beam, reinforced with a system of hangers. In this system, the hangers are inclined and work as a variable-section truss with rigid bottom “flange”

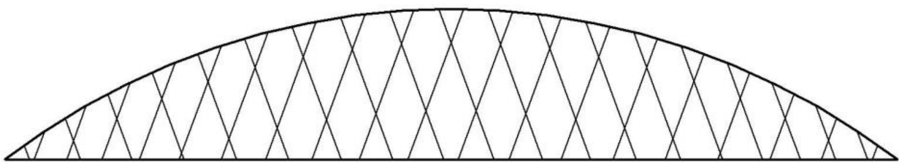

Fig. 2 – Tied arch bridge with Nielsen configuration of hangers.

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RISE-SPAN RATIO

The rise-span ratio has a relatively large impact on stability of structure. The rise-span ratio is the most important geometric parameter of arch bridges. The rise-span ratio has comparatively large effect on stability of structure. Excessively large or small rise-span ratio is drawback for structural stability

When the rise-span ratio is excessively large, which increases the height of arch rib will lead to increasing of length of arch rib, thereby reducing the structural rigidity and increasing weight, finally leading to reduction of arch stability.

When the rise-span ratio is excessively small, the arch rib will be too flat and straight, so the axial compression force in arch will increase causing the arch to destabilization.

METHODOLOGY:

The Analysis is carried out in “STAAD PRO V8I” software, where we assume some initial sizes of the bridge components like deck, tie beams, arch etc., and then the structure is made to act upon the dead and live loads to analyze the structure for structural steel. This procedure is repeated until we get economical sections and economical reinforcement.
The criterion for the arch requires the arch member to be shaped to avoid bending moments in the rib for downward loads. Maxima or minima for the internal reactions of a specific arch having a particular circular or parabolic shape may be developed for a unique set of external loads but not for all external loading combinations. That is, for a specific arch shape and loading, the axial thrust may be maximized while the bending moment is minimized. Moreover, fabrication and construction techniques for arches commonly involve connecting straight members on chords to for the best fit to the mathematical arch shape. For this reason, internal bending moments cannot be entirely eliminated in arch structures. As a result, the best outcome is to minimize bending moments in the arch rib for many arch structures including the bow string arch structure.

- Collecting the geometrical data of Godavari arch bridge.
- Developing of initial model in STAAD Software and analyzing the model subjected to railway loads.
- Replacing the model with different rise and span values and comparing results and finding most suitable solution for a railway bridge consisting of two concrete arches, with one lane subjected to railway loads.
- Comparing the model with different hanger arrangement.

IDEALISATION OF MAKING OF ANALYTICAL MODEL OF STRUCTURE:

The dimensions of the different structural elements or members is assumed to some approximate values of the dimensions of the Godavari arch bridge which can be altered once after the analysis is completed according to requirement of safety and serviceability of the structure.
Once the span and width requirements of the structure are known, we assume the height of the arch to be provided and the arch model is prepared in the auto cad as the arch is a curved member which cannot be drawn or developed in the Staad pro v8i. Importing of the arch member from auto cad to Staad is also not possible, hence we drop vertical coordinates from arch on to the longitudinal girder at regular intervals of relatively lesser values compared to the span (half meter etc.,) and the spacing of the hangers. Now this model which when imported to Staad pro v8i is left with the longitudinal girder and the vertical ordinates dropped. This can be used to develop the arch. Now all the vertical drops are connected at their top ends using beams in the Staad pro to get the arch profile. As the distance between the tips of the adjacent ordinates is very low, the beam connecting them will no longer acts as a linear flat member but in a bulk in the whole arch looks as a curved member due to large scaling. These inter-connected beam members will perfectly resemble an arch profile. Now the ordinates are removed and hanger ordinates are placed at required intervals. This gives us the single arch which is translational repeated and these two arches are connected using lateral bracings at the arch and transversal beams at the longitudinal girders.

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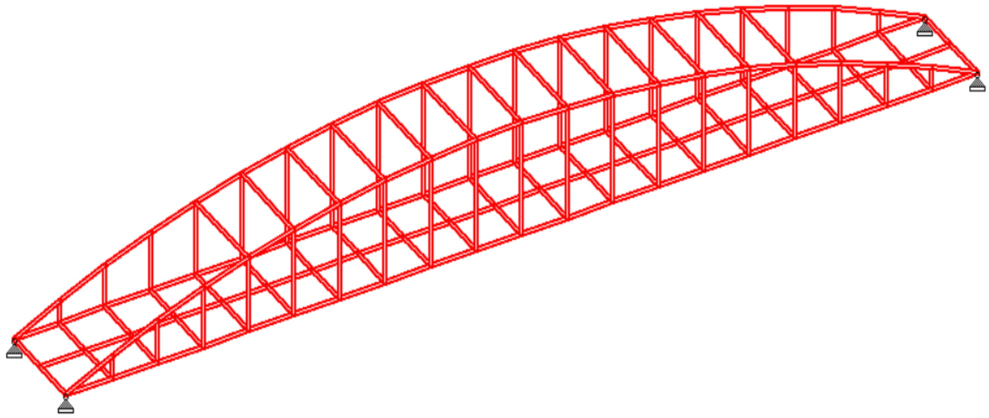

FIG:3 Model of bridge structure.

