

ANALYTICAL STUDY OF STEEL ARCH BRIDGE

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Abstract - It has been a year since bridge engineers and designers not only considered the stability of bridges but also aesthetics as well as efficiency. So in this paper, an arch bridge is considered for study, which satisfy both conditions. In this study, we changed the rise of an arch of the bridge and deck positions, analyzed the behaviour of the bridge by deflection, bending moment, and self-weight. By comparing all these parameters, we propose an alternative lightweight and more stable bridge structure.

Key Words: Steel Arch bridge, arch rise change, deck positions, deflection in bridges, lightweight bridge.

1. INTRODUCTION

Over the years, people have constantly looked for ways to move their goods from one location to another. It was difficult and time-consuming to cross across valleys, rivers, or other impediments with horses and camels in the past. This was done by going along the rivers and valleys in search of ideal crossing locations, which took a lot of effort. After a number of years, increased population led to increased demand for goods like agricultural products as well as the use of increasingly sophisticated and substantial vehicles like carts. This complicated the transport process even more. This gave rise to the concept of building a bridge over rivers and valleys to provide much quicker access in order to meet the demands of the expanding population. Now these structures are known as bridges.

A bridge is a structure that spans natural or artificial materials to give access over barriers like valleys, rugged terrain, or water bodies. When the earliest modern civilizations emerged in Mesopotamia in antiquity, they were initially employed. After that, engineering, manufacturing, and understanding of new materials for building bridges moved beyond national borders, allowing for the gradual but steady development of bridges throughout the world.

2. METHODOLOGY

First modelling of arch bridge structures in sap 2000 with different rise ratio (L/3, L/4, L/5, L/6).

Apply the pedestrian load of 3.6kN/m², live loading in this study is HS20-44 truck loading.

Analysis the all models , comparing all results optimize arch rise.

After optimizing rise modelling of bridges for different deck position with optimized rise.

Comparison of generated data for all models.

Results of the comparative study & Conclusion.

2.1 Geometry of bridge

The Span of the Bridge is 225 m.

Span of Arch Bridge: A long-span bridge is decided to use, so a 225-metre span is considered for analysis. It meets the long-span requirement and provides a clear length and number of panels.

Panel Arrangement: Panels should not exceed 1/15 of the bridge span. Therefore, 15 panels were provided.

Arrangement of Hangers: Hangers are provided every 15 metres; their height can be obtained from the arc equation in the x-z plane.

Where f is the crown of the arc and L is the span length.

$$a. \quad Y=f*[1-(2x/L-1)^2]$$

Allowable Deflection- Highway bridges consisting of simple or continuous span should be designed so that deflection due to live plus impact load does not exceed 1/800th of the span.

For a bridge span of 225 m, only 28.12 cm of deflection is allowable as per AASHTO code..

2.2 Vehicle Load Considered for Bridge-AASHTO Load

The live load for a bridge consists of the weight of the applied moving load of vehicles and pedestrians.

Live load is considered as per the AASHTO LRFD code. The specification of live loading in this study is HS20-44 truck loading and a pedestrian load of 3.6 kN/m². The application of this loading is shown in Fig.1

The weight and the spacing of axle and wheel for the design truck shall be as specified in the figure.

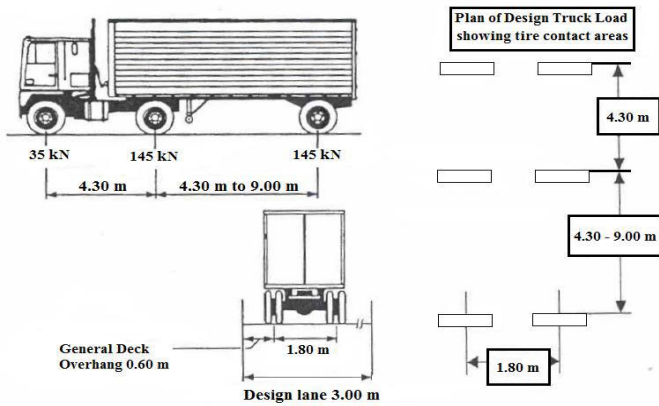


Fig -1: Characteristics of the Design Truck

2.3 Modelling of bridges:

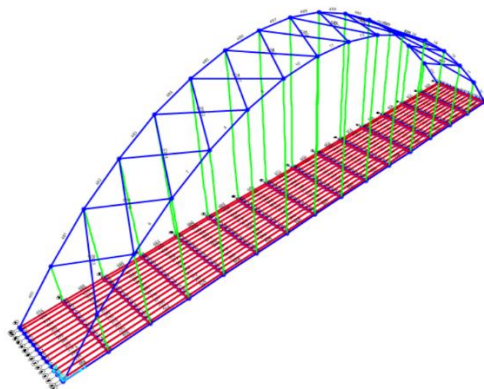


Fig -2: Model of Arch bridge with rise L/3.

