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Structural Behavior Analysis of Masonry Stone Pagoda Considering the Inner Construction Types of Stylobate

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Abstract We have many difficulties in the modeling and analysis of masonry stone pagoda structure because this structure has the discontinuum behavior characteristics, compared with the general continuum structures. Also, we need to consider the inner construction types of stylobate for the reasonable analysis of structural mechanism of masonry stone pagoda. Most masonry stone pagoda structures built in Korea are largely classified into three parts such as top part, body part and stylobate. Specifically, the stylobate takes a very important structural part, performing the role of foundation in ordinary structures, and the reduction of stylobate's bearing capacity has great influence on the safety of structure. As for stylobate, the construction types of inner Jeoksim result in the different structural behaviors. Therefore, this study selects three-story stone pagoda in Goseon-sa temple site that shows the typical type of stone pagoda structure in Korea. Also, this study investigates the construction types of stylobate and evaluates the structural and mechanical behaviors of masonry stone pagoda structure according to many application variables of stylobate's Jeoksim forms. To this end, we considers the contact surface and block modelling for the discontinuum elements through the discrete element method and finite element method. Through the comparison of analysis results, we can find out the load transfer mechanism according to the inner Jeoksim types of stylobate.

Keywords: Stone pagoda, construction type, discrete element modelling, load transfer mechanism

Introduction

There are many difficulties in the analysis of force transfer mechanism because the stone pagoda structure consists of indivisual stone blocks with stacking form. Therefore, this study selects stone pagoda in Goseon-sa temple site that is the representative stone pagoda of Korea and analyzes the construction form and structural type of top part, body part and stylobate. Also, we analyze the structural mechanism through the modelling and analysis of stone pagoda by considering the behavior characteristics of discontinuum structure. To this end, the discrete element analysis technique that can be able to analyze the discontinuum model of masonry stone pagoda. In this study, the inner Jeoksim type of stylobate is considered as the column & stacking form such as the stone pagoda in Goseon-sa temple site.

Structural Form of Stone Pagoda

The stone pagoda in Goseon-sa temple site which is representative in Korea is shown in Fig. 1. This stone pagoda with three stories consists of three parts such as top part, body part and stylobate.

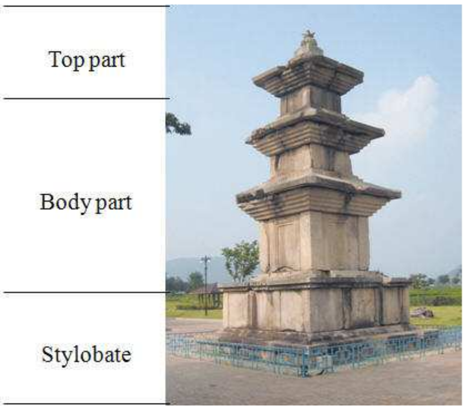


Figure 1: Stone pagoda in Goseon-sa temple site

Structural Modelling and Analysis of Stone Pagoda

Masonry structure shows the discontinuum behavior which is different from continuum structure. Structural modelling of discontinuum structure is very important to understand mechanical behavior of stone pagoda structure. Therefore, this study uses 3DEC program that is based in discrete element method for the analysis of vertical load mechanism. Especially, the block and joint models are given according to the construction type of stone pagoda.

