Comparison of Single and Continuous Span Arch Bridge: a Case Study

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COMPARISON OF SINGLE AND CONTINUOUS SPAN ARCH BRIDGE: A CASE STUDY

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Abstract: This paper aim to present the static and dynamic analysis of arch bridge. The modelling of arch is performed using finite element software ANSYS. Comparisons of results of Static and dynamic analysis of two arch bridge models is presented in details. Model analysis is also performed and presents comparison of Modal frequencies for two cases. Study shows that the continuous span arch bridges are more stable as compared on single span bridges considering parameters like deformation, bending stresses, natural frequencies and material quantities.

Keywords: Single span arch bridge, continuous span arch bridge, modal analysis.

INTRODUCTION

The term arch in architecture and civil engineering is defined as a vertical curved member which is used to span over an elevated space which may or may not support the weight above it. Arches were well known in ancient Egypt and Greece but were considered very unsuitable for monumental architecture and seldom used but the Romans, by contrast, used the semicircular arch in bridges, aqueducts, and large-scale architecture. The pointed arch which was used in the mosques was popularized by Arabs has first acquired its religious significance. The pointed arch was made a great use by medieval Europe. In the late Middle Ages the segmental arch and the elliptical arch was introduced which had great value in bridge engineering because they permitted mutual support by a row of arches by carrying the lateral thrust to the abutments at either end of a bridge. Modern arches of steel, concrete, or laminated wood are highly rigid and lightweight, thus the horizontal thrust against the supports is small. The horizontal thrust can be reduced to a further extent by stretching a tie between the both ends of the arch.

Analysis of arches is a complex process can could be done effectively using finite element analysis. ANSYS software is widely used for finite element analysis, especially for dynamic analysis [1]. Behavior of composite bridge under seismic loading was studied using ANSYS by Jayakrishnan and Lekshmi Priya [1]. Here, the response of the structure under seismic loading was presented based on response spectrum method. Modal analysis was performed and natural frequency and deformation of the bridge is measured using ANSYS.

Another study by Karabörk et al. [2], historical arch bridge located in Anatolia, which was constructed in 13th century A.D. was analysed using LUSAS software. Similar type of analysis was carried using ANSYS and SAP2000 software 3D model of historical Tokatlı Bridge constructed in the Karabuk, Turkey by Memduh Karalar and Mustafa Yeşil [3]. Shallow arches were analysed by Fernandes et al. [4] to analysed dynamic instability using finite element approach. Finite element approach was also used in dynamic analysis of arch dams to [5-7]. Arches are also used in bridges that needs to be assessed for stability after its designed life. One such study was performed by Sarhosis et al. [8] wherein assessment of old masonry bridge was presented using experimental investigation. Another study by Zong et al. [9] illustrating finite element analysis of arch bridge consisting of concrete filled steel tubular sections.

Literature shows that finite element software like ANSYS can be used for performing dynamic analysis of structures. Arch bridge can be easily analyzed using ANSYS software when subjected to dynamics loading. Present paper discusses the static and dynamic analysis of arch bridge as a case study. It shows finite element analysis of two arch bridges cases and compares them for best possible combinations. The effect of continuity on behavior of arch bridge is studied and presented.

ARCH BRIDGE

For the analysis purpose, an actual bridge constructed over the River TARALI, Taluka-Paltan, Dist.- Satara near village aamble is considered. This bridge was designed for IRC 6 loading. Figure 1 show the longitudinal section of the arch bridge.