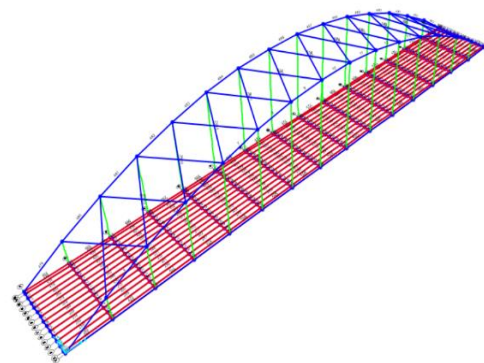


Fig -3: Model of Arch bridge with rise L/6.

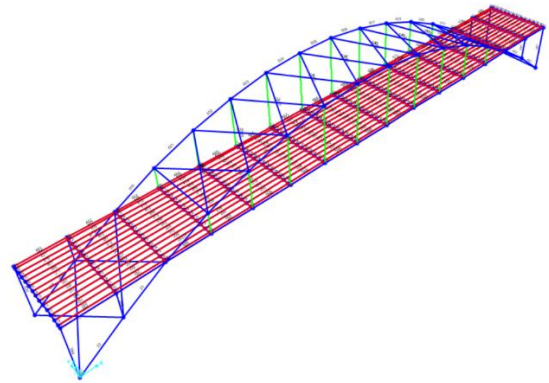


Fig -4: Model of Semi-Through type Bridge.

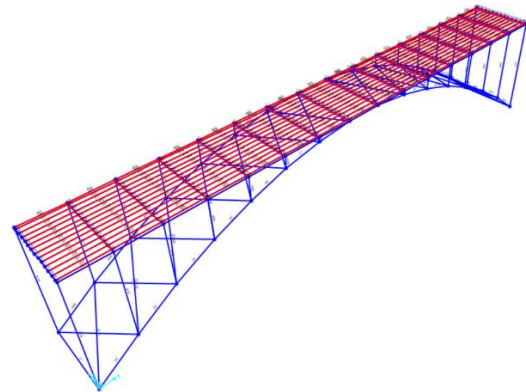


Fig -5: Model of Deck type Bridge.

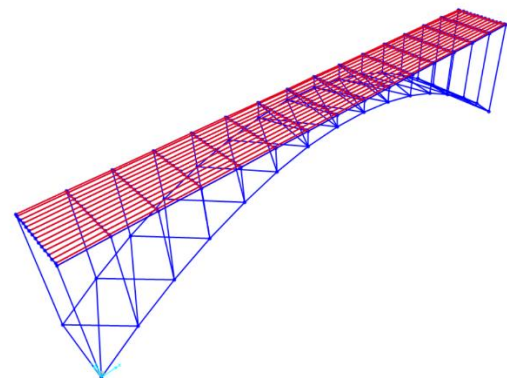


Fig -6: Model of Deck completely above arch

3. RESULTS AND DISCUSSION

Optimizing Rise arch of bridge-

Bending moment : It is observed that in models with L/3, L/4, L/5, and L/6 ratios, the bending moment increases with the decreasing rise of an arch of a bridge. Negative moment near support due to fixed support and positive moment near support due to fixed support and positive moment

(sagging) bending moment start increasing when we move to center. Maximum moment at the center to be observed. Bending moments at a distance of 112.5m (at center) for models are as follows:

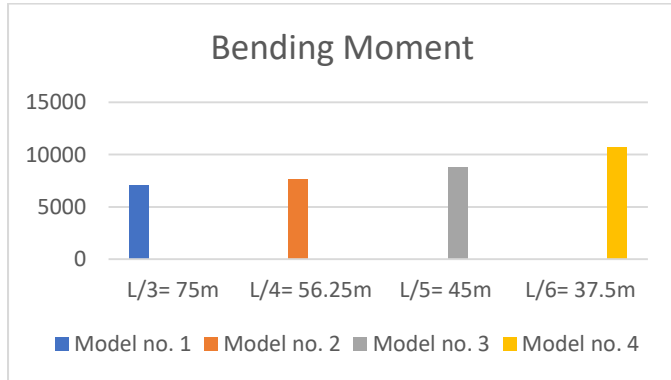


Chart -1: Graph Representing Bending Moment of Bridge.

