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Comparative Study on Performance of Beam and Arch Bridge Subjected to Uniformly Distributed Load

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ABSTRACT

In this paper, an attempt has been made to study the behavior of beam and arch bridges subjected to static uniformly distributed loads. The target audience of this research paper is Architecture students because they would like to visualize the structural concepts for better understanding with minimal calculation. For this reason, a static load test was conducted on three types of beam bridges and on three types of arch bridges. The performance of the arch bridge is studied by changing the type of beam, and the results are compared with the beam bridge. Based on the test results, it is found that the performance of glued beam bridges is recommended for less span than arch bridges.

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1. Introduction

A bridge is a structure built to span physical obstacles without closing the way underneath, such as water, road, etc., for the purpose of providing passage over the obstacle. The design of bridges depends on the function, material, span, and construction cost [1-3]. In this paper, experimental investigation has been conducted on two different types of bridges: Beam and Arch bridges. A beam bridge is one of the simplest types of bridge, and it is also called a culvert bridge. It is normally used for bridges that span up to 3m [4, 5]. For a long span, the bridge needs to have supports in the middle, called a continuous beam bridge. The performance of the bridge is increased by providing carbon cables, and strips, prestressed concrete, composite box girder, and fiberglass reinforced foam concrete [6-11]

Arch bridge use curve structures to provide more resistance to bending forces. Instead of pushing straight down, the weight of an arch bridge is carried outward along the curve of the arch to the supports at each end [12-14].

The bridge must meet various demands: architectural, technical, environmental, economic, production, and service life design [15]. The main important technical demand is to study the resistance, including the load and the actions that happen within the system of the bridge. Also, Favre [16] addresses the arch bridges as the long-span bridge.

2. Beam Bridge and Arch Bridge

A beam bridge is one of the simplest types of bridge where both ends are supported by piers. The simplest form is about one rigid horizontal element, known as a lintel, and two vertical supports, known as posts. In general, it has little bending because of resisting the static load, which is the own weight of the beam. Moreover, the external load, known as dynamic form, affects the ability of the lintel to carry more weight. Both static and dynamic loads react together and make the beam difficult to resist; therefore, internal compression and tension forces will happen [17]. The compression occurs at the top of the lintel as it is being pushed while the bottom is pulled apart, and tension occurs at the bottom of the lintel. The size of the beam, especially the depth, plays an important role in controlling the distance that the beam can span. Beam bridges are likely to be relatively used for short distances because they are supported only by two end piers: therefore, the more the distance, the weaker the beam bridge [18].

On the other hand, the arch bridge is another common type of bridge whose basic principle is about distributing the load along the curve of the arch, which ends with supports called abutments. These supports hold the arch and carry the weight of the whole bridge. The top of the arch is responsible for conveying the forces along the curve [4]. In this paper, both beam bridge and arch bridge are taken into the study and are subjected to static uniformly distributed load. Mathematical structural calculations or material properties are not considered in this study. This paper focuses mainly on the form of the two different types of bridges, and their performance is summarized.

3. Experimental Setup

The experiment uses simple tools such as a wood pillar/pier, arch, and beam made from cardboard representing a short-span beam bridge. There were three types of beams: simple beam SB -using one cardboard as a beam-, unglued beam UGB-using four of the simple beams on top of each other without any binder- and finally, glued beam GB- using four simple beams on top of each other combined with glue as a binder. The glue used remains the same throughout the experiments. Each beam has been laid over two wooden pillars without any supports to form the bridge. The load is applied uniformly throughout the length of the beam and is increased gradually. The load is applied on the beam in the form of a bar, and its length is equal to the length of the beam and is added as increments of 1 gm, 2 gm, etc. The total load is measured once the beam starts to yield (bend) and is increased till the beam fails. This study considers six different types of bridges, and the beam's width remains the same in all cases. All three types of beam bridges are shown in Fig. (**1**).