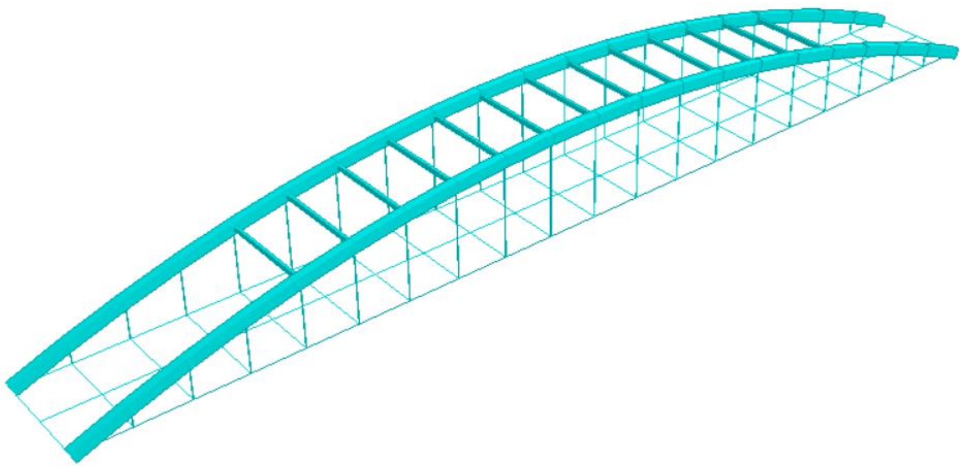

FIG 4: Solid view of the model of the structure

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4.2CROSS SECTION DRAWING OF THE GIRDER