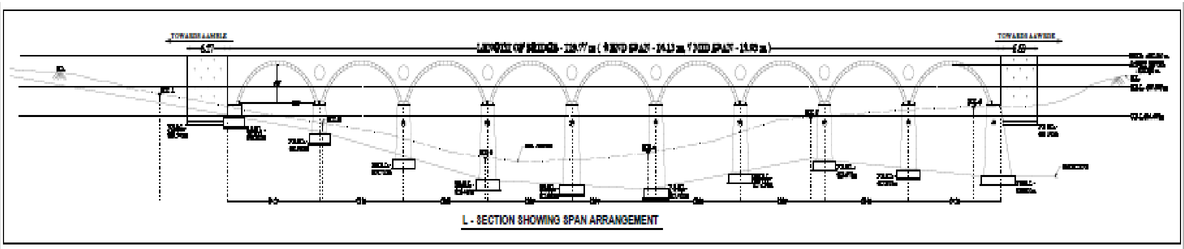
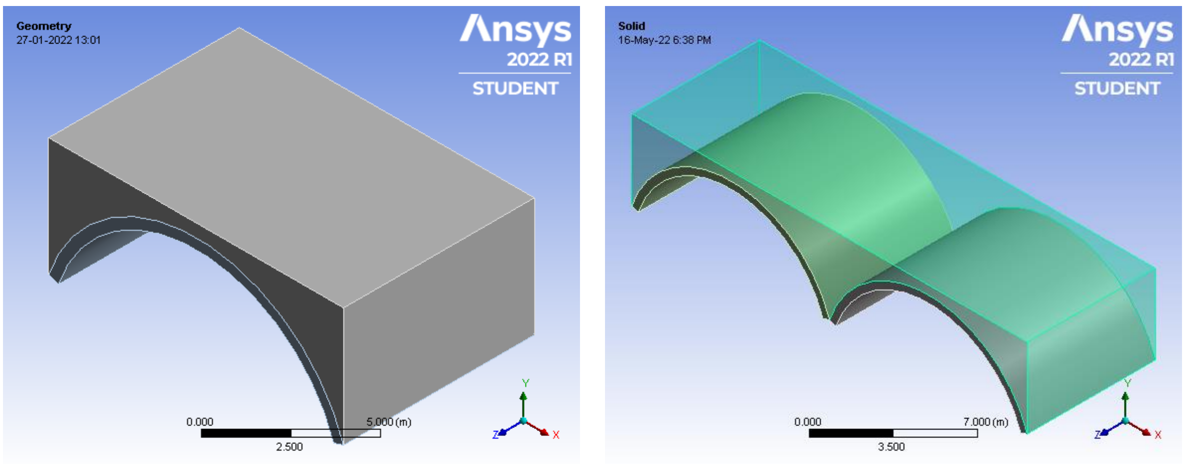


Figure 1. Longitudinal section of arch bridge



(a) (b)

Figure 2: Solid models of (a) single span arch bridge (b) continuous arch bridges

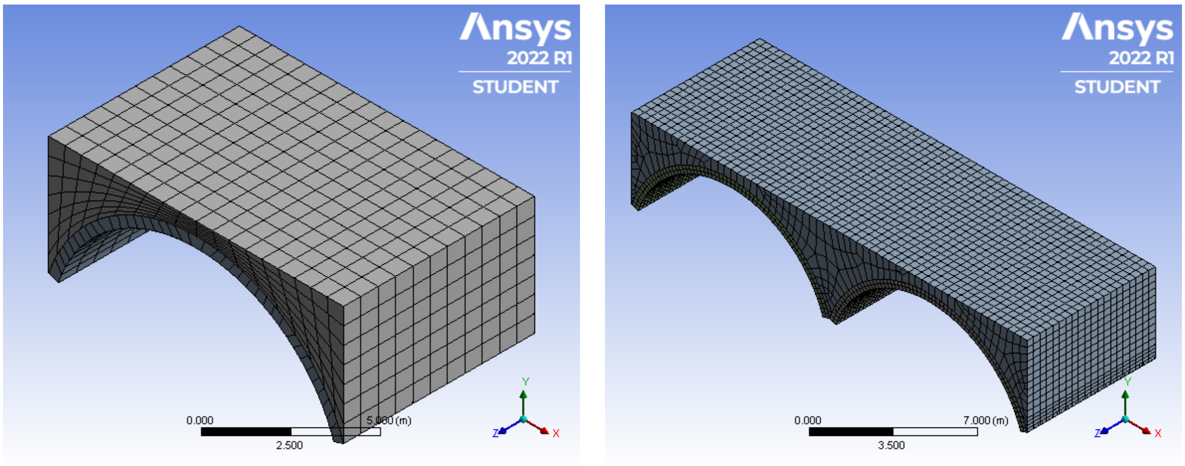
FINITE ELEMENT MODELLING

Finite element analysis and modelling of arch bridge are carried out by using software ANSYS Workbench 2022 R1 (Academic) [10]. Analysis of arch bridges are performed by choosing 3D solid element. Two cases (Figure 2) are analyzed using ANSYS

- Single span arch bridge with length 11.59 m

- Continuous span arch bridge with length 23.18 m with two arches.

