STRUCTURAL BEHAVIOR CHARACTERISTICS OF ARCHED STONE BRIDGE ACCORDING TO FOUNDATION AND FILLER TYPE

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ABSTRACT

The Korean traditional stone bridges which are located in the historic temple and palace site have been deteriorated by the various damages due to the natural disaster. So, it is needed to establish the structural plan for the preservation of stone bridges. Therefore, it is important to evaluate the structural characteristics and mechanism according to construction types considering the foundation and filler types of stone bridge. To this end, this study selects the arched stone bridge type which is the representative stone bridge in Korea and classifies the structural components according to the construction types. Also, this study considers the various design variables considering the load conditions and the several constructed types of the foundations and fillers of arched stone bridge. Especially, this study presents the finite element method for the structural modelling and analysis of the masonry stone bridges. Through the analysis results, we evaluate the structural performance and load transfer mechanism according to the design variables of arched stone bridges.

Keywords: Arched stone bridge, Foundation type, Filler type, Structural behaviour characteristics

1. INTRODUCTION

The Korean traditional arched stone bridges are located in the historic temple and palace sites for the purpose of aesthetic structural variety. These arched stone bridges have the several types of foundations and fillers according to the construction locations and materials. Therefore, it is very important to evaluate the structural behavior characteristics considering the construction types of foundations and fillers. To this end, this study selects the representative arched stone bridge and performs the structural modelling and analysis by the finite element method. Also, this study evaluates the structural performance and load transfer mechanism under the design variables according to foundations and filler types.

2. CONSTRUCTION TYPES OF FOUNDATION AND FILLERS

The arched stone bridge is totally composed of the sleeper stones, spandrel wall stones, arch stones, post stones and keystones. The transfer process of upper loads is the keystone, arch stone and post stone. Especially, the spandrel wall stones prevent the loss of fillers, and the sleeper stones prevent the twister of arched stone bridge. The arched stone bridge in temple site has the natural rock foundation as located in the mountain. But, the arched stone bridge in palace site has the artificial rectangular stone foundation with the lattice shape. Also, the fillers within the arched stone bridge have the several types according to the construction location and the used materials. This study considers the two types of fillers. The one is the native stone fillers with the relatively strong pressure stress, and the other is the soil and rubble fillers with the fine particles and voids.

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3. STRUCTURAL MODELLING ANALYSIS

3.1. Representative model selection
It is not easy to select the representative model of arched stone bridge because it has the various types of foundations and fillers according to the construction locations and structural forms. Therefore, this study selects the arched stone bridge in the seonamsa temple site as the representative model. This model has the semicircle arched structural form and preserves the original shape without the great structural damages.

3.2. Structural modelling process
The structural modelling process of representative model is shown in Fig. 3. The arch is composed of forty-one stories with two to five arch stones in a story. Also, the spandrel wall stones are composed of the natural stones with the various sizes and shapes. So, it is not easy to model the real structure considering all members and elements. Therefore, this study performs the simple modelling process as shown in Fig. 3a and 3b through the assumption of the bilateral symmetry for the spandrel wall stones and single mass for the arch stones.

Fig. 1 Foundation and filler types

Fig. 2 Representative model of arched stone bridge

Fig. 3 Structural modelling process
4. STRUCTURAL BEHAVIOR CHARACTERISTICS

4.1. Stress and displacement distribution

This study performs the finite element analysis of the representative model by using ADINA program under the various design variables considering the foundation and filler types. The applied loads are the self-weight load and moving live load. Fig. 4 shows the stress and displacement distributions according to the various model cases. Especially, Fig. 5 shows the measure locations of analysis results considering the load transfer mechanism.

![Stress and displacement distribution](image)

**Fig. 4 Stress and displacement distribution**

![Measure locations of analysis results](image)

**Fig. 5 Measure locations of analysis results**

4.2. Analysis results according to foundation types

4.2.1. Analysis results of stresses

Fig. 6 shows the analysis results of stresses according to foundation types. Totally, the stresses are increased gradually to the bottom parts from the top parts. Especially, the relative larger stress is shown at the post stone parts in the rectangular stone foundation model. This shows the stress concentration in the bottom parts according to the difference of construction types of foundations.

![Stress distribution](image)

**a) Stress distribution according to the native rock filler**

![Stress distribution](image)

**b) Stress distribution according to the soil and rubble rock filler**

**Fig. 6 Analysis results of stresses**
4.2.2. Analysis results of displacements

The displacements are decreased gradually to the bottom parts from the top parts. Especially, the rectangular stone foundation model shows the larger displacement distribution than the natural rock foundation model by the reason of the differences of stress distribution and load transfer mechanism.

![Displacement distribution graphs](image1)

**Fig. 7** Analysis results of displacements

4.3. Analysis results according to filler types

4.3.1. Analysis results of stresses

The maximum stresses are shown in the bottom parts and the soil and rubble filler model shows the larger stress than the native rock filler model. This means that the load transfer mechanism and stress distribution are influenced by the difference of inner filler density.

![Stress distribution graphs](image2)

**Fig. 8** Analysis results of stresses

4.3.2. Analysis results of displacements

The maximum displacements are shown in the top parts and the soil and rubble filler model shows the larger displacements than native rock filler model by the reason of the differences of the inner density and stress distribution.

![Displacement distribution graphs](image3)

**Fig. 9** Analysis results of displacements
5. CONCLUSIONS

This study evaluates the structural behavior characteristics of arched stone bridge according to the foundation and filler types. Through the analysis results, the stresses and displacements of rectangular stone foundation model are larger than those of natural rock foundation model. Also, the stresses and displacements of soil and rubble filler model are larger than those of native rock filler model. This means that the load transfer mechanism is influenced by the construction form and inner density distribution according to the foundation and filler types. Therefore, it is expected that we could secure the structural performance of arched stone bridge through the structural evaluation of foundations and fillers.

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