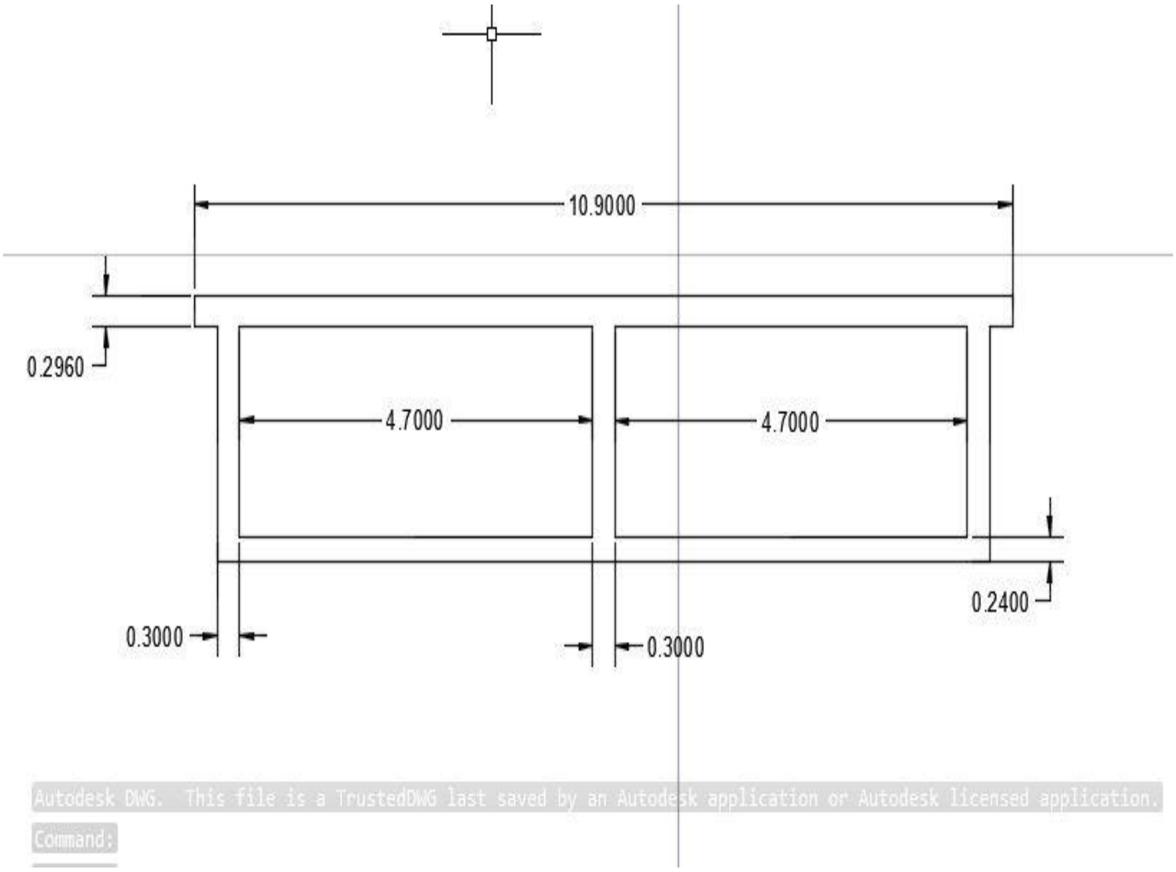

FIG5: CROSS SECTION OF THE GIRD

CROSS SECTION DRAWINGS

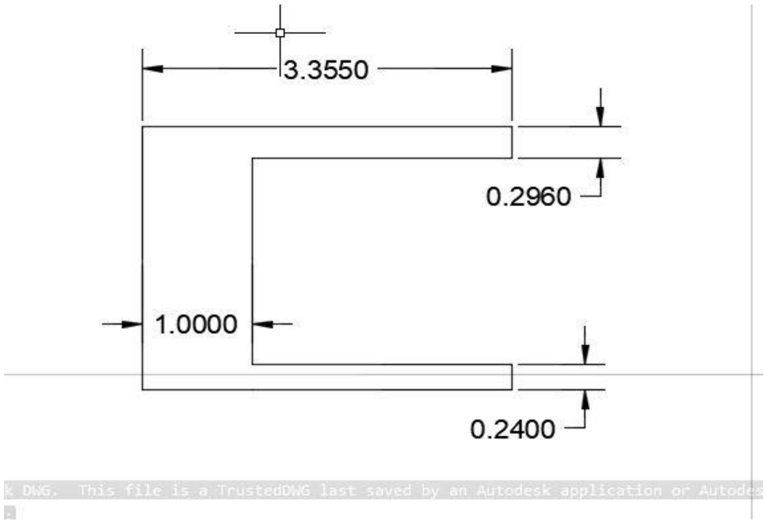

FIG 6:C SECTION DRAWING

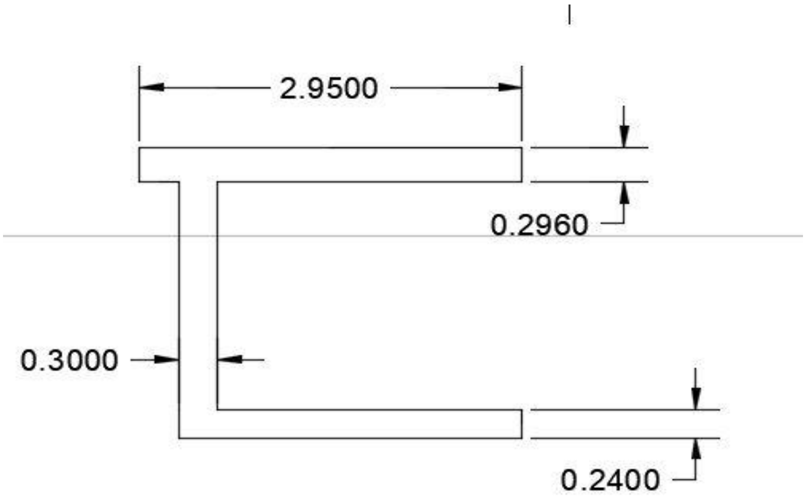

FIG 7: J SECTION DRAWING

CROSS SECTION DRAWINGS

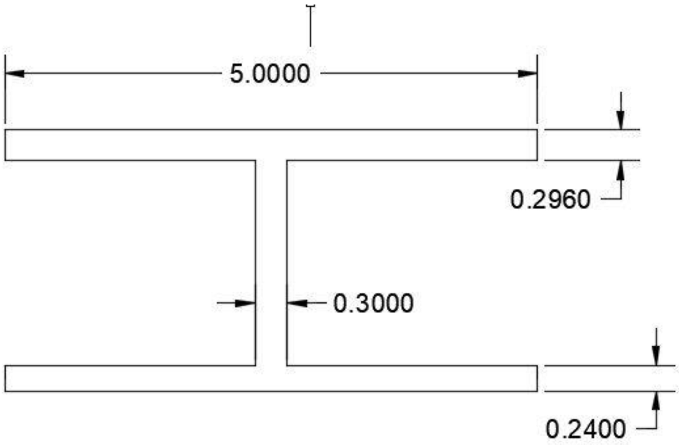

FIG 8: I SECTION DRAWING

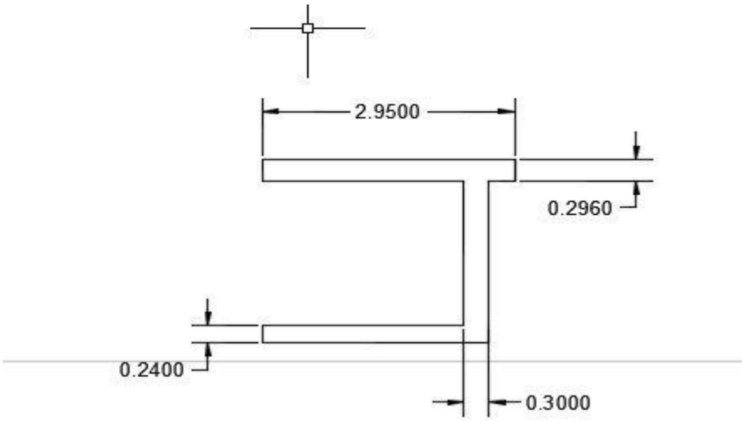

FIG 9: J SECTION DRAWING

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GRILLAGE SECTION

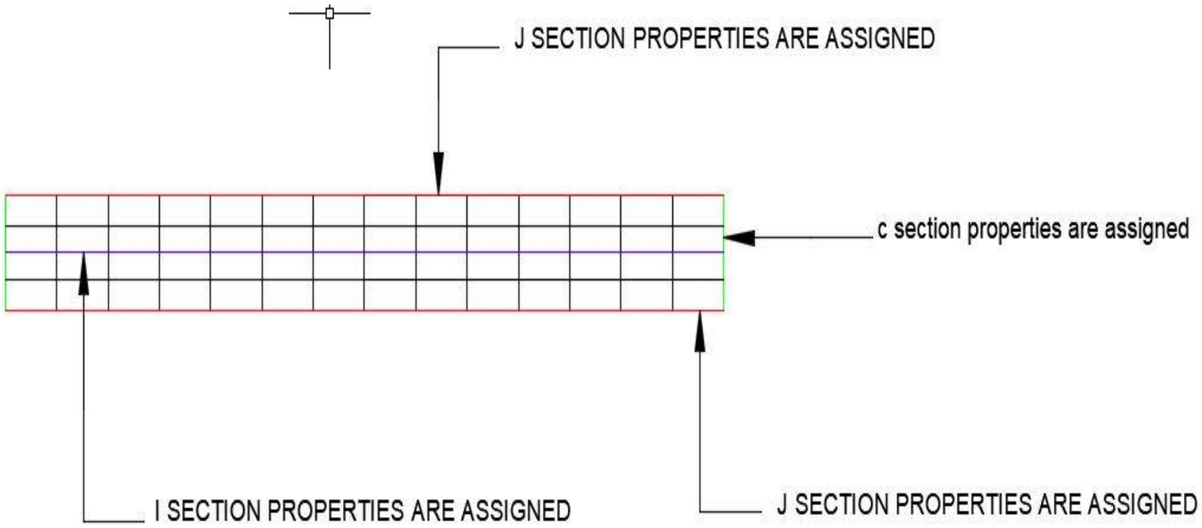

FIGURE-10: Top view of the grillage section

LOADING PATTERNS

Railway bridges: Railway bridges including combined rail and road bridges are to be designed for railway standard loading given in bridge rules. The standards of loading are given for

- **Broad gauge** - Main line and branch line
- **Metre gauge** - Main line, branch line and Standard C
- **Narrow gauge** - H class, A class main line and B class branch line

The actual loads consist of axle load from engine and bogies. The actual standard loads have been expressed in bridge rules as equivalent uniformly distributed loads (EUDL) in tables to simplify the analysis. These equivalent UDL values depend upon the span length. However, in case of rigid frame, cantilever and suspension bridges, it is necessary for the designer to proceed from the basic wheel loads. In order to have a uniform gauge throughout the country, it is advantageous to design railway bridges to Broad gauge main line standard loading.

