The 2021 World Congress on
Advances in Structural Engineering and Mechanics (ASEM21)
GECE, Seoul, Korea, August 23-26, 2021

Analytical Hybrid Simulation of Precast Concrete Beam Column Connection

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ABSTRACT

In order to evaluate the seismic performance of the moment-resisting frame, the beam-column connection specimens were typically tested under the lateral loading condition. For the interior beam-column connection, it will be more correct if all degrees of freedom (3 DoFs at each node, total 12 DoFs) could be controlled, but practically it is very difficult to be realized because it needs many actuators and a complicated test setup. The moment-rotation relationship around the joint can represent the behavior of the beam-column connection, and the moment-rotation relationship can be modeled using the lumped spring at the joint. During the hybrid simulation, the loading is applied until the measured rotation gets to the target rotation sent from the main model, and the force data is sent to the main model after loading. In this study, the analytical hybrid simulation was carried out for the validation of a new hybrid simulation method. The Lumped spring model simulated the behavior of the beam-column connection similar to the test results, and it is confirmed that the data communication was well simulated.

1. INTRODUCTION

The moment resisting frame is the most basic system for the seismic resistance. In general, the seismic performance of the moment resisting frame is determined how much the beams and columns can resist the bending moment, or the joint can resist the shear force. In order to evaluate the seismic performance of the moment resisting frame, the beam-column connection specimens were typically tested under the lateral loading condition. For the interior beam-column connection, it will be more correct if all degrees

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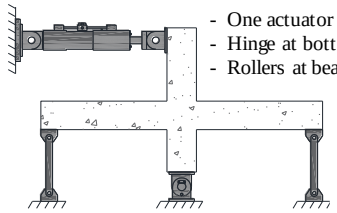
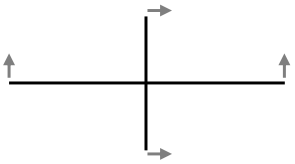
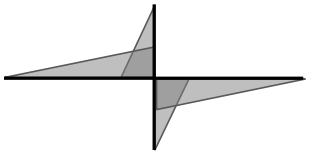
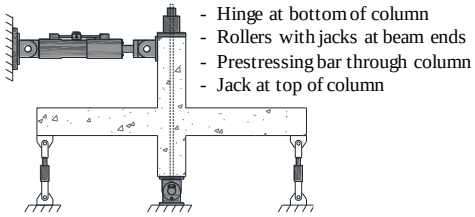
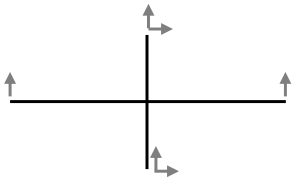
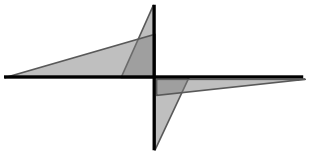
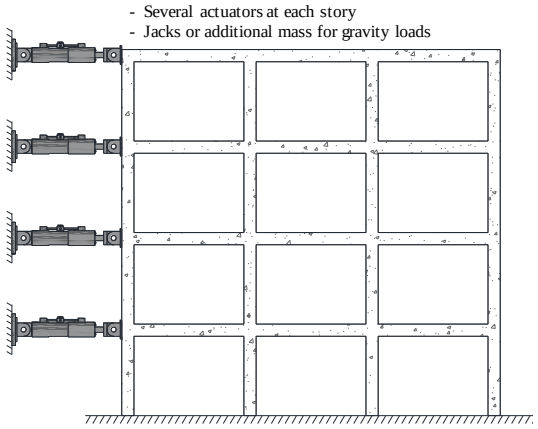
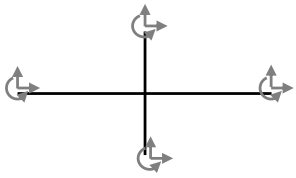
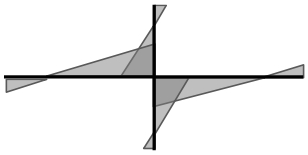
of freedom (3 DoFs at each node, total 12 DoFs) could be controlled, but practically it is very difficult to realize because it needs many actuators and complicated test setup. Table 1 shows the previous test configuration of the beam column connection test. Many previous researchers assumed that the contra-flexure point would not change, and the axial deformation would be very small, so that the only one DoF at each node (total 4 DoFs) was controlled as shown in Table 1. It meant that the cutting point was modeled as the pinned connection. With this assumption, only one or two actuators were needed for loading and the rest nodes were realized by the pin or roller supports.