The width of both bridge is considered as constant of 8.30 m. The thickness of concrete in arch is considered as 400 mm consisting of M50 Grade concrete. Limestone is used as filling above the concrete arch. The material properties used for the analysis are as per IS-456: 2000. The density of concrete and lime stone was considered as 25 kN/m^3 and 27.3 kN/m^3. The arch and filling above arch are modelled separately and appropriate material properties are assigned. Figure 3 shows the finite element mesh for both cases.



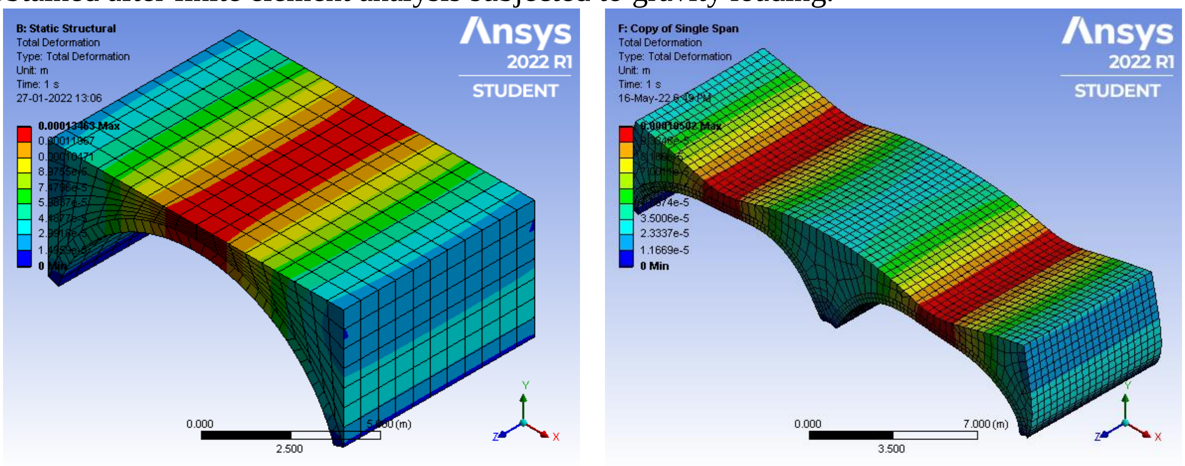
(a) (b)

Figure 3. Finite element mesh for (a) single span arch bridge (b) continuous arch bridges

The above illustrated finite element models are further analyzed for static loading especially for gravity loading and dynamic loading (modal analysis). The boundary conditions are chosen such that the bottom of the arch is kept fixed.

RESULTS AND DISCUSSION

Initially, all three models are analyzed for gravity loading and parameters a like deformation and maximum bending stress were measured. Figure 4 shows the contours of deformations obtained after finite element analysis subjected to gravity loading.



(a) (b)

