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Comparison and Analysis of Vierendeel Beams under Shear and Bending in RCC, Composite and Steel – A Review

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***Abstract*: Vierendeel beams are used for longer spans, it is found in the year of early 19th century and it is founded by a Belgian Engineer, Jules Arthur Vierendeel. This project covers the long span beam of RC, Steel and Composite. All the material components are compared with each other and the model & analysis will be done by using STAAD PRO software. Comparison of the material properties are RC, steel and composite in bending moment, shear force, deflection, durability and cost effectiveness. Pure steel and concrete can be replaced by worldwide acceptance of steel-concrete composite construction. Long span bridge is constructed for many purposes like canal, river, railway track, etc. to cross over the obstacles. The paper presents the results of the experimental modal analysis of a composite arch bridge, about 50 m long, crossing the railway track close to the village of Irugur in Coimbatore city and the experimental modal and analysis of a steel bridge, crossing the railway bridge in Mullaipadi village in Coimbatore city. The mechanism in the tied arch bridge is horizontal beam and arch beam are connected by hangers are vertical support. Hanger system will permit the stress at higher level. The research of improving the three properties in the arch beam, with arch is in elliptical shape. After the bridge is analysed, the technique to reduce the bending moment and shear force at the arch ends.**

***Keywords*: Vierendeel bridge, arch beam, property classification, bridge girder, STAAD Pro.**

1. Literature Review

Fox, G. F., & Bridges, A. (2000). Bridge Engineering Handbook. Ed. Wai-Fah Chen and Lian Duan Boca Raton, CRC Press, 2000.

The rise-to-span rate for bends may vary extensively because a bow can be veritably shallow or, at the other extreme, could be a half- circle. utmost bends would have rise-to-span rates within the range of 1:4.5 to 1:6. The main reason for the arch bridge is built for longer span for deep valleys, railway tracks. A deck arch is the bride deck includes the structure directly supports the traffic load is located above the arch, the deck arch is otherwise known as true arch (or) perfect arch. Through arch, the bridge deck is placed at the spring line of the arch. The tied arch is the reactive force acting on the arch ribs, there will be tension tie at the deck level.

Hendy, C. R., Smith, D. A., & Chiarello, M. (2017, June). Walton Bridge– arch bridge over the River Thames, UK. In the Proceedings of the Institution of Civil Engineers- Bridge Engineering (Vol. 170, No. 2, pp. 102-115). Thomas Telford Ltd.

Arch bridge is a plastic section modified for the continuously curved steel plating making for the arch ribs. The required local non-linear analysis for curved plating had similar strength and ductility of equivalent flat plate. Brittle failure and fatigue for bar-type hangers in design & specification. Walton bridge is the steel thrust bridge with pad foundations supporting a steel concrete composite ladder deck via bar-type hangers. The continuous span end carry the bridge deck between the arch and end abundment. This paper mainly focuses about vertical curvature and its effect on compactness and limiting stresses for the component plates.

Hendy, C. R., & Iles, D. C. (Eds.). (2010). Steel bridge group: Guidance Notes on best practice in steel bridge construction. Steel Construction Institute.

The tied arch is a solution, it can be arranged for deck, such a level it can carry a horizontal force as a tie member. Therefore, tied arch is referred to as a bowstring arch, also arch thrust is the tie-member. The primary requirement of the substructure reduces carring the vertical loads. This may see at one end with longitudinal restraint to carry wind, bracing, acceleration and skidding forces, and that the other end is permitted to move longitudinally.

Ubertini, F., Materazzi, A. L., Gentile, C., & Pelliccia, F. (2012, June). Automatic identification of modal parameters: Application to a reinforced concrete arch bridge. In Proceedings of the 5th European Conference on Structural Control, Genoa, Italy (pp. 18-20).

Structural health monitoring (SHM) is said to known as dynamic measurements in a very active field, especially in bridge engineering, the main idea is to monitor the health state of a bridge structure by looking at its dynamic response. Structural health monitoring is the potential to the possibility of performing a continuous acquisition of the structural response and a real-time processing of a large amount of data. This paper

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represents the dynamic test under operational conditions and the automatic SI of a reinforced concrete arch bridge. The vibration test was extended for a sufficiently long time period to allow extraction of eight data sets recorded under similar conditions.

Mulla, R. J., Peerzade, N. S., Shaikh, S. H., Pathan, S. I., Mujawar, S. M., Mansoori, Z. K., & Shaikh, S. S. Cost Comparison of RCC and Composite Structures.