Type 1: Single beam bridge (SB), depth of the beam is d

Type 2: Unglued Beam bridge (UG), four single beams are placed over one another and the depth of the beam is 4d

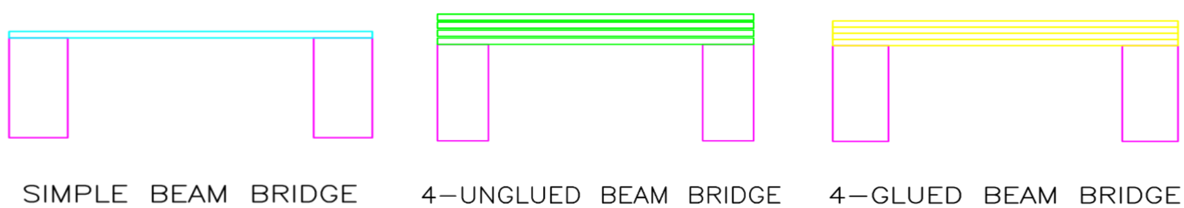
Type 3: Glued Beam bridge (GB), four single beams are placed over one another, glue is applied between each beam, and the depth of the beam is 4d

An arch is added to the three types of beam bridges explained earlier. The size of the arch remains the same for all three cases.

Type 4: Single Arch bridge (SAB), depth of the beam is d, and an arch is created below the beam

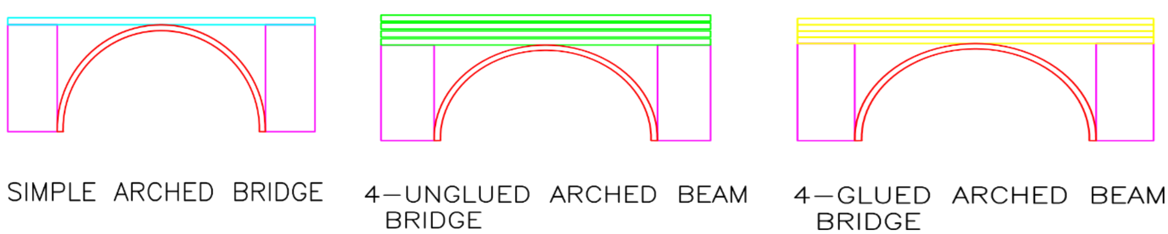
Type 5: Unglued Arch bridge (UGAB), four single beams are placed over one another, the depth of the beam is 4d, and an arch is added below the unglued beam

Type 6: Glued ARCH bridge (GAB), four single beams are placed over one another, and glue is applied between each beam, and an arch is provided below the glued beam. The depth of the beam is 4d. All three types of arch beam bridges are shown in Fig. (**2**). The actual model of the six bridges is shown in Fig. (**3**).



Type 1 **Type 2** **Type 3**

Figure 1: Different types of beam bridges.



Type 4 **Type 5** **Type 6**

Figure 2: Different types of Arch beam bridges.

Figure 3: Model of the six types of bridges.

4. Results & Discussion

1. It is found that glued beam bridge GB has more stiffness and load-carrying capacity than the other two beam bridges and is clear in Fig. (**4**). It is found that SB failed first, and GB's load-carrying capacity was the greatest. The load-carrying capacity of the beam bridge follows linearity; for example, if 4d increases the depth of the beam, then the load-carrying capacity is also increased by 4 for the unglued beam bridge. In the case of glued beam bridge, nonlinear behavior is noticed, and the load-carrying capacity is increased by 68 times that of a single beam bridge (Fig. **4**).