Table 1. Considered degrees of freedom according to test

Test configuration	Considered degrees of freedom	Bending moment diagram
		
	- One DoF at each node - Only consider lateral load	
		
	- One or two DoFs at each node - Consider lateral load and gravity load	
		
	- All 3 DoFs at each node - Consider lateral and gravity loads	

However, the contra-flexure point can move due to the gravity load or the change of stiffness. The change of contra-flexure point will affect the forces of joint which are most important in the beam-column connection. Therefore, this study proposed a new hybrid method for the beam-column connection not dependent on the test setup. If one or two elements can represent the behavior of beam column connection, it could be easier to control the degrees of freedom of the beam column connection and reflect the various moment distribution as shown in Fig. 1.

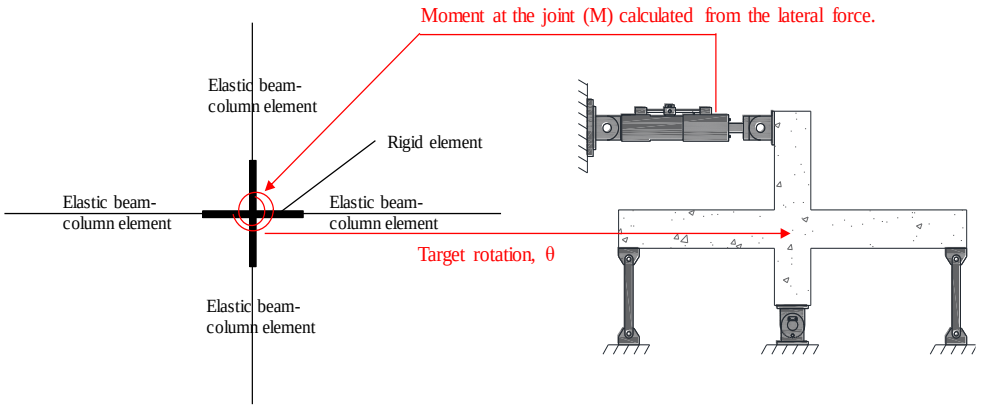
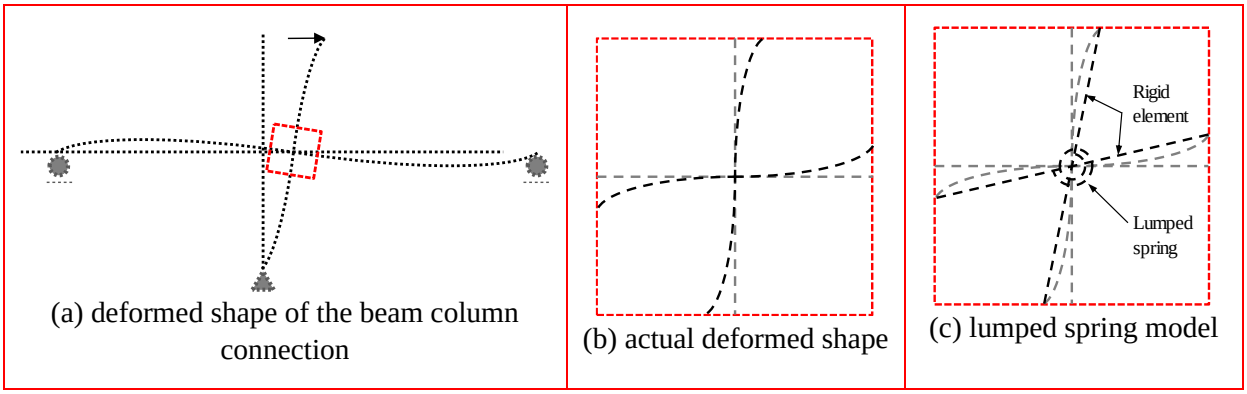


