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# Static load test on progressive collapse resistance of precast concrete structure in Korea

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**ABSTRACT**

Recently, in Korea, the precast concrete (PC) structure is frequently used in the industrial buildings, such as factories and warehouse, to enhance economy. However, the PC structures are vulnerable to the progressive collapse, since the integrity of beam-column joint is not secured under construction. Thus, the present study investigates the progressive collapse resistance of PC structures with joint details majorly used in Korea. The static loading tests were carried out for three frame level specimens. Based on the test results, effects of the joint details on the progressive resistance of the PC structure were investigated.

## 1. INTRODUCTION

In order to reduce labor cost, construction cost, and construction period, the precast concrete (PC) structure is frequently used in the industrial buildings, such as factories and warehouse. However, since the structural integrity of beam-column joint is not secured under construction (and even after construction), PC structures are vulnerable to the progressive collapse.

Several existing studies (Zhou et al., 2019; Feng et al., 2020) were carried out to investigate the progressive collapse resistance of PC moment frame structure, using the static and dynamic tests for the moment sub-frame specimen. However, the connection and construction details of PC structures used in Korea are significantly different from others. Thus, for the PC structures using such details. the evaluation of progressive collapse resistance is needed.

In the present study, the connection details of PC structures frequently used in Korea was investigated. Based on the practical details, the three sub-frame specimens

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were tested under monotonic static vertical loading. Based on the test results, the characteristics of the PC structures used in Korea were discussed.

## 2. Connection details in Korea

Fig.1 shows the connection details mainly used in the PC structures in Korea. To reduce the dimensions of the PC beam and slab, one-way pre-stressed concrete system is frequently used. Further, the connection details are classified in two types: 1) simply supported connection (pinned-joint); 2) continuous supported connection (continuous-joint).

In pinned-joint (Fig.1 (a)), the PC beam is seated on the bracket of the column, and fixed by bolting using the dower reinforcing bars extended from the bracket. Then, the topping concrete is casted. Any longitudinal reinforcement is not extended to the beam-column joint. Thus, in the case of pinned-joint, the progressive collapse resistance is significantly decreased.

On the other hand, in continuous-joint (Fig.1 (b)), the longitudinal reinforcement of PC beam is extended to the beam-column joint. Thus, the flexural strength is fully developed in both ends of the PC beam. Thus, in the case of continuous-joint, the progressive collapse resistance is increased compared to pinned-joint.

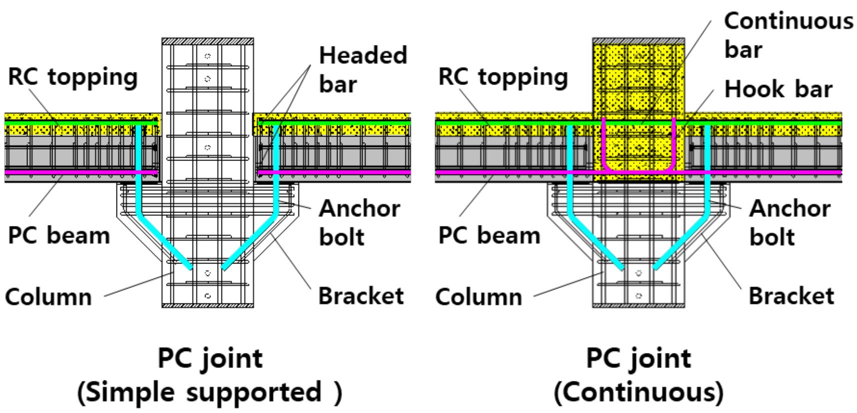


Fig. 1 Connection details of PC structures in Korea

## 3. Evaluation of progressive collapse resistance

*3.1 Test plan*

Fig.2 shows the details of test specimens. Table 1 shows the design parameters of the specimens. To simulate the progressive collapse of PC moment frame structure, the sub-frame specimens with two spans were prepared. Based on the prototype model, the specimens were scaled down by one-third. The dimensions of columns were 400 mm (width) x 300 mm (breadth) x 2800 mm (height). The dimensions of beams were 300 mm (breadth) x 300 mm (depth) x 2600 mm (net length). For the test parameters, the type of connection was addressed: 1) reinforced concrete moment frame (RC); 2) PC moment frame with pinned-joint (PC-P); and 3) PC moment frame with continuous-joint (PC-C).

The concrete strengths of all specimens were $f_c'$ = 33.6 – 47.2 MPa. The yield strength of reinforcement was $f_y$ = 538 MPa for D10, $f_y$ = 534 MPa for D13, and $f_y$ = 648 MPa for D16. In PC specimens (PC-P, and PC-C), prestressing was applied: jacking force = 205 kN. Due to prestressing, relatively low longitudinal reinforcement ratio of beam was used ($\rho$ = 0.51 – 1.02 %).