Loading patterns have been taken according to BRIDGE RULES (Rules specifying the loads for design of super-structure and sub-structure of bridges and for assessment of the strength of existing bridges)

According to BRIDGE RULES specifying the loads for design of super-structure and sub-structure of bridges and for assessment of the strength of existing bridges (APPENDIX II PAGE NO 21)

Modified Broad gauge loading-1987, Broad guage-1676 mm
Equivalent Uniformly Distributed Loads (EUDL) in kilo Newtons (tonnes) on each track
For Bending Moment, L is equal to the effective span in metres. For Shear, L is the loaded length in metres to give the maximum Shear in the member under consideration. The Equivalent Uniformly Distributed Load (EUDL) for Bending Moment (BM), for spans up to 10m, is that uniformly distributed load which produces the BM at the centre of the span equal to the absolute maximum BM developed under the standard loads. For spans above 10m, the EUDL for BM, is that uniformly distributed load which produces the BM at one-sixth of the span equal to the BM developed at that section under the standard loads.
EUDL for Shear Force (SF) is that uniformly distributed load which produces SF at the end of the span equal to the maximum SF developed under the standard loads at that section.

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2.SUPER IMPOSED DEAD LOAD

Super imposed load refers to a load that is in addition to the dead weight of the bar joists and bridging
The weight of the track is considered as 0.4413 kN/m

SELF WEIGHT

Self-weight is the load on a structure imposed by its own weight.
Self-weight is considered as 1kN/m

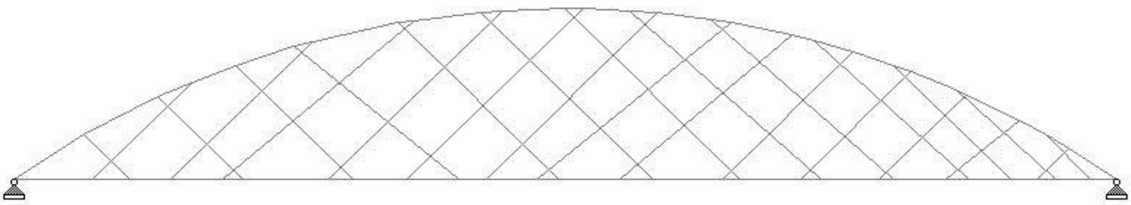
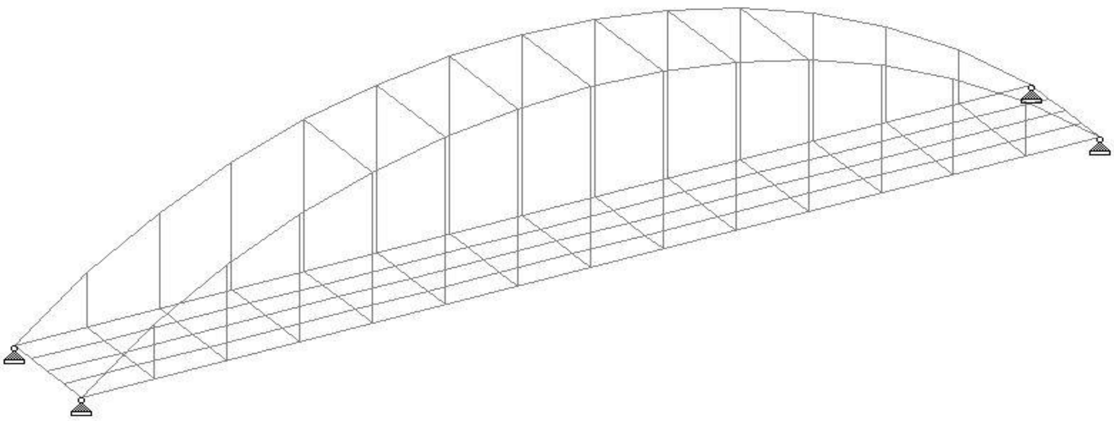


FIG 11: BOW STRING ARCH BRIDGE WITH NETWORK CONFIGURATION OF HANGERS



Bowstring arch bridge with 94m span and 18.8m (1/6th span-rise ratio) rise with vertical hanger configuration has been analyzed using STAAD software.

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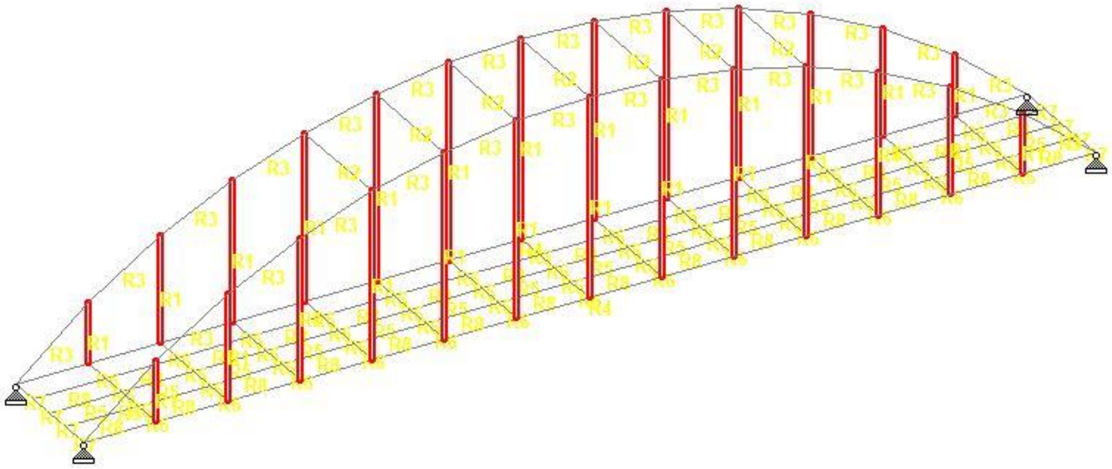