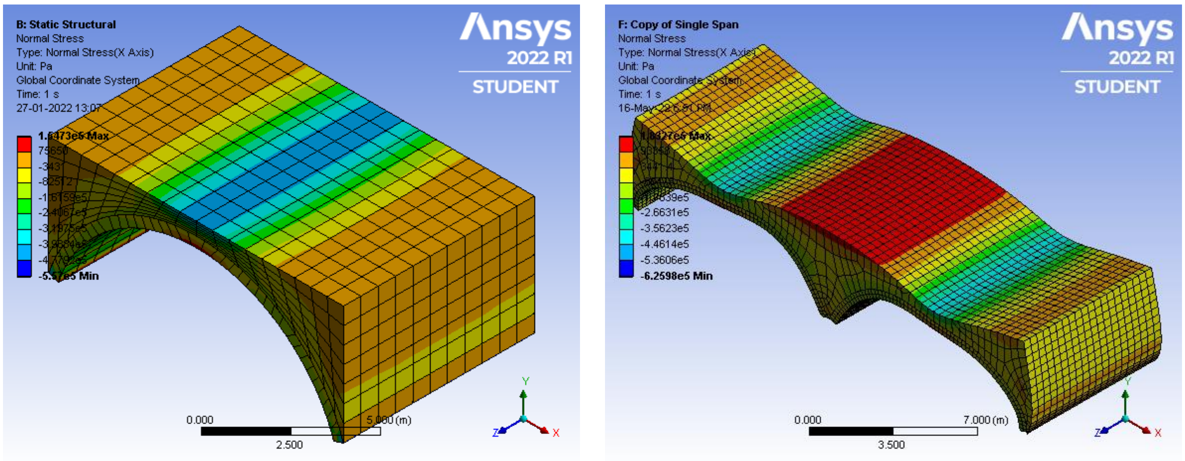
Figure 4. Deformation under gravity loading for (a) single (b) continuous arch bridges

Table 1 shows the magnitude of maximum deformation obtained in finite element analysis. The table shows that maximum deformation was observed in single span bridge whereas this deformation is reduced in continuous span bridge.

Table 1: FE Results of arch bridges

	Case 1	Case 2
Maximum Deformation	0.134 mm	0.105 mm
Maximum Bending Stress	5.57 MPa	6.259 MPa

The bending stresses are also measured after successful finite element analysis. Figure 5 shows the contours of bending stresses. The magnitude of maximum bending stresses are also shown in above table. It shows that smaller compressive stresses are induced in single span bridge whereas these stresses are increased in continuous span bridges subjected to under gravity loading. Similar pattern is also observed in bending tensile stresses in both the models.



(a) (b)

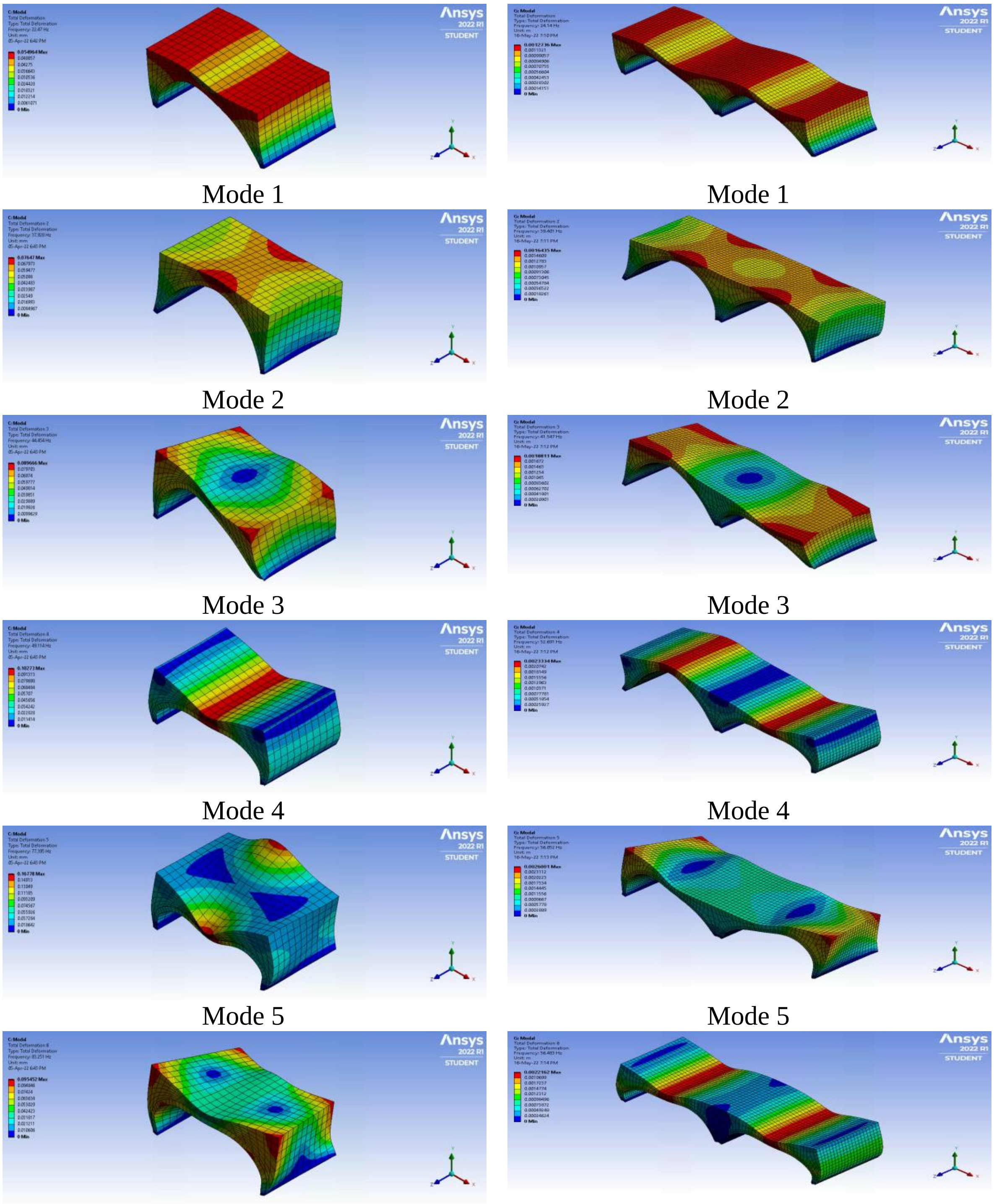
Figure 5. Bending stresses under gravity loads for (a) single (b) continuous arch bridges