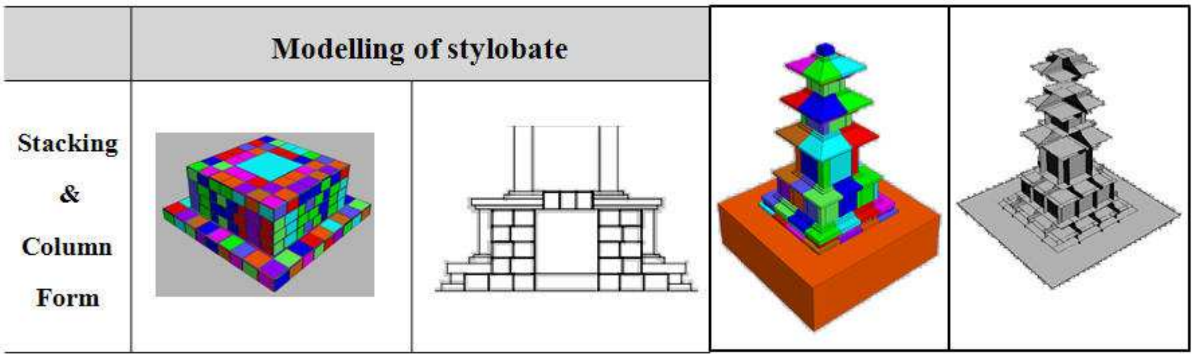


Figure 2: Structural modeling of stone pagoda

Analysis Results and Load Transfer Mechanism

Stress and Displacement Distributions Fig. 3 shows the stress distribution shape of stone pagoda under the vertical load by self-weight of stone pagoda. From analysis results, a large stress happens along the outside part than the inside part of Jeoksim. Maximum stress is shown from upper capstone part between lower stone and stylobate. Also, the maximum stress decreases in lower part as the load passes through the Jeoksim of stylobate because of the increase of support area. Also, the stresses are concentrated in external members with a large stiffness because the Jeoksim part of stylobate filled with soil can't support the big load, based on the small stiffness. From the displacement distribution results, the maximum displacement is shown in the body part within first floor. By this phenomenon, we can find out that the self-weight of upper part is given as the concentrated load in the Jeoksim part. Also, the large displacements are shown in the Jeoksim part of stylobate because of the absence of member with big stiffness. Especially, we can check the unstable state in the part of stylobate filled with soil through the lifting phenomenon in the upper capstone member.

From the results of Fig. 4, we can find out that the upper loads are transferred to the ground level through column formed stone. Especially, the maximum stresses are shown in the column formed stone and then the stresses decrease gradually in the lower part of stylobate. Also, we can find out that the stacking Jeoksim partially supports the stresses of the column formed stone. The maximum displacements are shown in the first floor part. But, the displacement value is reduced by 30%, compared with the model filled with soil. Therefore, it is shown that the model with column & stacking form can distribute stably the upper loads and performs the important role in improving the stability of stone pagoda.

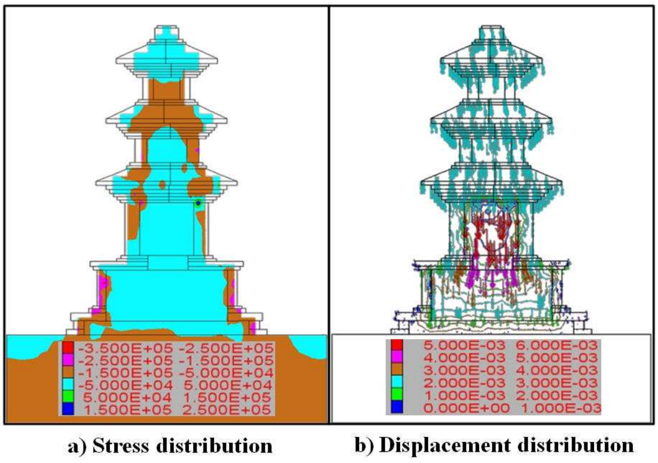


Figure 3: Stress and displacement distribution of stylobate model filled with soil

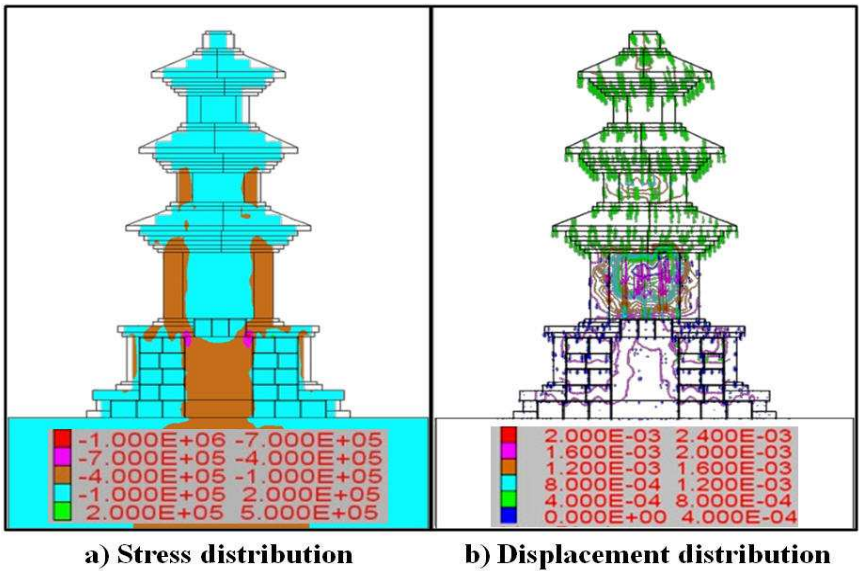


Figure 4: Stress and displacement distribution of stylobate model with column & staking form

