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Cyclic Loading Test for T-Shaped Coupled Wall Coupled by Slab

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ABSTRACT

Strength and stiffness of slabs have increased due to the introduction of a certified floor structure system in Korea wall-type apartments. This thickened slab made the error bigger between existing diaphragm models and real structure's behavior. This study was conducted to evaluate the strength and stiffness of the coupled wall by slabs. The experimental variables were the thickness of the slab and the distance between the walls.

1. INTRODUCTION

RC structural wall are commonly used as a lateral load-resisting system. When the structural walls coupled by beam, the seismic performance and the stiffness of a system are improved. There have been numerous studies to determine the capacity increase of the coupled wall. Shiu (1984) showed that the load carrying capacity of coupled wall is higher than the load carrying capacity of two uncoupled walls. And the relationship between amount of coupling of coupled wall and strength was investigated. Lehman (2013) have investigated the seismic behavior of RC coupled wall by large-scale experiment and showed the sequence of damage of RC coupled wall.

However, there were fewer studies about coupled wall coupled by slab. According to lack of studies and for the convenience, analysis model for wall-type apartments have been modeling without slab element. For the analysis model in which slabs are not included, seismic load is calculated lower due to increased period of the structure. When the thickness of slab is thin, seismic load decrement is not quite big, and conservative wall design is possible by neglecting the contribution of the slabs in the load distribution. But for the thick slab, the difference in calculated seismic loads is quite large.

In Korea, a certified floor structure system was introduced to cope with noise between floors, and slab thickness of more than 210mm was mandatory. This

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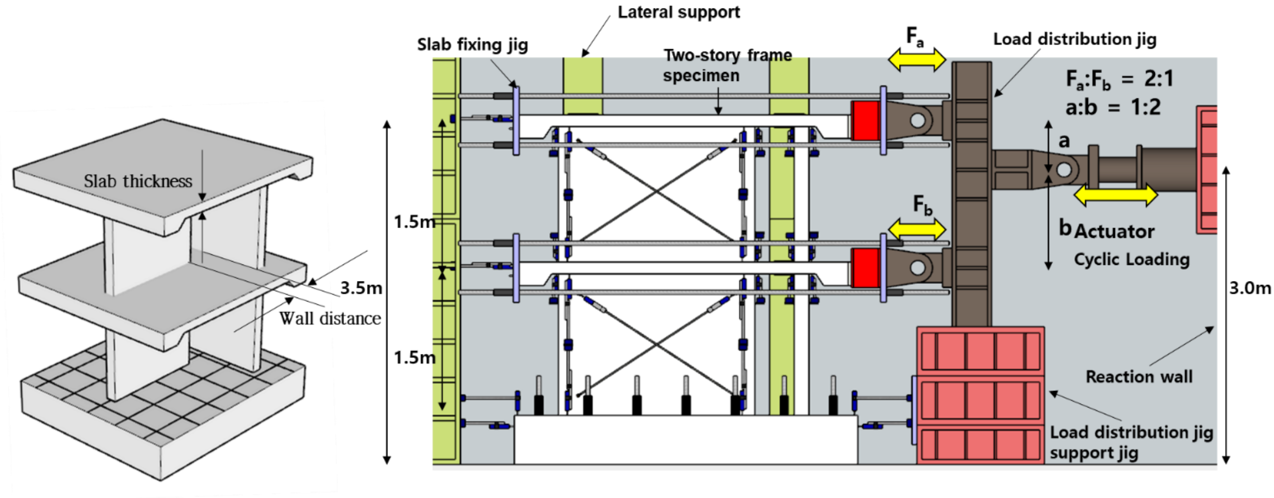
increased the thickness of slabs by 17% to 75% over the existing slab thickness 120 to 180mm, resulting in significant differences in period and behavior between analysis model modeled with and without slab.

To verify the contribution of slabs in behavior and capacity, experiments were conducted on two-story frame specimens. The experimental variables are the thickness of the slab and the distance between the walls. The design strength of two-story frame specimens and the experimental results were compared to confirm the additional capacity caused by the slab. The sequence of crack occurrence and failure mode of the specimens were observed.

2. Test Specimen and Test Setup

The shape of the specimen and test setup are shown in the Fig. 1. The geometry of specimen was one-second of the full-scale dimensions of general wall-type apartment. Total height of the specimen including base was 3.5 m (0.5 m base, 1.5 m first floor, 1.5 m second floor), the loading direction wall length was 1.5 m and the wall length vertical to the loading direction was 1.8 m and the thickness of the wall was 0.15 m. The thickness of slab was 0.12 m or 0.08 m according to the specimen and the distance between wall was 0.4 m or 0.6 m according to the specimen. The vertical and horizontal rebar ratios of the walls were designed to be 0.6% and 1.13%, respectively. Compressive strength of concrete was 30 MPa and the tensile strength of rebar was 500 MPa. The variables and materials of specimens are summarized in Table. 1.

A load distribution jig was devised to distribute the planned load to the specimen. This jig was designed to be connected to an actuator at a height of 2 to 1 on the second and third floor slabs so that the load was applied 1 to 2 on the second and third floor slabs. Load distribution jig was connected to slab by using slab fixing jig. To eliminate the weight of the load distribution jig, support jig is placed under the load distribution jig. To prevent the out-of-plane collapse, lateral supports were installed to each out-of-plane sides of the two-story frame specimen.



