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Experiment on Reinforced Concrete One-Twentieth Scale 3-D Model Frames

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ABSTRACT

A one-twentieth scale 3-D frame was envisaged representing the lower portion of the over 30-stories reinforced concrete building. Two specimens were manufactured: four-story, three-span buildings, with and without a slab. Considering the effects of an earthquake, vertical and horizontal forces were applied to the specimens.

A loading apparatus was designed, with which we could apply constant vertical force and the horizontal force of a fixed ratio to the top of each column.

The effects of the slab on the beam and on the horizontal resistance of the specimen were studied. We found that mechanical behavior such as load-displacement relationships, ultimate strength of structure, etc.; of both specimens could be estimated by the method commonly used among Japanese structural engineers.

INTRODUCTION

Reinforced concrete beams and columns forming up a structural frame exert influence on each other during loading and behave physically as one structural body. Thus, wherever analysis of the mechanical behavior of the reinforced concrete frame is concerned, experimentation carried out on the frame as a whole system makes more sense than just experimenting on the individual member. We experimented on the reduced model of a reinforced concrete plane frame taking a lower portion of a certain building and reported on the mechanical behavior of it [5]. An object of this study is to investigate the mechanical property of a beam sideways mechanism reinforced concrete 3-D frame reduced model under pulsating gradual increase cyclic load.

It has been done from several years ago to examine experimentally mechanical property of a multi layer frame under a seismic force with the reduced model. There are some experiments that used the 3-D whole frame as follows. Kumazawa and Okada [2] did a vibration test of 1/15 scale 3-D frame model of a high rise wall girder-column type rigid frame structure and told about the

mechanical property of it. Otani and Sozen [3] did a vibration test of 3 layer 1 span reduced model and told about the property of it. Qi and Pantazopoulou [4] did a static cyclic loading experiment on 1 layer 2 span frame and told about a redistribution of an internal force in a statically indeterminate structure. Many experiments that have used a reduced model were done.

SPECIMEN

Specimen Shape and Cross Section of Members

We referred to a reinforced concrete building over the 30-story when we decided a member length, bar arrangement of specimen and so on. We show a specimen shape with slab in figure 1. There are two specimens, one does not have slab and another has it. A reduced scale is as 1/20. We show cross section of members in figure 2. We mixed standard sand with a cement at mixture ratio 1:2.5, and used a mortar of a water cement ratio 75% instead of a concrete.

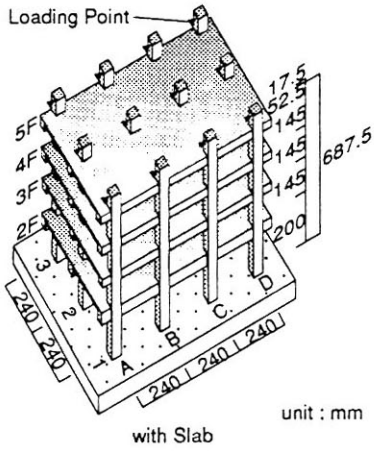

Figure 1 Specimen

Table 1 Mechanical Property of Materials

Rebar	Sectional Area (mm^2)	Yield Strength (MPa)	Tensile Strength (MPa)
D2	4.047	456	486
D1	1.003	284	392

Mortar		Material Age (Day)	Compessive Strength (MPa)	Strain at Compressive Strength ($x10^{-6}$)	Young's Modulus (MPa)	Tensile Strength (MPa)
without slab	Base	126	32.2	3280	19.3	2.0
	1F	120	33.4	2900	21.6	2.4
	2F	98	31.6	3053	25.0	2.6
	3F	88	28.9	3783	21.0	2.1
	4F	79	34.9	3420	23.3	2.4
	5F	71	35.7	3525	25.0	2.5
with slab	Base	133	36.2	3863	17.5	2.5
	1F	127	35.4	2763	26.3	2.6
	2F	105	38.6	3510	18.8	2.0
	3F	95	34.2	3702	19.8	2.0
	4F	86	37.2	3464	21.4	2.1
	5F	78	39.5	4165	21.7	2.1