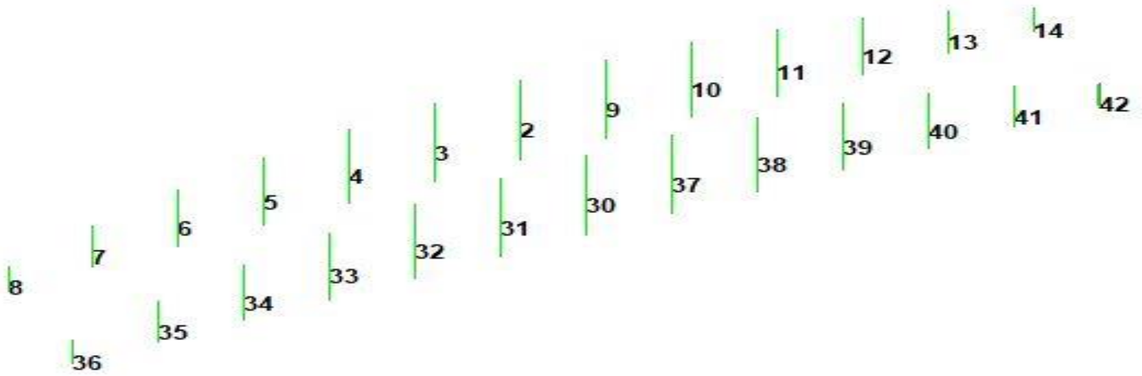

The axial forces in the hangers are examined and tabulated as follows.

BEAM		TOTAL LOAD (KN)	
2		1463.512	
3		1484.178	
4		1528.196	
5		1652.747	
6		2148.519	
7		1542.885	
8		794.189	
9		1484.181	
10		1582.211	
11		1652.736	
12		2148.501	
13		1542.866	
14		794.204	

30		1463.512
31		1484.578
32		1528.197
33		1652.747
34		2148.519
35		1542.885
36		794.189
37		1484.181
38		1528.211
39		1652.736
40		2148.501
41		1542.866
42		794.204

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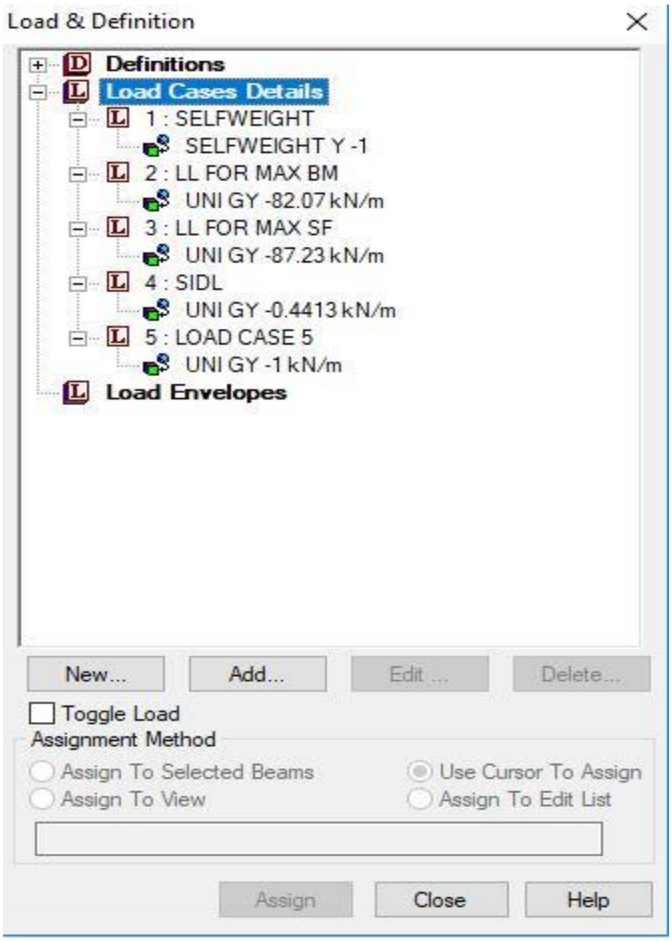
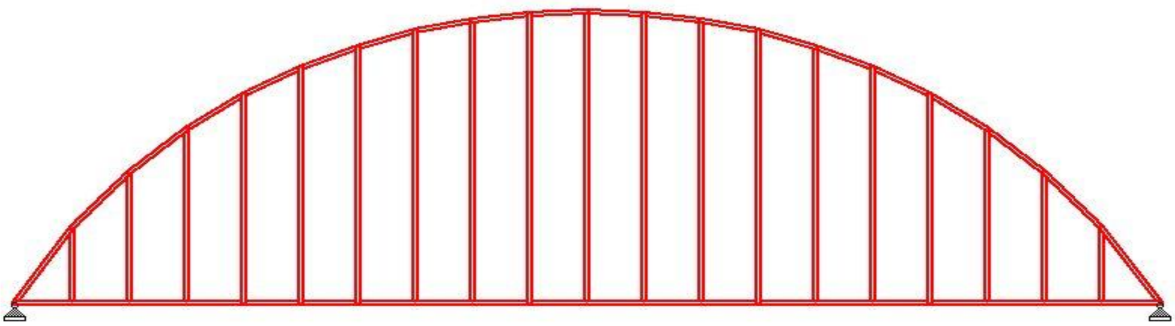
Loads imposed on the structure