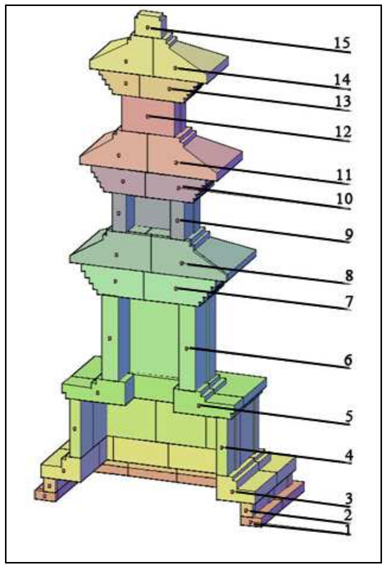
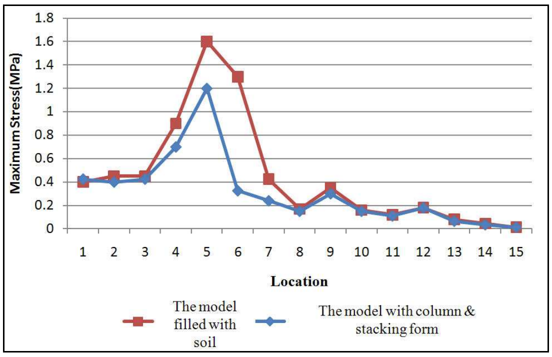


Figure 5: Location of load transfer process

Load Transfer Mechanism Analysis We analyze the vertical load transfer mechanism process of stone pagoda. To this end, the stresses and displacements of Fig. 6 are compared according to the each location of Fig. 5.

In the stress distributions of top and body parts, we can find out the similar distribution from top part to body part of stone pagoda. But, the maximum stresses are shown in the stylobate part. Especially, the large stress distribution is given in the model filled with soil than the model with column & stacking form. Similarly, in the displacement distributions, the displacements are efficiently reduced in the model with column & stacking form than the model filled with soil. By these results, the stylobate type with column & stacking form gives the big stiffness in the vertical load transfer process and performs the important role in supporting the stability of stone pagoda.



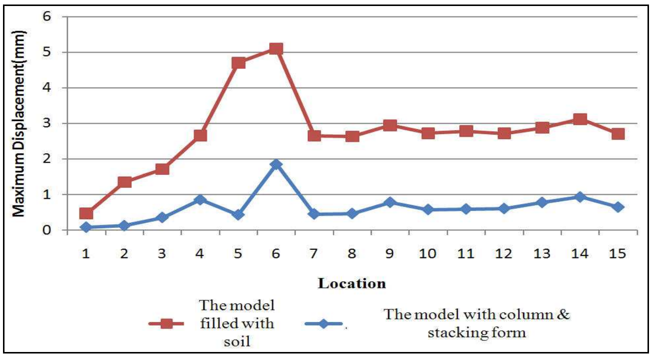


Figure 6: Stress distribution according to the location

Figure 7: Displacement distribution according to the location

Conclusions

Most masonry stone pagoda structures built in Korea are largely classified into three parts such as top part, body part and stylobate. Specifically, the stylobate takes a very important structural part, performing the role of foundation in ordinary structures, and the reduction of stylobate's bearing capacity has great influence on the safety of structure. As for stylobate, the construction types of inner Jeoksim result in the different structural behaviors. Therefore, this study selects three-story stone pagoda in Goseon-sa temple site that shows the typical type of stone pagoda structure in Korea. Also, this study analyzes the stress and displacement distributions considering the vertical load transfer mechanism through the discontinuum modeling and analysis. The inner construction types of stylobate are given as two types such as the model filled with soil and the model with column & stacking form. Generally, the stable distribution of stresses and displacements are shown in the model with column & stacking form than the model filled with soil within Jeoksim. From the analysis results, we can find out that the stylobate model with column & stacking form performs the important role of securing the stability and safety of stone pagoda.

Acknowledgements

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