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Numerical Modeling and Modal Analysis of Puranapul an Ancient Arch Bridge

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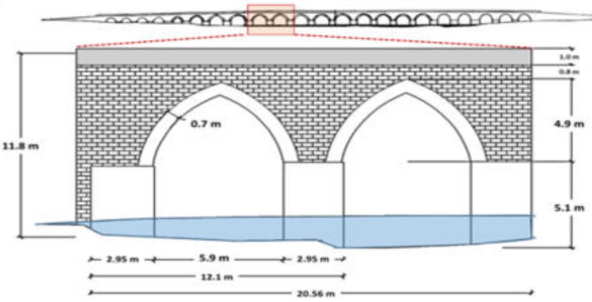
Abstract: Most of the masonry arch bridges prevailing since ancient times are still serviceable which, profoundly indicates their robustness in design and construction methodology. Abandoning such important bridges will influence the transportation practices and economy of the nation. The absence of proper maintenance and monitoring of the health of heritage structures can lead to deterioration at a much faster pace

PURANAPUL BRIDGE

The bridge is 185 meters long, 10.9 meters broad and 12.8 meters above the bed of the river and has 22 arches. The thickness of the spandrel walls and arch is 10.7 meters as shown in Fig[1]. This bridge was constructed using sandstone as the primary r



Each arch opening is 5.9 m and its height is 10 m from the bottom earth level. Arch thickness is 0.7 m and pier thickness is 2.95 meter. All the dimensions have been calculated during the visual inspection of the bridge.

NUMERICAL MODELLING

Three-dimensional approach modeling is preferred for the better understanding in ANSYS workspace by creating a finite element by providing properties mentioned in Table

Parameter	Units	Value
Compressive Strength	MPa	66.9
Tensile Strength	MPa	3.7
Youngs Modulus	GPa	1.13
Poisons Ratio	n/a	0.279
Unit Weight	kN/m^3	27.5

The **three dimensional finite element model** is tested for three types of meshes coarse (1.2 m), medium (0.6 m) and fine (0.3 m) but the results obtained were in the similar line. Current model has 31,103 nodes and 5,376 elements in total. An individual arch numerical model is also developed and analysis has been carried for **gravity analysis**, **modal analysis** and **dynamic analysis**.

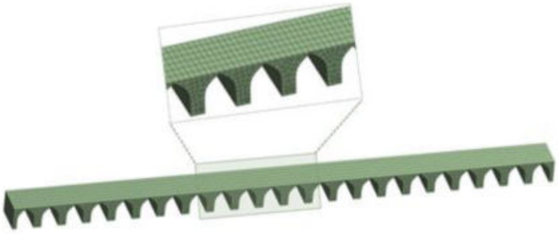


Fig4. Finite element model of the bridge with meshing

GRAVITY ANALYSIS

To understand the deformations in detail, a single span of the total bridge is considered including the dead weight material .

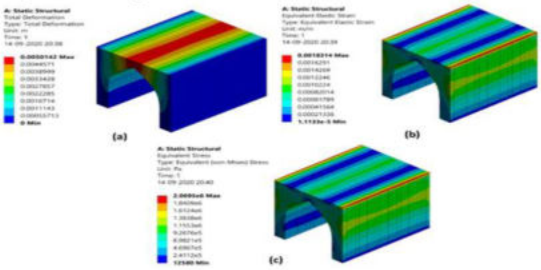


Fig. 5 Total deformations of the Single span bridge due to its self-weight

- The **max deformations** are found to be **5.01 mm** and observed at the mid of the span, **max strains** are found to be **0.00183** and **max stresses** are found to be at the corners in the range of **2.06e6 Pa**. (Fig.5)

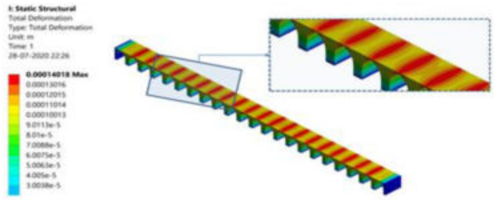


Fig. 6. Total deformations of the bridge due to its self-weight

- The **max total deformation** of the bridge tends to be at the centers of all the arches with a value of **0.14018 mm** and **min deformation** in the negative y-direction and at the two end surfaces and foundations of the bridge is **0 mm.** (Fig. 6)

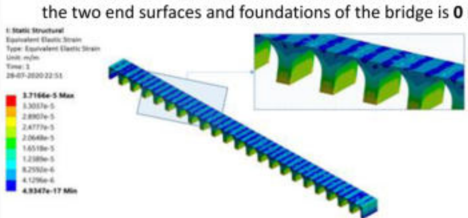
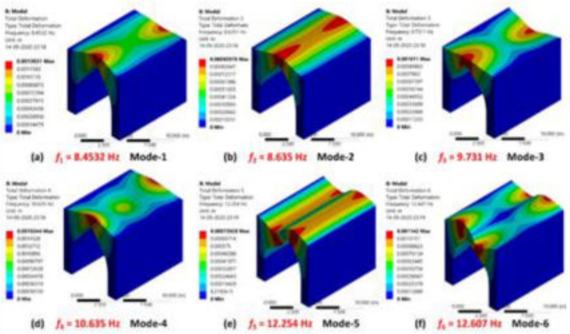


Fig. 7. Equivalent elastic strain distribution over the bridge due to its self-weight

- **Max strain** is observed to be **0.03716** and at the foundation level and reentrant corners, whereas the **min strain** is observed exactly on top of the piers projected to the passage way surface
- The **max stress** is observed to be **4.17e5 Pa** at the corners of the foundation and **min stress** is observed exactly on top of the piers. (Fig.8)

MODAL ANALYSIS



DYNAMIC ANALYSIS

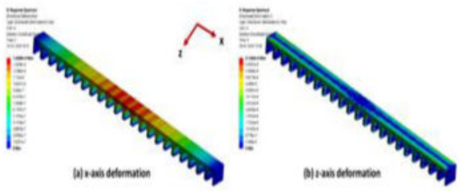


Fig. 10. Max deformations of the bridge for the "Bhuj" Earthquake ground motion

- **Max deformations** and the **max deformations** are found to be very minimal **1.4 x 10^{-6} m** and **6.14 x 10^{-8} m** in x and z directions respectively.

CONCLUSION

Based on the numerical analysis carried for static and dynamic, current configuration of the stone arch bridge is adequate to take its self-weight and live loads coming from the vehicular traffic. As expected maximum deformations are observed to be at the mid of the arch and principal stresses show that they are very much in the permissible limit. Stone piers are also found to be stronger based on the numerical analysis.

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