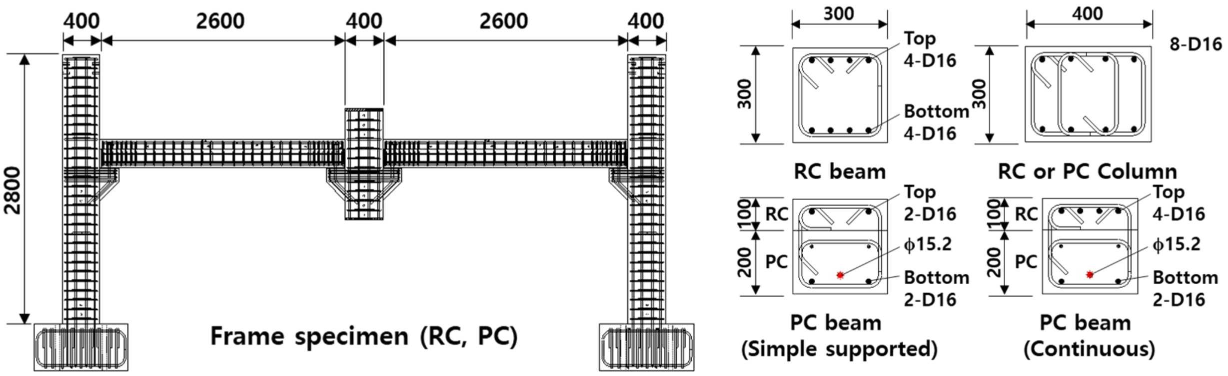


Fig.2 Details of the specimen

*2.2 Test Procedure and Instrumentation*

Fig. 3 shows the test setups and the linear variable displacement transducers (LVDTs) for the measurement of displacement. Using 1000 kN oil pressure machine, a vertical loading was applied to the top of the specimen. In the prototype model, the sub-frame is laterally supported by the adjacent beams and columns. To simulate such frame action, in the specimens, the top of the 2$^{nd}$ floor columns were laterally supported at the contraflexure point. The vertical displacements of the beam were measured at the four locations: middle of each span, and loading columns. The plastic hinge deformation of the beams and the deformation of the columns were measured.

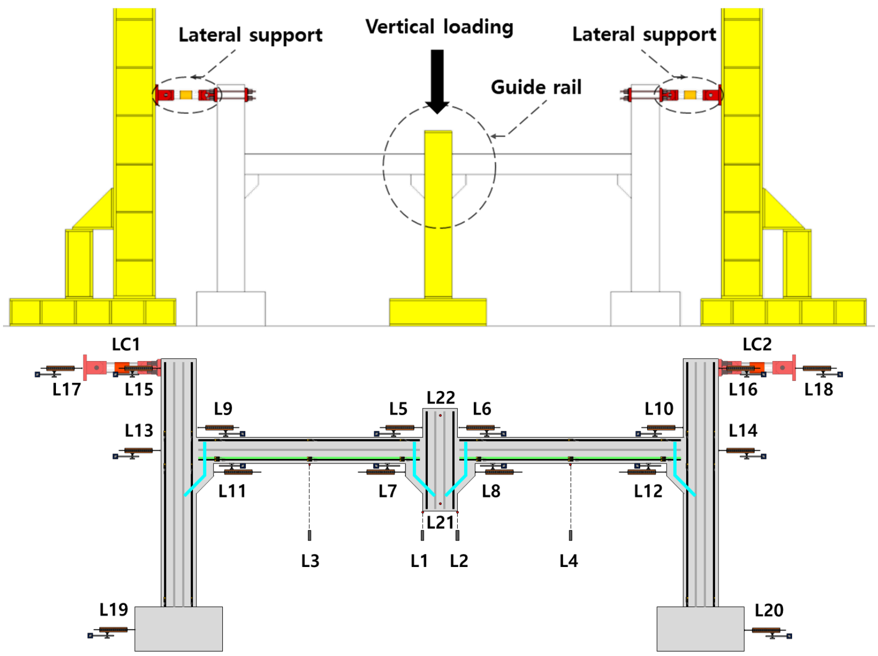


Fig.3 Test setup

## 3. TEST RESULT

### *3.1 Failure modes*

Fig. 4 shows the damage modes of the specimens at the end of the tests. In RC, after flexural yielding, the load carrying capacity was drastically decreased due to the tensile fracture of the beam reinforcement near the interior column. In PC-P with pinned-joint, the damages concentrated in the interface between beam end and column, whereas the damages of the beam were limited. The beams were rigidly rotated. Ultimately, the concrete crushing occurred at the beam end. In PC-C with continuous-joint, the damage modes were similar to those of RC.