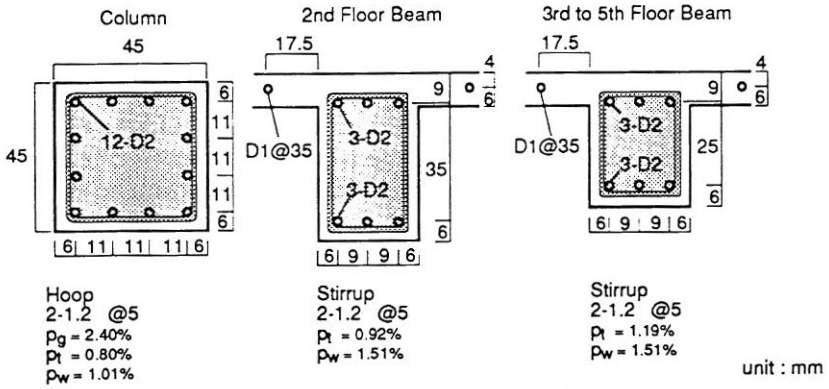

Figure 2 Cross Section of Members

Mechanical Property of Materials

We show mechanical property of rebar and mortar in table 1. When we tested a splitting strength with a compressive strength, we use three cylindrical test pieces of 5x10 (cm) in each test.

EXPERIMENTAL METHOD

Loading Apparatus

A loading apparatus is shown in figures 3. An axial force introducing frame and a horizontal loading frame makes a loading apparatus. An axial force introducing frame is supported by 2 rods with a both ends pin. Therefore, this can move smoothly in a horizontal direction accompanied by a horizontal displacement on the top of column. A horizontal loading frame is hung up an axial force introducing frame by means of steel bar bolts with a both ends pin.

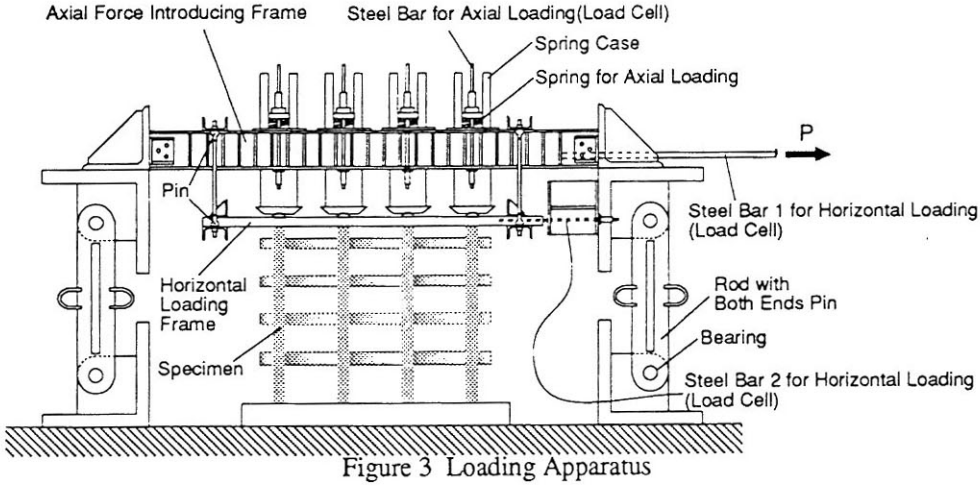

Figure 3 Loading Apparatus

Introduction of an axial force Figure 4 is a loading point position enlarged figure. The spring was shortened that is on the top of each column by tightening a nut of prestressing steel bars. Then, an axial force of 13.7kN was introduced for each column by means of a spring lid, roller and pin on the top of column. (An average ratio of axial force is 0.2.)

Horizontal Loading The 12 mini oil jacks were connected with one unit of hydraulic pump and a horizontal force was made act at a fixed ratio on central 12 loading point of clear height of fifth floor column. The horizontal forces act upon each loading point by means of a pin.

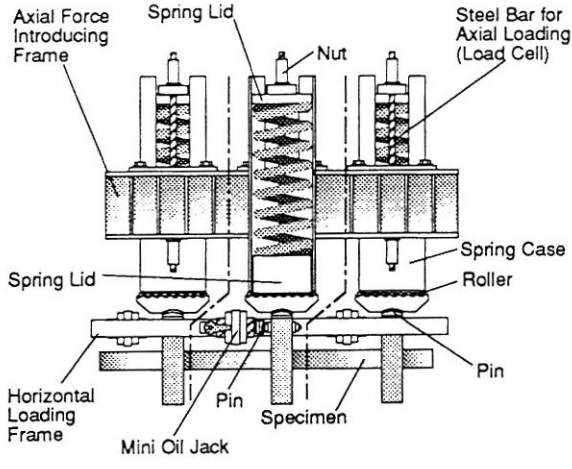

Figure 4 Enlarged Figure of Loading Point Position

EXPERIMENTAL RESULT AND DISCUSSION

We measured a total horizontal force P by a horizontal force prestressing steel bar 1 (load cell). Because there is a reaction to an axial force of a column in the rod shown in figure 3, degradation of horizontal force due to P-δ effect is canceled by increase of it due to an inclination of a rod.