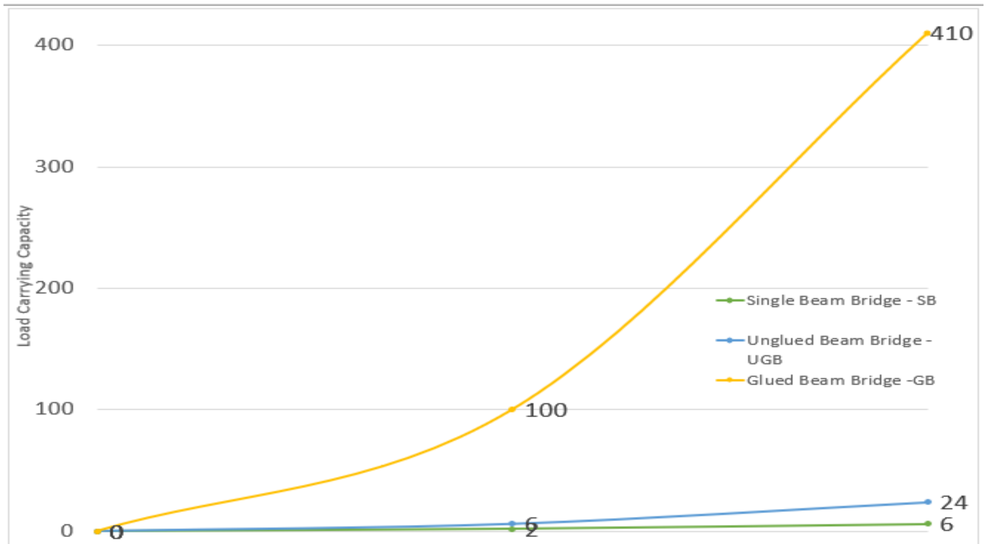


Figure 4: Load carrying capacity of different beam bridges.

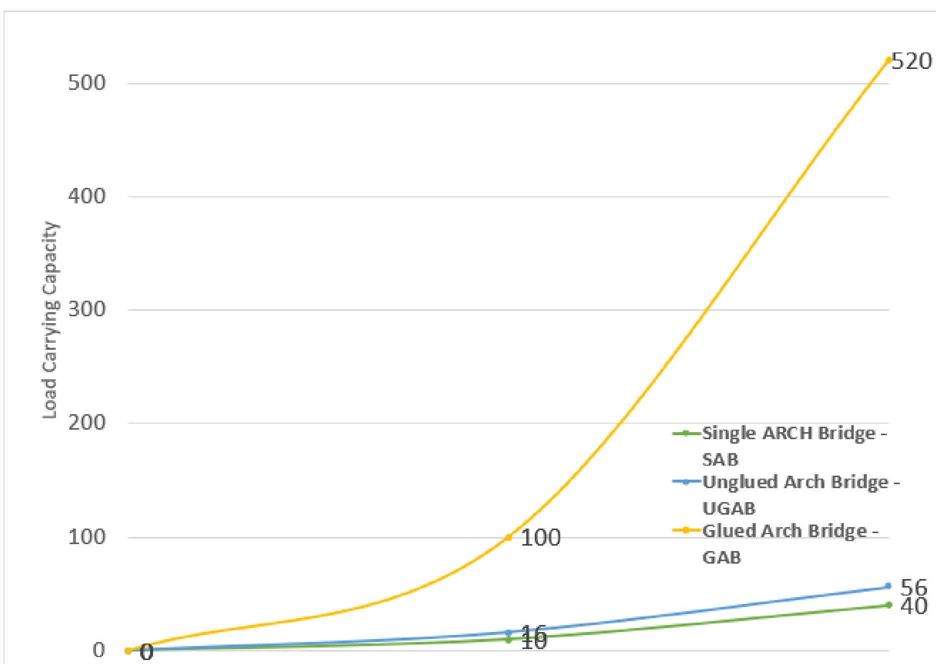


Figure 5: Load carrying capacity of a different arch bridge.

2. It is observed that single-arch and unglued arch bridge shows linear behavior. In contrast, the glued arch beam bridge showed more stiffness than the simple and unglued arch bridge, and it exhibits nonlinearity, as shown in Fig. (**5**).

3. The performance of the arch bridge is compared with the beam bridge, and it is found that the performance of the single arch beam bridge is more appreciable than glued arch beam bridge. The maximum load-carrying capacity of a single arch bridge is 7 times greater than the single beam bridge SAB (Fig. **6**). In contrast, the load-carrying capacity of glued arch bridge GAB is 1.3 times greater than a glued bridge (Fig. **7**).

