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2D RC frame cost optimization using plastic hinge

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ABSTRACT

This paper investigates the optimal design of 2D RC frame from the perspective of cost efficiency. Unlike the two general design codes represented by Strength design method and Limit design method, plastic design method is used in this paper. Adopting a plastic design leads to more optimal results than the other two design methods in RC frame design from moment redistribution. Introducing a plastic hinge as spring stiffness matrix, the structural analysis for frame optimization is conducted. Finally, the optimum design cost obtained from the plastic design are compared with Strength design method cost and Limit design method cost

1. INTRODUCTION

The cost of manufacturing a frame structure composed of beams and columns, which are the most basic members of a building, varies depending on the design method. In particular, in the case of a reinforced concrete structure, different moments can be received even with the same number of reinforcing bars depending on how the cross-section rebars are arranged. In addition to the unique material properties of reinforced concrete, the design cost of a structure may vary depending on which design method considers the behavior of the frame structure when subjected to extreme loads. That is, in order to optimally design a frame structure made of reinforced concrete, it is necessary to properly set the reinforced concrete cross section and adopt the most efficient design method.

Since the plastic design method focuses on the ultimate load of the structure rather than the member, it is necessary to define the hinge part of the connection part, which is a part of the connectivity between the members, as well as information about the member such as bending moment and axial force, unlike the existing design methods. This is the plastic hinge part used for plastic design, and in general, the part corresponding to a certain length of the member is defined as the plastic region. However, in this paper, plastic hinges are not defined as corresponding to a certain length of members, but are defined as the connectivity between members through an additional spring stiffness matrix in the structure analysis program. This shows that the connection is broken when the member reaches the yield point, so that it has an advantage in analysis.

By defining a database for members and plastic hinges for plastic design, the optimal design for frame structures performed by previous researchers was performed [1, 2]. In addition to the plastic design method, the optimal design of the structure was performed for the above-mentioned strength design and limit state design method, and it was checked how the design cost of the structure varies according to each design method. Torsion effect and bond slip effect were not considered, and it was programmed based on FORTRAN code based on 2-d planar frame modeling.

2. METHOD

(1) Plastic hinge

In this study, the plastic hinge introduced to proceed with the plastic design based on the 2D frame is different from defining the plastic hinge region according to the cross-sectional configuration as in previous studies. It was designed to act as a hinge. As shown in Fig. 1 below, the behavior changes from a spring connection that receives moments before and after yielding of a member to a complete hinge that does not receive a moment. After yielding, the additional moment for the applied load does not act on the corresponding point as shown in Fig. 2, but additionally acts on the other point. The goal of this paper is to show that the perfect plastic hinge belongs to the safety side of the structure and that the plastic design has advantages over other design methods compared to the complex elastic-plastic hinge. Therefore, even if there is a small error, a plastic hinge was assumed as a perfect plastic hinge and the analysis process was simplified.