Horizontal Force - Horizontal Displacement Relationship

Figure 5 shows a horizontal force and fifth floor horizontal displacement relationship of both specimens. The upper section shows a specimen with slab, and the lower shows a specimen without slab. Solid line shows measurement result of grid line 1 and doted line shows for grid line 2. When specimen receives a horizontal force in a direction from column-A to column-D, a horizontal displacement is larger in order of A < B < C < D. This phenomenon was observed on second floor of both specimens. As pay attention to grid line 1 and 2, each column in both specimens almost draws the same path and we can understand that loading without torsion of a specimen was done.

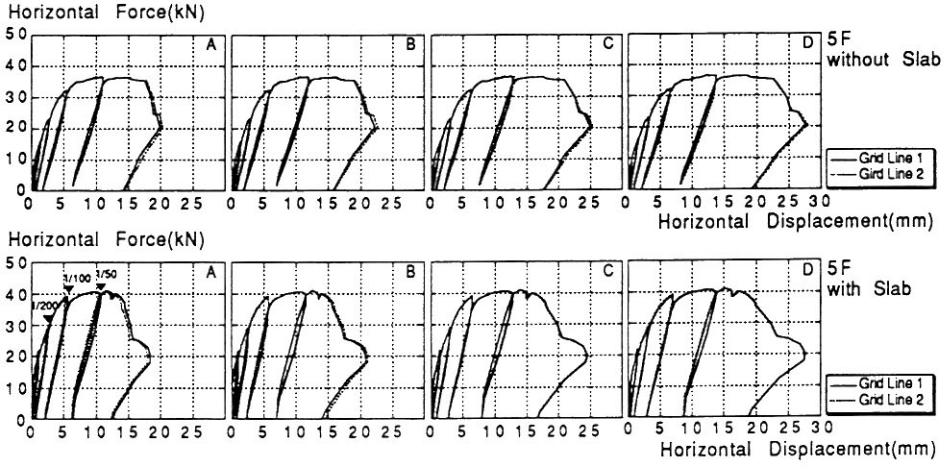

Figure 5 Horizontal Force - 5th Floor Horizontal Displacement

Axial Strain Distribution of A Beam

Figure 6 shows axial strain distribution of beam-BC in grid line 2 at the whole average angle of rotation 1/100, 1/50, 1/26. Axial strain of the center of gravity of a beam is calculated from strain measured by strain gauges stuck on the middle of beam.

On second floor, a compressive strain of an about 50μ came up in both specimens at whole average angle of rotation 1/100, 1/50, 1/26. On third floor, a small tensile strain came up at whole average angle of rotation 1/100, 1/50 and a tensile strain increased at whole average angle of rotation 1/26. On fourth floor, though a strain was zero at whole average angle of rotation 1/100 in both specimens, a compressive strain came up at whole average angle of rotation 1/50 in a specimen without slab and it became a compressive strain in a both specimens at 1/26. On fifth floor, there was a small compressive strain at 1/100, 1/50 and it became a tensile strain at 1/26.

Crack Situation

Figure 7 shows the ultimate crack situation of grid line 1 in both specimens. You can find that a bending crack occurs in a beam in both specimens.

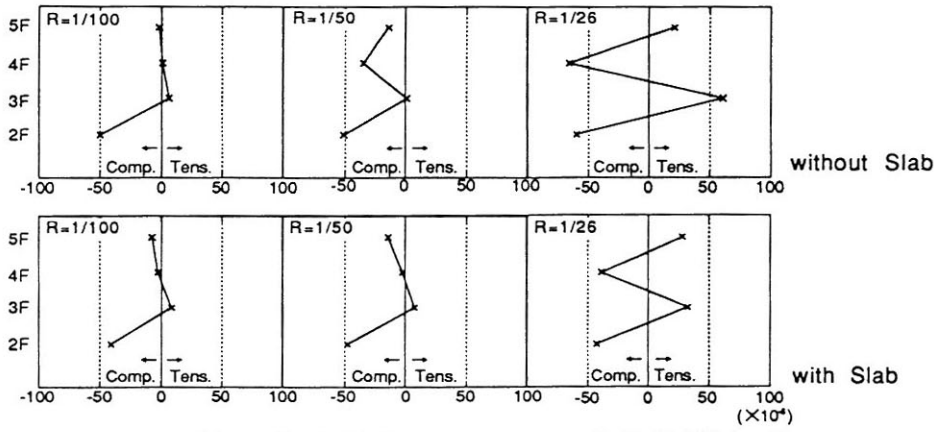

Figure 6 Axial Strain of The Beam B-C (Grid Line 2)