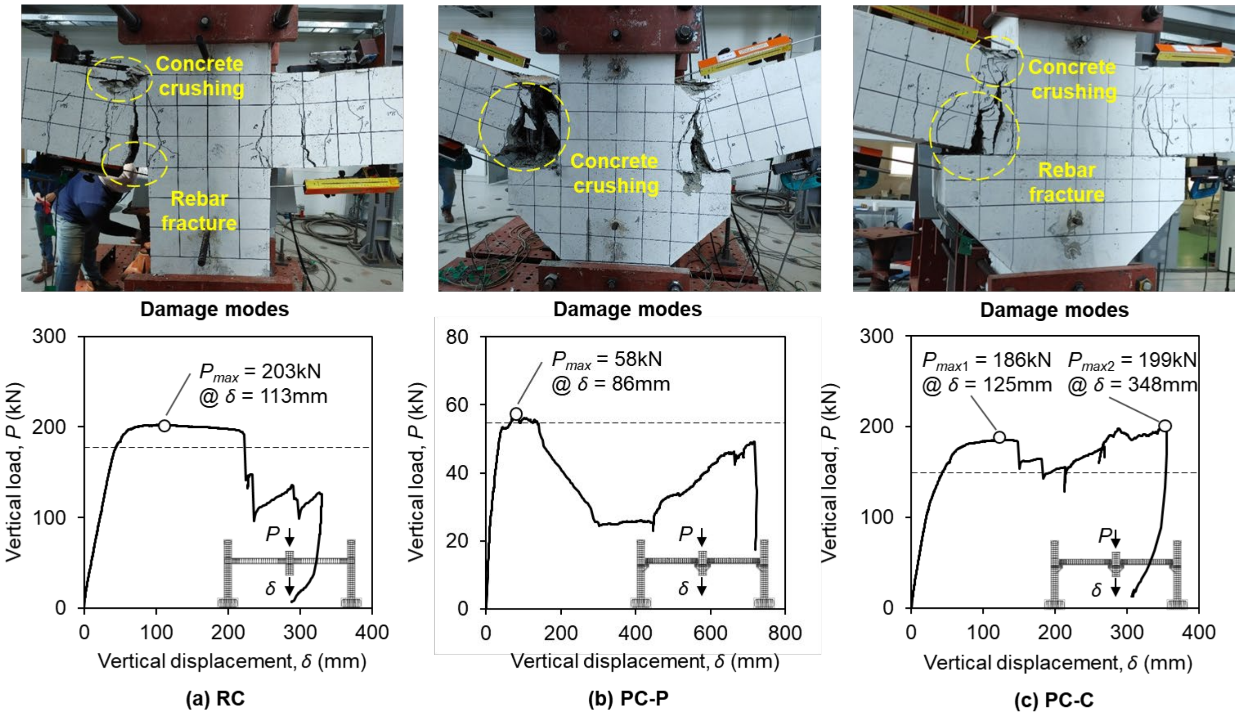


Fig.4 Test results

### *3.2 Load-displacement relationships*

Fig. 4 also shows the vertical load and displacement relationships of the test specimens. The vertical displacement was calculated as the average of the measured vertical displacement of the interior column. In the calculation of flexural strength, actual material strength was used. In all specimens, the maximum tested strength $P_{test}$ was greater than the predicted flexural strength.

In RC and PC-C, the over-strength occurred due to axial compression developed by compression arch action. After the first peak strength, the load carrying capacity was degraded due to tensile fracture. After the tensile fracture, the load carrying capacity was increased due to catenary action. In particular, in PC-C the 2$^{nd}$ peak strength was greater than the 1$^{st}$ peak strength. In PC-P, the peak strength reached the predicted strength. After the peak strength, the load carrying capacity gradually decreased and beams were rigidly rotated. As the vertical displacement significantly increased, the load carrying capacity increased due to Catenary action.

## 4. CONCLUSIONS

In the present study, to investigate the progressive collapse resistance of PC structures in Korea, the moment sub-frame specimens were tested by monotonic vertical loading. The specimens failed due to tensile fracture of longitudinal reinforcement, and the load carrying capacity was decreased. However, after first peak strength, as the vertical displacement increased, the second peak strength was developed due to catenary action.

## REFERENCES

Zhou, Y., Chen, T., Pei, Y., Hwang, H. J., Hu, X., Yi, W., and Deng, L. (2019), "Static load test on progressive collapse resistance of fully assembled precast concrete frame structure", *Engineering Structures,* 200, 109719

Feng, F. F., Hwang, H. J., & Yi, W. J. (2020), "Static and dynamic loading tests for precast concrete moment frames under progressive collapse", *Engineering Structures*, *213*, 110612.