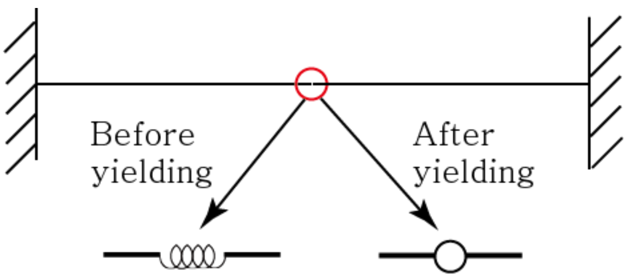

Fig. 1 Implementation of rotational spring elements

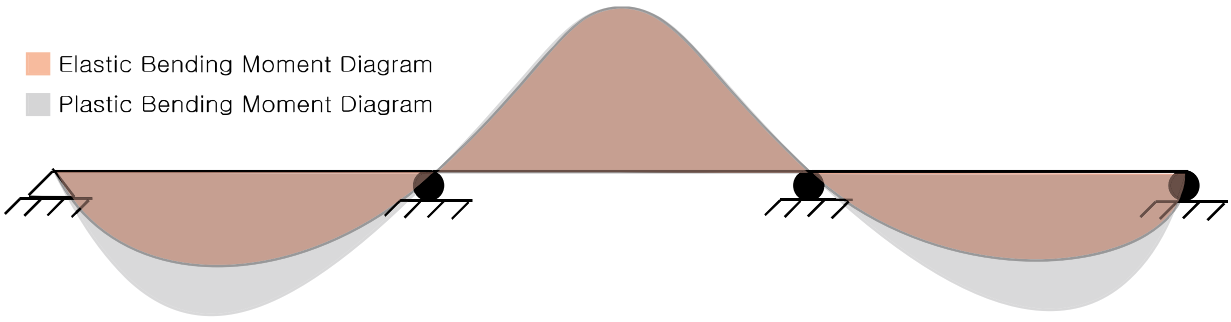

Fig. 2 Difference between Elastic theory and Plastic theory bending diagram

(2)Section database

If mathematical optimization is performed to optimally design the RC structure, the sizes of concrete and reinforcing bars are designed in a continuous distribution. However, in general, when designing the RC section, the rebar has a given standard, and the height and width of the concrete section are also designed based on a specific length. Therefore, in order to actually apply it to the field, in this paper, an optimal design was made by configuring D/B based on discrete values. Referring to the database of previous researchers [1], 238 beams and 353 column cross-sections were converted into a database. D/B was constructed by using the same values for the elastic modulus and strength of concrete and reinforcing bars.

3. CONCLUSIONS

Just before the collapse of the structure, a plastic hinge was created as shown in Fig. 3, and it was confirmed that the cost was significantly reduced compared to the example of the same structure made by other design methods. The introduction of the plastic hinge reduced the cost of the member compared to the existing design method, and the use of the database significantly reduced the increase in analysis time due to the plastic design, improving the optimal design method of the structure.

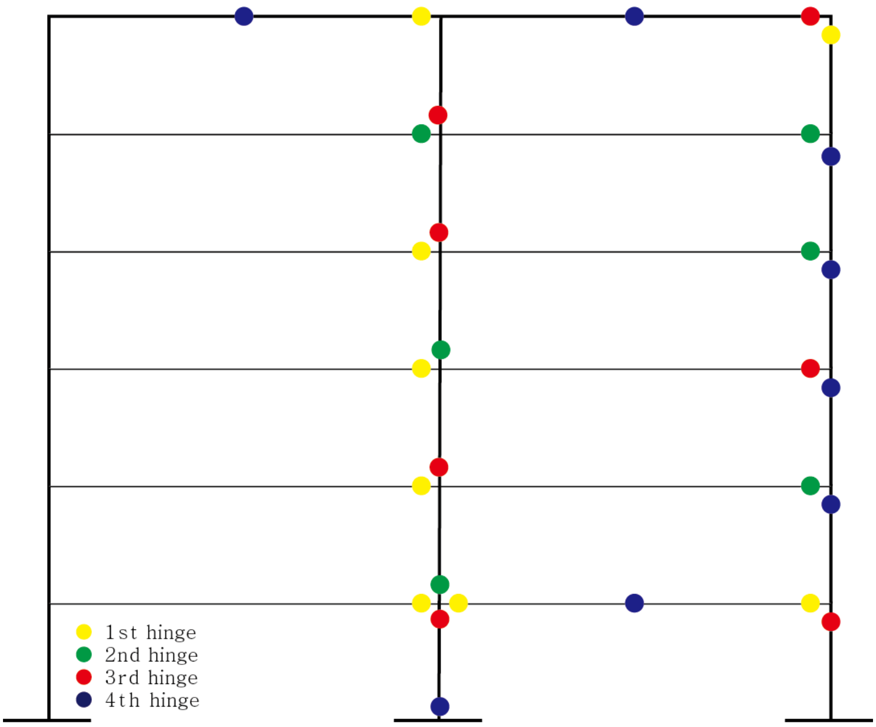

Fig.3 Hinge pattern at 2-D frame

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