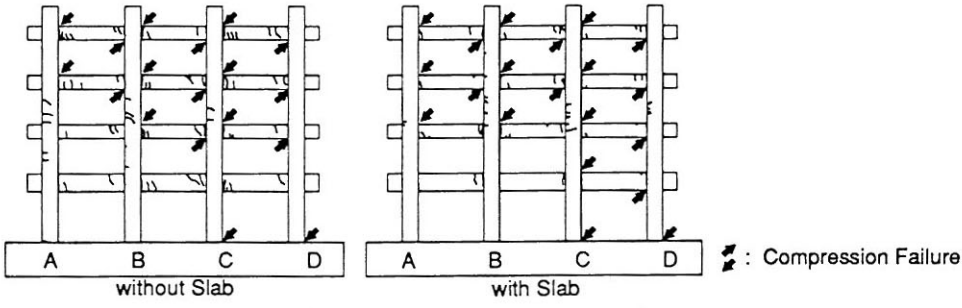

Figure 7 Ultimate Crack Situation

It can be found that there is tendency that a crack of second floor beam is a little. It is thought a reason that a compressive force coming up in second floor beam like to discussed in figure 6. Generally in a specimen without slab, more cracks occurred. Ultimately a resistance force fell accompanied by the compression failure at end of beams shown in figure 7.

Ultimate Resistance Force

"A horizontal force due to an inclination of a rod" is also included in the total horizontal force P. The loading apparatus used in this experiment supports reaction force of an axial force by 2 rods with a both ends pin. Subtraction "A horizontal force due to an inclination of a rod" from a total horizontal force P is horizontal force that has worked upon a specimen.

Figure 8 shows horizontal force at loading points and average horizontal displacement relationship with an ultimate resistance force by simple analysis.

You can see that simple analysis calculated by assuming axial force in the beams as zero is smaller than experimental value in a specimen without slab. It is thought that a resistance force of a specimen increased because that a compressive axial force acts on the beam and an ultimate bending moment got large. This experimental value shows good correspondence with simple analysis considering that an axial force came up only in second floor beam. An axial force was calculated by using axial strain of the beam.

In a specimen with slab, an ultimate resistance force is larger than the value that was calculated by using T-shaped beam with full width didn't receive axial force. Experimental value is also

larger than the value that is got by using T-shaped beam with an effective flange width received an axial compressive force only in second floor beam. Effective flange width was calculated from the equation in reference [1]. However experimental value is smaller than value that is calculated by using T-shaped beam with full width receives an axial compressive force only in second floor beam.

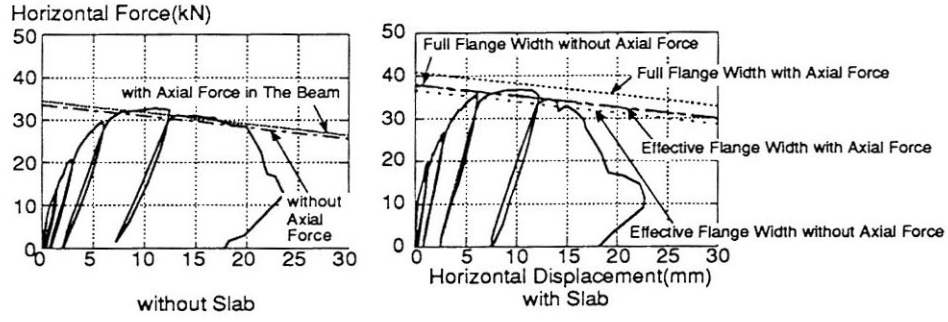

Figure 8 Ultimate Strength

CONCLUSIONS

1. When the frame is receiving rightward monotonic loading, the difference of a horizontal displacement of each column comes up and the deformation of column that located closer to right becomes greater.
2. An ultimate resistance force of a specimen without slab can be calculated by means of making the compressive axial force in second floor beam. In a specimen with slab, an ultimate resistance force is larger than the value that is calculated by using T-shaped beam with full width doesn't receive axial force. Experimental value is also larger than the value that is got by using T-shaped beam with an effective flange width takes an axial compressive force only in second floor beam. However experimental value is smaller than value that is calculated by using T-shaped beam with full width receives an axial compressive force only in second floor beam.

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