The steel-concrete composite construction has gained the worldwide acceptance of alternative in pure steel and pure concrete construction. Reinforced concrete members are used for framing system for most of the buildings, since this is the most convenient and economic system for low-rise buildings and for the requirement of longer span steel structure is highly preferable. The steel-concrete composite frame system can provide an effective and economic solution to most of the problems in medium to high rise buildings(or)structure. This study concludes the explore cost effectiveness of composite construction. India is one the fastest growing countries across the globe and need of shelter with higher land cost in major cities where further horizontal expansion is not much possible due to space shortage, we are left with the solution of vertical expansion and merits of the composite structure.

Mohan, K., & Vijaykumar, S. P. (2016). Analysis of Bridge Girder with Beam and without Beam. International Journal of Civil Engineering and Technology, 7(5), 337-346.

The bridge girder is depends upon the vehicles pass, span of the bridge, where the bridge locates, these are factors in design consideration- material, size, shape and selection are based on engineering and economic criteria. Steel concrete composite construction has attained wide acceptance as an alternative to pure steel and concrete structures, there is no need for formwork because the steel beam is able to withstand the self-weight of steel and concrete with some load combination. In this paper, they represent the analysis and results of steel and steel reinforced bridge girders, based on STAAD Pro analysis and manual analysis, combinations of bridge girders are taken and compared. The results and discussion of the values for deflection, bending moment and shear is taken from the staad-pro.

Gattulli, V., Potenza, F., & Piccirillo, G. (2022). Multiple tests for dynamic identification of a reinforced concrete multi-span arch bridge. Buildings, 12(6), 833.

This paper represents the results of an experimental dynamic force carried out on a reinforced concrete multi-span arch bridge. Five expeditious vibration tests were conducted separately for five spans (one test in each span) of the bridge using only six piezoelectric uniaxial accelerometers. Modal parameters are done using Enhanced Frequency Domain Decomposition (EFDD) procedure developed in the software is Matlab R2021b. At the same time, a finite element model was accurately expressed through a commercial software (Midas Civil) to understand the main modal features, a complete instrumentation was not found global experimental dynamic tests. This paper describes multiple dynamic tests on multi-span arch bridges. The conducted bridge dynamic tests are ambient vibration test, forced vibration test and free vibration test.

Mauritius. Khapre, R. N., & Pachpor, P. D. (2013). Effect of Reinforcement on Flexural Behavior of RCC Beam with Opening.

An opening will be provided in RCC beam so that utility lines can pass through beam without providing bend. The provision of opening in beam creates complex stress distribution and increases risk of collapse. These beams are analysed using finite element method it shows typical bending stress in top and bottom stress are same but opposite in nature. The stress distribution cannot be seen in the reinforced concrete beam at the bottom section to resist tension. This investigation is carried out on several finite element models of RCC beams with circular and rectangular opening to study impact of reinforcement on the necessary terms like deflection and bending stress in RCC beams with openings.

T, Gupta, S., Jain, S., (2021). Study on Interfacial Shear Properties of Concrete Reinforced Stone Arch Bridges Using Staad. pro A Review.

Bridges are structural components required for efficient movement of trains, vehicles and earth embankment for crossing of water course like streams across the embankment as road embankment cannot to obstruct the natural water way. The bridges are constructed in different materials like (brick or stone) or reinforced cement concrete. These are bridges subjected to traffic loads as the road carries. The structural elemens should be withstand maximum bending moment and shear force. This paper presents the use of finite element modelling of the arch bridge and they uses STAAD pro for finite element modelling.

Zhang, J. L., Hellmich, C., Mang, H. A., Yuan, Y., & Pichler, B. (2018). Application of transfer relations to structural analysis of arch bridges. Computer Assisted Methods in Engineering and Science, 24(3), 199-215.

The curvature of arches, the structural analysis is more challenging and expensive than the straight beams. These methods facilitating the structural analysis of arches is a topic of ongoing scientific research and this method of consistent deformations for pinned arches, representing structures that are statically indeterminate to the first degree of freedom. In which the partial derivative of the strain energy with respect to a force gives the displacement in the direction of this force, such as analytical methods are easily applicable to arches with low degrees of statical indeterminacy and different types of external loads. The shallow arches subjected to a concentrated axial load acting at the end of the arch, most bridge designers use numerical methods for structural optimization. For sensitivity analysis of arch bridges, frequently involving several changes in the geometric dimensions of the arch and the number and arrangement of the hangers or the columns.

Gauri Ingole, Chetan Pise, “Using time history analysis of vierendeel girder”, IJSART, volume 7, issue 4, April 2021.