Fig. 1 Hybrid simulation method using the lumped spring

2. PROPOSED HYBRID SIMULATION METHOD

In the beam-column connection, the displacement of the system is governed by the deformation around joint such as the plastic hinge at the beam ends and shear distortion of the joint. The deformation around the joint will appear as shown in Fig. 2(a) including the nonlinear behavior, and using the lumped spring and rigid elements, a similar deformed shape(Fig.2(c)) can be made to the actual deformation(Fig.2(b)).



(a) deformed shape of the beam column connection

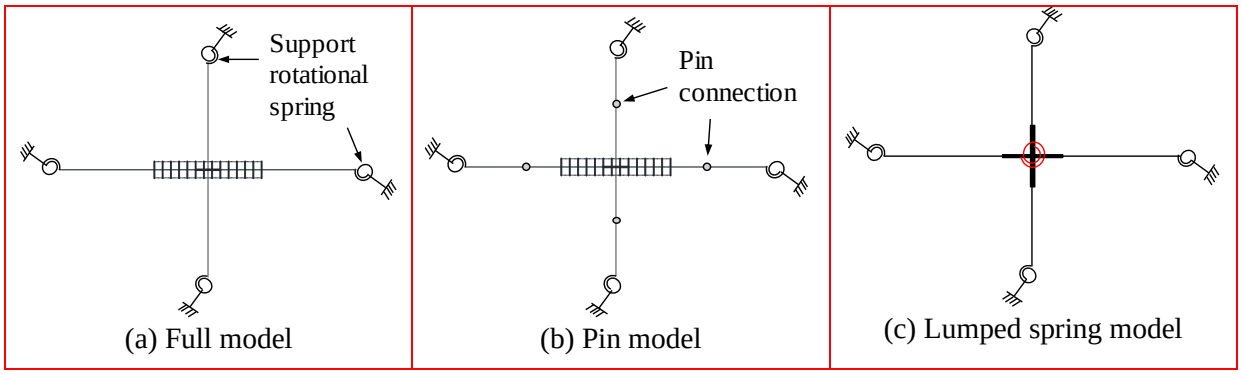
(b) actual deformed shape

(c) lumped spring model

Fig. 2 Representation of the deformation with the lumped spring and rigid elements

