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Performance Comparison of Through Arch Bridge at Different Arch Positions

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Abstract— A through arch bridge is a special-shape arch bridge also known as a half-through arch bridge and through-type arch bridge, is a bridge made from materials such as steel or reinforced concrete in which the base of an arch structure is below the deck, but the top rises above it, so the deck passes through the arch. An arch is a pure compression form. It can span a large area by resolving forces into compressive stresses and, in turn eliminating tensile stresses. This is sometimes referred to as arch action. As the forces in the arch are carried to the ground, the arch will push outward at the base, called thrust. Arch height has a great significance in the support forces and stresses. This paper presents the behavioral aspects of through arch bridge with different arch positions and to compare them with the real structure by using 3D bridge model in Finite Element Analysis software – ANSYS.

Index Terms— arch height, compressive stresses, deck, deformation, through arch bridge, thrust

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1 Introduction

A through arch bridge is a special-shape arch bridge also known as a half-through arch bridge and through-type arch bridge, is a bridge made from materials such as steel or reinforced concrete in which the base of an arch structure is below the deck, but the top rises above it, so the deck passes through the arch. Cables or beams in tension suspend the central part of the deck from the arch. Its structure and mechanics are significantly different from normal arch bridges because of its single arch rib skewing across the girder and its arch rib being subjected to massive axial compression force, torque, and shear stress.

Tobia Zordan et.al (2014) reported the calibration of the FE model of a reinforced concrete tied-arch bridge using Douglas-Reid method in combination with Rosenbrock optimization algorithm. Based on original drawings and topographic survey, a FE model of the investigated bridge was created. Eight global modes of vibration of the bridge were identified by ambient vibration tests and the frequency domain decomposition technique. Then, eight structural parameters were selected for FE model updating procedure through sensitivity analysis. Finally, the optimal structural parameters were identified using Rosenbrock optimization algorithm. Results showed that although the identified parameters lead to a perfect agreement between approximate and measured natural frequencies, they may not be the optimal variables which minimize the differences between numerical and experimental modal data. FE model updating based on Douglas-Reid method and Rosenbrock optimization algorithm could be used as an alternative to other complex updating procedures.

Wen-Liang Qiu et.al (2010) conducted a stability investigation of a special-shape arch bridge with a span of 180 m. In this paper, the eigenvalue method was used to analyze some of the main influencing factors, such as different loads, restraint conditions of arch spring, stiffness of arch rib, stiffness of main girder and rise-span ratio of arch rib. The study results showed that the slant hangers at both sides of the girder reduced the tendency of arch instability, which is obviously helpful to maintain overall structural stability. Increasing the height of the main girder can improve the structural stability, but the effect was limited. A reasonable rise-span ratio for the special-shape arch bridge studied here is around 0.37 that is larger than an expected ratio for a normal arch bridge obtained in existed studies.

Yan Li et.al (2016) studied the dynamic property of a specially shaped hybrid girder bridge with concrete-filled steel tube (CSFT) arches is investigated based on experimental and numerical methods, especially under moving vehicles. A dynamic field test was conducted. A refined three-dimensional finite element model was built to represent the complex structural mechanic property of the bridge. The impact effect, ride and pedestrian comfort, and related parameters were analysed for the bridge with moving vehicles and were studied by numerical simulations and experimental tests. The results indicate that the impact factor formula from design standards significantly underestimates the dynamic impact effect, which may result in an unfavorable influence on the bridge safety.

1.1 Through arch bridge

Arch Bridge in which deck is not situated completely above the arch, but it travels in one part below it and is suspended to it via cables or tie bards. Arch bridge is one of the most popular types of bridges, which came into use over 3000 years ago and remained in height of popularity until industrial revolution and invention of advanced materials enabled architect to create other modern bridge designs. However, even today arc bridges remain in use, and with the help of modern materials, their arches can be build on much larger scales. A through arch bridge is a special-shape arch bridge also known as a half-through arch bridge and through-type arch bridge, is a bridge made from materials such as steel or reinforced concrete in which the base of an arch structure is below the deck, but the top rises above it, so the deck passes through the arch. Cables or beams in tension suspend the central part of the deck from the arch. Its structure and mechanics are significantly different from normal arch bridges because of its single arch rib skewing across the girder and its arch rib being subjected to massive axial compression force, torque, and shear stress.

1.2 Description Of Arch Bridge Concept

The basic principle of arch bridge is its curved design, which does not push load forces straight down, but instead they are conveyed along the curve of the arch to the supports on each end. These supports (called abutments) carry the load of entire bridge and are responsible for holding the arch in the precise position unmoving position. Conveying of forces across the arch is done via central keystone on the top of the arch. Its weight pushes the surrounding rocks down and outward, making entire structure very rigid and strong.

1.3 Function Of An Arch Bridge

For masonry arches, the proportions of the arch remain similar no matter what the size: wider arches are thus required to be taller arches. For a semi-circular arch, the height is half of the span. Bridges across deep, narrow gorges can have their arch placed entirely beneath a flat roadway, but bridges in flatter country rise above their road approaches. A wide bridge may require an arch so tall as to become a significant obstacle and incline for the roadway. Small bridges can be hump-backed, but larger bridges such as the Old may become so steep as to require steps, making their use for wheeled traffic difficult. Railways also find arched bridges difficult as they are even less tolerant of inclines. Where simple arched bridges are used for railways on flat terrain the cost of building long approach embankments may be considerable.