Dynamic analysis is also performed by performing Model analysis using ANSYS Workbench 2022 R1 (Academic). Natural frequencies up to 6th mode of the three models are evaluated and tabulated in Table 2. It is observed that the Mode 4 is predominant considering the vertical deformation caused due to gravity loading. Figure 6 show the deformation shape of all modes for single and continuous span bridge.

Table 2. Natural frequencies of arch bridges

Mode	Frequency (Hz)	
	Single Span	Continuous Span
1	22.470	24.140
2	37.928	39.401
3	44.454	41.547
4	49.114	52.691
5	77.395	56.052
6	83.251	56.483

It is observed that the Mode 6 in the continuous span bridge also shows vertical deformation. When compared with frequencies, it is observed that there is marginal difference in the frequencies for Mode 4 (52.691 MHz) and Mode 6(56.483 MHz). The behavior of deformation for other Modes are almost similar for both the models.



Mode 1 | Mode 1
Mode 2 | Mode 2
Mode 3 | Mode 3
Mode 4 | Mode 4
Mode 5 | Mode 5
Mode 6 | Mode 6
(a) | (b)

Figure 6. Deformed shape all Modes for (a) single (b) continuous arch bridges

CONCLUSION

In this paper, arch bridge is analyzed using finite element software ANSYS. Two cases of Sing span and Continuous span bridges are considered for comparative study wherein the static and dynamic analysis is performed. Based on the analysis, following conclusions are drawn.

- Maximum deformation was found to be 0.134 mm and 0.105 mm for single span and continuous span bridges respectively. This indicates that continuity in bridges make it more stable in deformation.
- The value of maximum bending stresses was found to be 5.57 MPa and 6.259 MPa single span and continuous span bridges respectively. Although the magnitude for stresses induced in continuous span bridge is more as compared to single span bridge, the difference between magnitudes is marginal.
- The frequencies for mode shapes from 1 to 6 shows lesser values for single span bridge as compared to continuous span bridge initially, but exhibits reversed behaviour for higher modes.
- Mode shapes indicates that Mode 4 is predominant considering vertical deformation. The frequency at Mode 4 for single span bridge is 49.114 Hz which slightly less than continuous span bridge (52.69 Hz)
- Mode 4 (52.691 Hz) and Mode 6 (56.483 Hz) are predominant considering vertical deformation for continuous span bridge.
- Dynamic analysis (frequencies) indicates two span arch bridge is more stable when compared with single span arch bridge as their values are much more on higher side.
- In general, continuous span arch bridge is more suitable compared with single span arch bridge.

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