(a) Shape of test specimen **(b) Test setup**

Fig. 1 Shape of test specimen and test setup

Table. 1 Variables of two-story frame specimen

Specimen	Slab thickness (mm)	Concrete Strength (MPa)	Distance between wall (mm)	Rebar strength (MPa)	Horizontal rebar ratio (%)	Vertical rebar ratio (%)	Slab rebar ratio (%)
SWA1	**80**	30	400	500	1.13	0.6	0.8%
SWA2	120	30	400	500	1.13	0.6	0.5%
SWA3	120	30	**600**	500	1.13	0.6	0.5%

3. Loading Protocol

Loading protocol was planned according to the ACI 374.2R-13 as shown in Fig. 2. Loading protocol consists of 13 steps, starting with 0.05% lateral displacement ratio of the specimen and increasing to 2.00%. From 1 to 10 steps, tensile-compressive displacement was repeated 3 times, and from 11 to 13 steps, tension-compression was repeated 2 times.

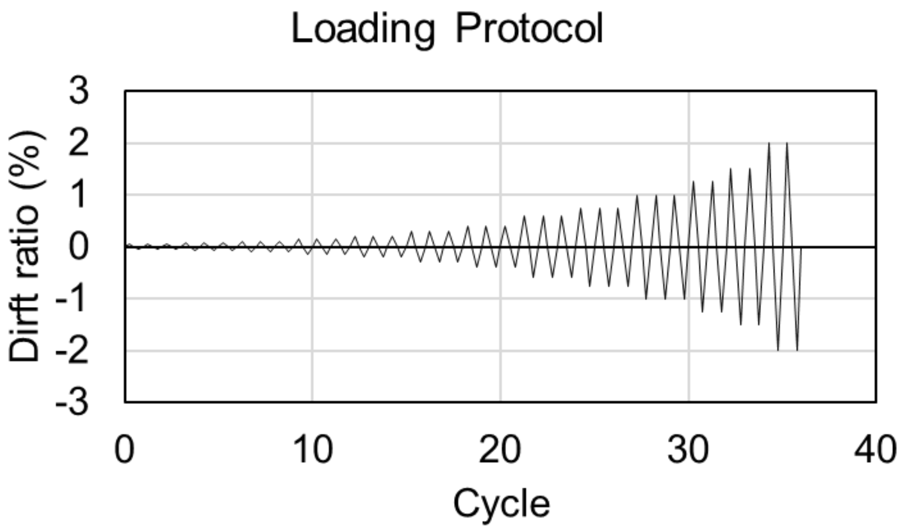


Fig. 2 Loading protocol

4. Experimental Results

The Cyclic loading test for two-story frame specimen provided experimental data proving enhanced load carrying capacity of coupled wall system and contribution of slab. Table.2 shows the test results. Design Capacity was decided by non-linear finite analysis of diaphragm models.

All the failure mode of specimens was flexural failure and load carrying capacity were increased compare to the design capacity. Cracks occurred in the order of wall cracking - slab cracking - the slab spalling - wall crushing at the edge of the wall.

Horizontal cracks occurred at the edge of the wall from the early step and extended to the middle as the lateral displacement ratio of the specimen increased. In the middle part of the wall, horizontal crack changed to the diagonal crack. Crushing of the concrete occurred in the plastic hinge zone at the 12 to 13 steps of test. The length of the crack in the second floor wall was smaller than that of first floor.

Crack of slab occurred at the near edge of the loading direction wall to the diagonal direction. It is extended to the edge of the slab. As lateral displacement ratio increased, thickness of the cracks is increased and spalling of the lower and upper face of the slab is occurred.

From the load carrying capacity increasing ratio, it can be seen that SWA2 had the greatest load carrying capacity increase due to slab. In specimen SWA1 which had 80 mm thick slab, load carrying capacity is increased 48%. When the thickness of slab increased to 120 mm (SWA2), load carrying capacity is increase 85%. When the distance of the wall between the walls is increased to 600 mm (SWA3), load carrying capacity is increased 68%. This increasing capacity is smaller than that of SWA2.

Table. 2 Test results

Specimen	Design Capacity (kN)	Test results (kN)	Test results/ Design Capacity (%)	Failure mode
SWA1	244	358	148	Flexural failure
SWA2	242	449	185	Flexural failure
SWA3	240	405	168	Flexural failure

5. Conclusion

When modeling wall-type apartment, slab element did not include in the model and considered as diaphragm. However according to the increasing thickness of slab, the contribution of the slab to the load carrying capacity should be verified. Test results show that coupled wall coupled by slab had larger load carrying capacity than sum of capacities of each wall. Slab thickness is the most influential variable. When slab thickness was increased the load carrying capacity was increased. Distance of the wall also affect the load carrying capacity. When distance of the wall increased the load carrying capacity was decreased. The following summarizes the findings and conclusion of the experiment.

1. Coupled wall coupled by slab has increased load carrying capacity compare to the design capacity. For the SWA1, SAW2, SWA3 specimen load carrying capacity was increase 48%, 85% and 68% for each specimen.
2. Slab thickness and distance of the wall affect to the load carrying capacity. When the slab thickness was increased 80 mm to 120 mm, load carrying capacity was increased (148% to 185%). When the distance of the wall was increased 400 mm to 600 mm, load carrying capacity was decreased (185% to 168%).
3. Crack of the wall occurred horizontally at the edge of the loading direction wall and extended to the middle of the wall to the diagonal direction. Crushing of the concrete occurred in lower edge of the wall at the 12 to 13 steps of test.
4. Crack of the slab occurred diagonal direction at the near edge of the loading direction wall and extended to the edge of the slab. As lateral displacement ratio increased, spalling of the lower and upper face of the slab is occurred.

REFERENCES

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