Further issues are the foundations for the bridge. Arch bridges generate large side thrusts on their footings and so may require a solid bedrock foundation. Flattening the arch shape to avoid the humpback problem, such as for Brunel's, increases this side thrust. It is often impossible to achieve a flat enough arch, simply owing to the limitations of the foundations - particularly in flat country. Historically, such bridges often became viaducts of multiple small arches.

With the availability of iron or concrete as structural materials, it became possible to construct a through arch bridge: a bridge where the deck does not have to be carried over the top of the arch. This requires a structure that can both support the deck from the arch by tension rods, chains or cables and allow a gap in the arch, so the deck can pass through it. The first of these in particular cannot be achieved with masonry construction and requires wrought iron or steel.

The use of a through arch does not change the proportions or size of the arch: a large span will still require a tall arch, although this can now reach any height above the deck without obstructing traffic. The arch may also reach downwards at its sides, to either reach strong foundations or to place the roadway at a convenient height for spanning a deep valley from a plateau above.

2 FE MODELING

The FE modeling is conducted on ANSYS Workbench. The through arch bridge taken for this study is the middle span of Aluva Manappuram bridge. The details of the through arch bridge for study are taken from detailed project report from Department of Design of Bridges and Roads, Trivandrum. The span of the through arch bridge considered for study is 66 m length span.

3 GEOMETRY AND LOADING

The span considered is the middle span of 66m and has a width 6.7m. The road has a width of 6.2m. A maximum 75mm cover is provided for the reinforcement. The models with different arch position was modeled in the similar way.

In these models, the support given is fixed support. The different loads to be considered include the self weight of the deck, arch, cross beams etc. The load is given as static load for analysis. Therefore, total load on deck is taken as 200kN.

The concrete used is M40 concrete with RHT concrete properties with 40MPa compressive strength. The tensile failure stress is 5000kPa and the geometric strain erosion is 0.0035. The steel material used for HC-FCS with elastic modulus of 200GPa, yield stress of 420MPa and Poisson's ratio of 0.30(Caltrans 2006).

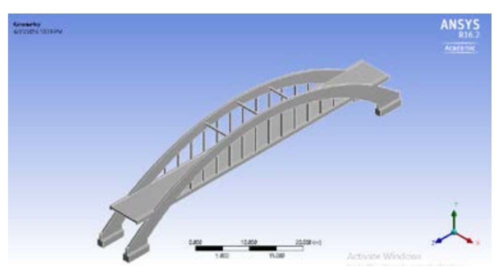

Fig 1: Through arch bridge model

4 RESULTS AND DISCUSSIONS

The deflection occurred in model is collected and compared. The real bridge is compared with bridge models with different arch positions. The deformation increase as the arch position

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goes below the deck.

The position of arch below the deck increases the deformation to a large extends. Maximum deformation is showed by the arch below deck bridge and the maximum deformation is found at the center position.

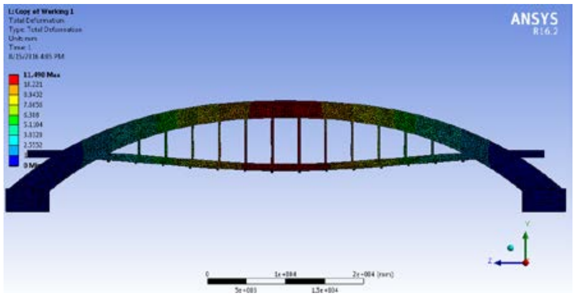

Fig 2: Arch position at top

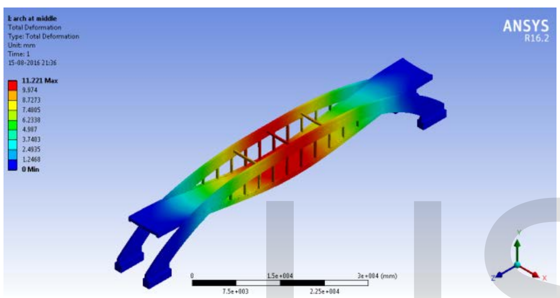

Fig 3: Arch positioned at middle

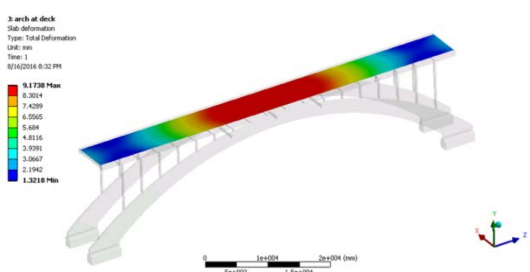

Fig 4: Arch positioned at deck level

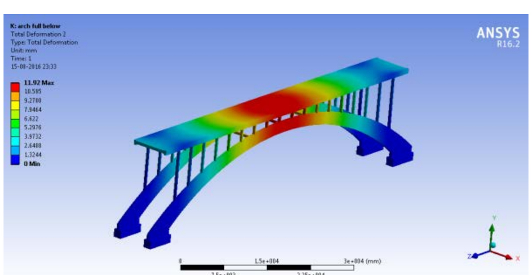

Fig 5: Arch positioned below deck level

ARCH POSITION	DEFORMATION (mm)
Arch at top	11.498
Arch at middle	11.221
Arch at deck	9.1738
Arch below deck	11.92

Table 1: Deformation

5 CONCLUSION

The behaviour of a fixed supported through arch bridge was studied by changing the arch positions. The parameter investigated is deformation. The deformation increase as the arch position goes downwards. Maximum deformation is showed by the bridge having its arch positioned below the deck level and the maximum deformation is found at the centre portion. The positioning of arch at deck level shows lesser deformation compared to the other cases. But as the arch is positioned below the deck level, the deformation exceeds thus making it unstable.

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