Bow string arch bridge with 100m span and 30m (0.3 rise-span ratio) rise with vertical hanger configuration is analyzed in STAAD software

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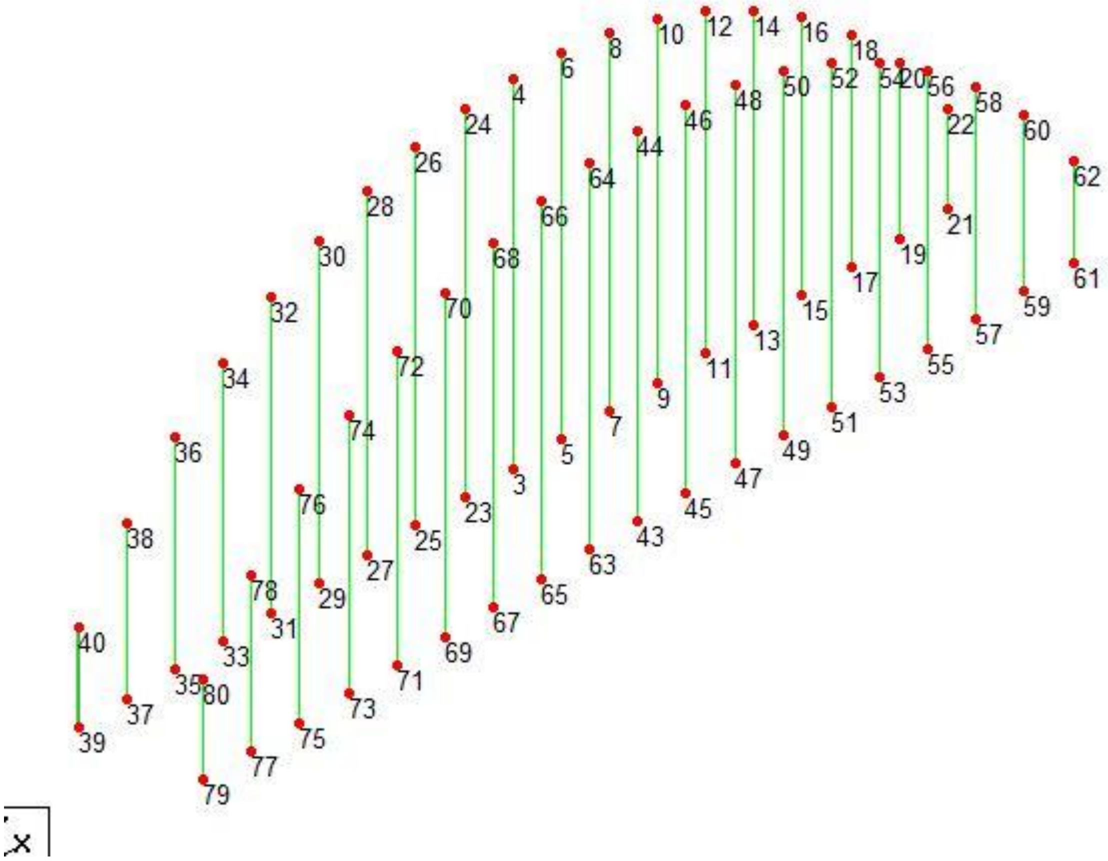