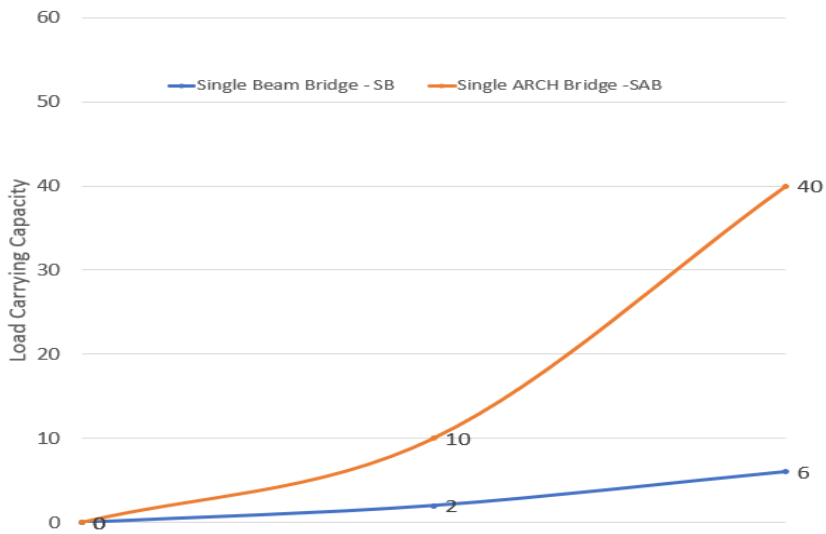


Figure 6: Performance of single beam and arch bridge.

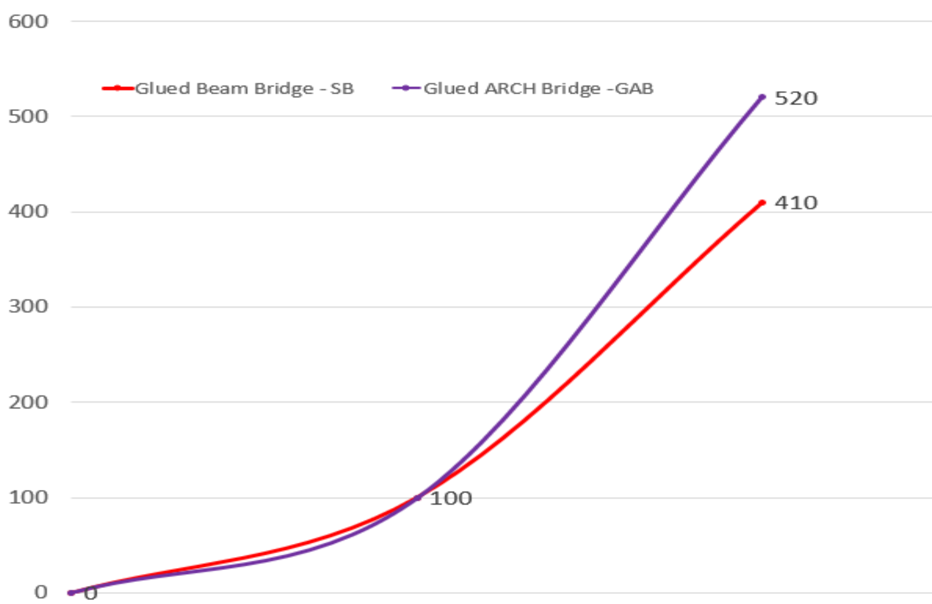


Figure 7: Performance of glued beam and arch bridge.

5. Conclusion

Bridges are one of the most important structures in the field of engineering. The high demand and requirement for bridges make it more important to develop concepts and methods to build bridges. From the results, it is concluded that if the span of the bridge is short (small), then construct glued beam bridge because it has more stiffness. In other words, load-carrying capacity is high, easy to design, and economical to construct. Then the next option is a single-arch bridge, but the arch and beam are designed separately.

In the case of a longer span, an arch beam bridge (SAB) has more stiffness than the other types because it carries more load. Glued beam bridge performed well in both cases (beam bridge and arch bridge), but the difference between them was very small, so it was not economical to add the arch. The ratio in which the load carried by the arch beam bridge and single beam bridge was 7:1, and the ratio between the glued arch bridge and glued beam bridge was 1.3:1.

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