Deflection: Deflection starts increasing from support and gets maximum value at the centre of the bridge. For the initial four models, deflection starts increasing with a decreasing rise arch. Last model no. 4 (L/6 = 37.5 m) crossed the deflection allowable limit.

The allowable limit for deflection of the bridge is 1/800th of the span of the bridge (deflection <0.2818m). Deflection values for four models are shown in the graph.

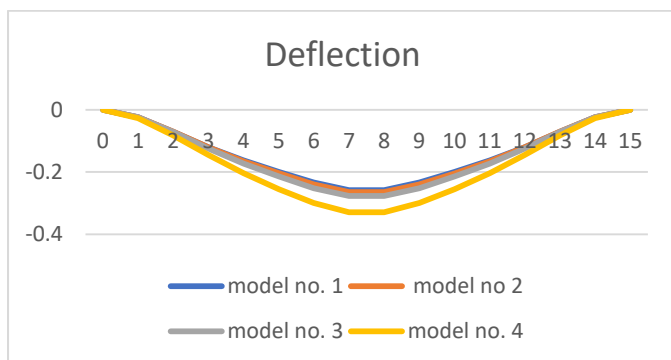


Chart -2: Graph Representing Deflection of Bridge.

Weight: The weight difference between L/3, L/4, L/5, and L/6 models is 86268 kg > 46295 kg > 21924 kg, as shown in the graph.

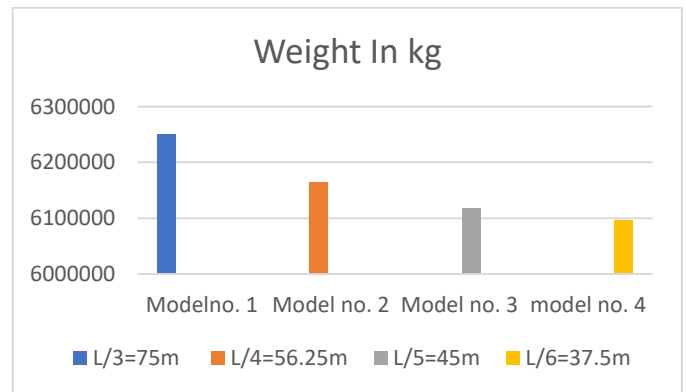


Chart -3: Graph Representing Weight of Bridge.

Cable height: The cable height difference between L/3 to L/6 models is 18.75 m > 11.25 m > 7.5m at center span of bridge. Graph also show the cable height difference.

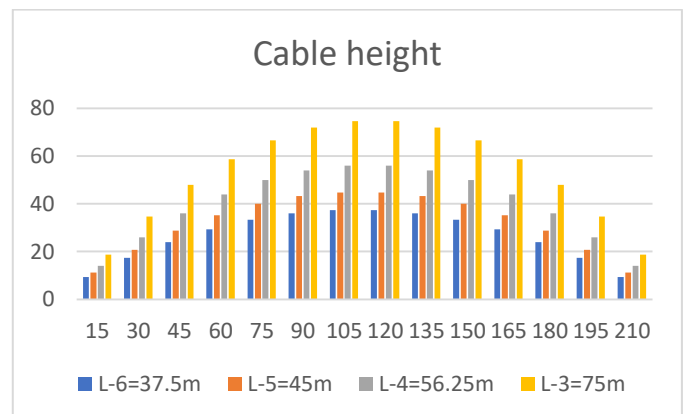


Chart -4: Graph Representing Cable height of Bridge.

Optimizing Deck position-

Deflection for different deck positions: It was observed that deflection decreased when deck position moved from bottom to top. Because structures get more stiff by adding spandrels. Maximum deflection is observed at the centre of the span of a through-type bridge; in every next model, deflection decreases, up to model no. 3 (deck-type bridge). Deck bridges give a minimum deflection of 16.43 cm. But in last model no. 4 (arch below deck), deflection started increasing. Deflection values for all models are shown in the graph.

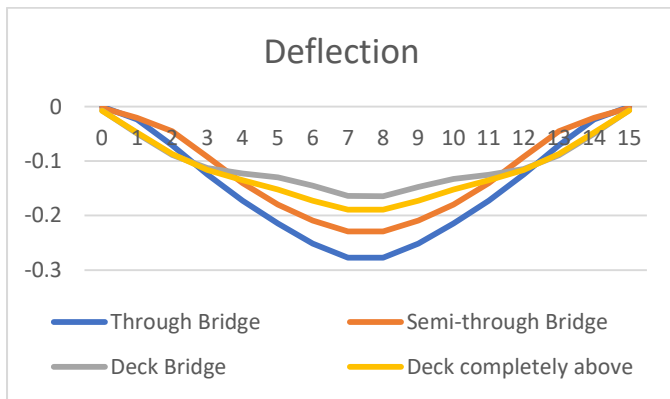


Chart -4: Graph Representing Deflection of Bridge.