Beam	L/C	Node	Axial Force kN
49	5	58	951.477
9	5	18	951.363
18	5	36	943.065
58	5	76	942.061
8	5	16	937.562
48	5	56	935.69
17	5	34	912.162
57	5	74	911.127
60	2	80	871.839
20	2	40	871.839
51	2	62	871.804
11	2	22	871.804
50	2	60	827.469
10	2	20	827.469
59	2	78	827.467
19	2	38	827.467
60	1	80	823.159
20	1	40	823.159
11	1	22	823.125
51	1	62	823.125
7	5	14	800.395
50	1	60	781.265

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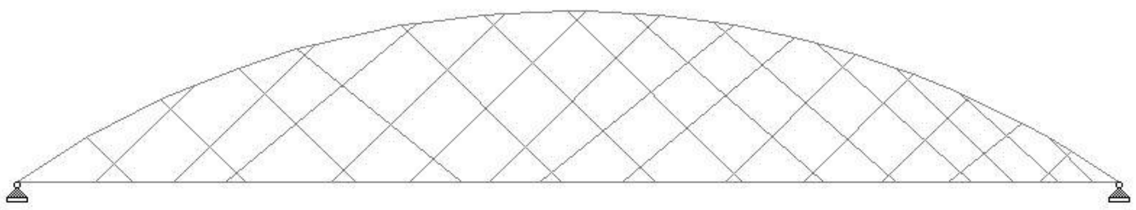
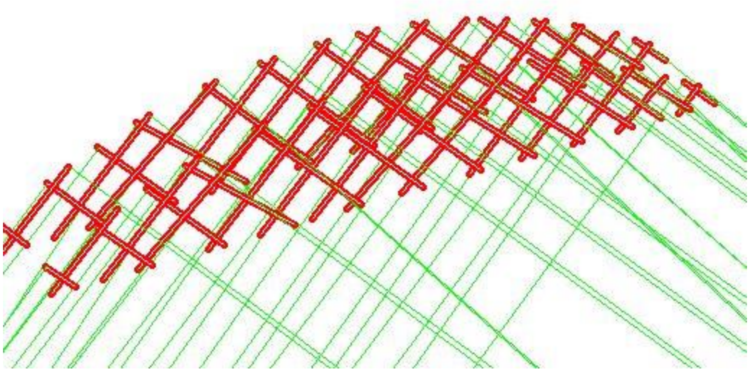
Axial forces of the hangers



Bow string arch bridge with 94m span and 18.8m (0.2 rise-span ratio) rise with network hanger configuration is analyzed in STAAD software



beam	axial force kn	
2	20.256	
3	55.875	
4	71.057	
5	84.308	
6	110.221	
7	113.011	
8	111.812	
9	91.329	
10	64.292	

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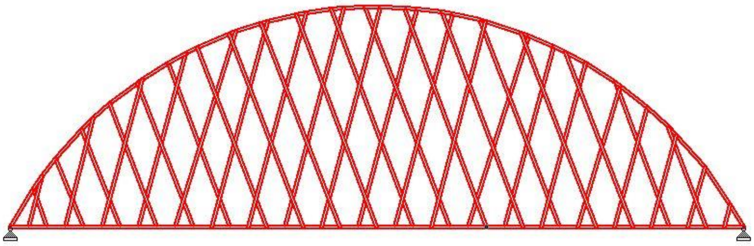

Bow string arch bridge with 100m span and 30m (0.3 rise-span ratio) rise with network hanger configuration is analyzed in STAAD software

Axial forces of the hangers

Beam	Axial Force kN
112	524.448
32	522.941
110	507.534
111	505.689
30	504.641
31	503.7
109	498.358
29	494.036
108	470.234
28	466.015
114	448.058
34	447.199
107	430.706
27	428.026
115	412.458
35	411.757
105	395.424

CONCLUSIONS

- The bowstring arch bridge with 94 m span and 18.8m rise (0.2 rise-span ratio) with vertical arrangement of hangers has greater axial forces compared to bowstring arch bridge with 94m span and 18.8m rise (0.2 rise-span ratio) with vertical arrangement of hangers.
- Bow string arch bridge with 100m span and 30m (0.3 rise-span ratio) rise with network hanger configuration has lesser axial forces than Bow string arch bridge with 100m span and 30m (0.3 rise-span ratio) rise with vertical hanger configuration.
- In vertical arrangement of hangers, the axial forces on hangers are high and bending moments on arch and tie are high as compared to network configuration of hangers, this is because there is low stiffness of arch plane in the vertical configuration of hangers.
- This negative effect does not occur in network configuration of hangers because of crossing hangers, which increases arch stiffness.
- A reasonable rise-span ratio for bow string arch bridge studied here is around 0.25-0.3
- The rise-span ratio has comparatively large effect on stability of structure. Excessively large or small rise-span ratio is drawback for structural stability.

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