This paper involves the nonlinear procedures used for Performance Based Design, the Nonlinear dynamic procedure (time history). The purpose of a study is to determine in depth understanding of inelastic seismic response of rectangular RCC buildings with diaphragm with openings, in this analysis, where the seismic events happened due to energy dissipation. This

paper deals with an investigation of simple parallel chorded reinforced concrete Vierendeel girders in their elastic as well as ultimate load conditions. This simple method is suggested for predicting the exact mode of failure and to calculate the ultimate load. Comparison in Vierendeel girders designed on elastic theory and girders with arbitrary uniform reinforcements has also been investigated and their relative advantages discussed. This paper investigates the RCC vierendeel girder is analysed and compared with conventional building both static linear and dynamic nonlinear analysis is done using FEA tool ANSYS.

Rudi, S. L. (2019). Network arch bridge: Optimization of the arch applying simple loads (Master's thesis, Universitetet i Agder; University of Agder).

The network arch bridge can be compared to the simply supported I-beam. The arch acts as the compression flange, the main girders as the tension flange and the inclined hangers takes all the shear force working as the web. The hangers (or) columns distribute the force between the tie and arch so that little bending occur. The big difference the main difference between the network arch bridge and a tied arch bridge with vertical hangers becomes evident when only half of the bridge span is loaded. In the tied arch bridge, the axial forces in the arch and tie decreases, but the arch moves towards the unloaded side, which leads to an increase in both deflection and bending moments. The network arch bridge is loaded on half the span the inclined hangers contribute to distribute the forces in an angle to the arch, where the cross section has larger stiffness, which leads to a decrease in bending moments and deformation. In the Network arch bridges are for the most part built with arches in steel. Prefabrication and ease of transport makes it the most effective and economical material to use. Hanger types are discussed in this project. These two model types are analysed in this project to see if they can improve in the circular arch shape and the three-centre arch (TCA) and the elliptical arch.

Pipinato, A. (2018). Structural optimization of network arch bridges with hollow tubular arches and chords. Modern Applied Science, 12(2), 36-53.

In the framework of a bridge engineering, cable structure represents a key argument. The development of bridge solutions, are necessary to keep time and costs, maintaining with its high-level safety and functionality. Network arch is the cross hangers with supports arch rib and horizontal beam and hangers' type, configuration and optimization are discussed. In this paper, they investigate the introduction on the network arch solution for horizontal overloading in the bridge structure, the relevant data and the structural analysis are done. In additional to, a development of certain types of road ways, railway bridges are presented in the particular case of hollow sections and types of cable are discussed here.

Maugh, L. C. (1935). The analysis of Vierendeel trusses by successive approximations. Le Calcul par iteration des poutres Vierendeel... LC Maugh.

Vierendeel trusses are rigid type of structure, the diagonal members are omitted in these structures, there by subjected to flexural and shearing stress to the ordinary truss action. The statically indeterminate framed structure is used in the construction buildings and bridges. The mathematical application of analysis to the design of structure. This paper discusses the moment distribution method and panel distribution method.

Silva, A. O., Junior, N. O., & Requena, J. A. (2015). Numerical Modeling of a Composite Hollow Vierendeel-Truss. International Journal of Engineering and Technology, 7(3), 176.

Composite trusses is a very efficient alternative to overcome large spans for civil engineering, are these are constructed with corner sections, and in many cases, have a central Vierendeel panel, in the two successive method, they are panel method and moment distribution method. In panel method, the calculation of moments in the Vierendeel trusses by chords of equal rigidity and numerical data's are used. In moment distribution method, the joints can undergo rotation and it is considered as the displacement. This paper says that the study of feasibility and ultimate limit state to extend Vierendeel panels across the central third of the structure and replace the corner for hollow sections. This paper discusses the results found demonstrate that to make it possible to construct a composite Vierendeel-truss using welded hollow sections and Vierendeel panels across the whole central third of the span, here the steel member, joints, welds, horizontal longitudinal shear in the stud bolts, and the resistances of the slab within safe limits, making the ultimate limit state be effected by the yield of the bottom chord, both of them will undergo under tension and bending moment.

2. Conclusion

1) As per the above paper, the rise-span should not less than 1/3, this terms that the parabolic arch should be certain height.
2) Vierendeel bridges are done in reinforced cement concrete, composite and steel. Here we are comparing all the three.
3) The loadings are done using as per IRC 6-2017, Class – A loading, a trained type of vehicle is given to state highways and National highways.
4) When the axial force acts on the bridge, the uniform load is transmitted on the entire bridge through the arch.
5) The dynamic(moving) load are not considered in the Vierendeel bridge because the arch takes the entire weight. The deck slab weight only transferred to the sub-structure of the bridge.
6) The bridge modelling and analysis is compared in STAAD-PRO software.

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