Weight: In analysis, the weight of models starts increasing as deck positions move upward. The minimum weight is observed in the fifth model (through-type bridge), and in every next model, the weight gets increased and reaches up to 6430228 kg.

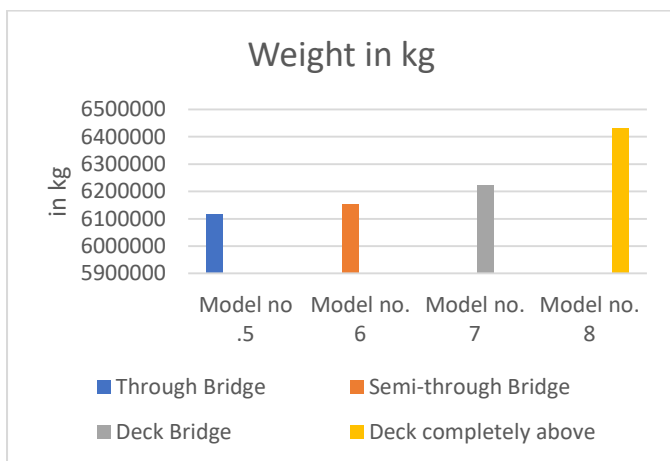


Chart -5: Graph Representing Deflection of Bridge.

4. RESULT COMPARISON

Table -1: Comparing Bending Moment for change in rise arch of bridge.

Sr. No.	Model Name	Bending Moment at distance of 112.5m.(center of bridge)
1.	L/3=75m	7078 kN-m
2.	L/4=56.25m	7639 kN-m
3.	L/5=45m	8808 kN-m
4.	L/6=37.25m	10707 kN-m

Table -2: Comparing Weight and deflection for change in rise arch of bridge.

Sr. No .	Model Name	Weight (in kg)	Deflection (in cm)	Decreasing Weight (in %)	Increasing Deflection (in %)
1.	L/3=75m	6250860	25.76 cm		
2.	L/4=56.25 m	6164592	26.44 cm	1.38 %	2.57% (Allowable)
3.	L/5=45m	6118297	27.71 cm	2.12 %	7 % (Allowable)
4.	L/6=37.25 m	6096373	32.28 cm	2.48 %	20.19 % (Not Allowable)

Table -3: Comparing Deflection and weight for change in deck position of arch bridge.

Sr. No .	Model Name	Deflection (in cm)	Weight (in kg)	Decreasing Deflection (in %)	Increasing Weight (in %)
1.	Through Bridge	27.71 cm	6118297		
2.	Semi-through	22.89 cm	6152253	17.92 % (Less)	0.55 %
3.	Deck bridge	16.43 cm	6220824	40.7 % (less)	1.64 %
4.	Deck completely above arch	18.93 cm	6430228	31.68 % (less)	4.85 %

5. CONCLUSIONS

In this project steel arch bridge for a typical span 225m is analysed for various structural position of deck and for different ratio of arch rise to span in the range 0.16 to 0.33. following are conclusion.

When the rise of an arch decreases, the bending moment in the deck of the bridge increases.

The rise of an arch decreases, deflection is found to be increasing.

The self-Weight of bridge decreases with decrease in rise to span ratio.

The allowable limit for deflection of the bridge is $1/800^{\text{th}}$ of the span of the bridge as per AASHTO specification.

In L/5 rise to span ratio, weight is decreased by 2.12 % compare to L/3 rise to span ratio and deflection is also in allowable limit of $1/800$ of the span, i.e < 28.12 cm .

Rise to span ratio L/5 is suggested for use in arch bridges because for this ratio bending moment is moderate, deflection is in allowable limit and the weight is less compared to the other models.

By comparing the different deck positions through type, semi-through type , deck tangential type and deck type bridge, it observed that when deck position moves from through to deck, deflection decreases but weight increases.

In deck position completely above arch both deflection and weight increases.

In deck type bridge with rise ratio L /5, it was observed that reduction in deflection is 40.7% by only increasing 1.64% weight compared to through type bridge with rise ratio L/5.

To summarise by comparing all models, a deck-type bridge tangential to arch with a rise ratio of L/5 is more efficient. It meets requirement for low-weight structure and stability criteria

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