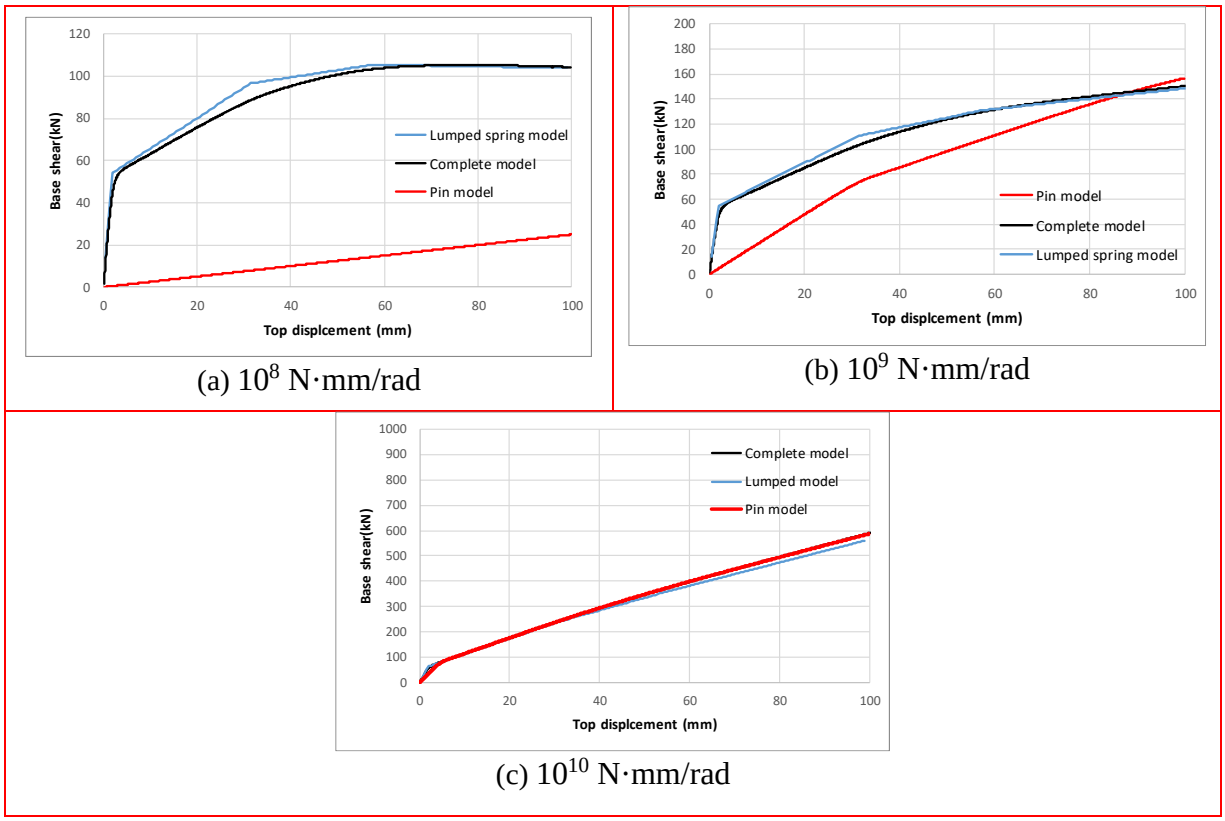
For the validation, the modeling method proposed in the previous study was used(Hwang et al., 2021). During the pushover analysis, the rotation between the line segment of the beam and column was measured. After that, the material model of lumped spring was defined using the measured rotation. In order to compare with the pinned

connection model, which represents the conventional beam-column connection test, full detailed model, the full model with pinned connections, and lumped spring model were modeled as shown in Fig. 3. The pinned connections were applied at the middle of each member. Additional rotational springs were modeled at all supports to take account of the various moment distribution. In case that the spring stiffness was sufficiently high like fixed support, all the three models showed similar results as shown in Fig. 4, but the pinned connection model showed much different behavior in some other cases while the lumped spring model showed very similar to the full detailed model.



(a) Full model (b) Pin model (c) Lumped spring model

Fig. 3 Analytical models for the parametric study (K_s = 10^8, 10^9, 10^{10} N·mm/rad)



(a) 10^8 N·mm/rad (b) 10^9 N·mm/rad

(c) 10^{10} N·mm/rad

Fig. 4 Pushover Analysis results

3. CONCLUSIONS

In this study, the lumped spring method for the hybrid simulation of the beam-column connection was proposed, and numerical validation was conducted. This hybrid simulation method will come very useful for considering any incomplete boundary conditions as well as the beam-column connection.

REFERENCES

Hwang, J.-H., Choi, S.-H., Lee, D., Kim, K. S. and Kwon, O.-S. (2021), “Seismic Behavior of Post-tensioned Precast Concrete Beam-Column Connections,” *Magazine of Concrete Research,* **73**(9), 433-447.