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FALL-DOWN TEST OF COLUMNS WITH LOWER PART CUTTING

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When walls and columns are demolished on demolition sites in Japan, they are pulled down by heavy machinery or wire rope after the lower part of walls and columns are cut to weaken their structural integrity before pull-down. However, when the cut is too deep, the walls and columns can collapse and crush workers. It needs to examine the relationship between the cutting of the lower part of wall and column and the stability of the wall and column for a reduced number of accidents. In this paper, it was focused on the column as basic unit of walls and columns. This study carries out the fall-down test of columns with the lower part cutting to review and ensure safe cutting of walls and columns. From the results, the model without concrete on the compression side of the fall-down was lower strength. The model with one row of reinforcement was low strength as felled down by the weight of wire rope. It was proposed that when the lower part of columns is cut on demolition sites, the workers should leave two rows of main reinforcement and leave concrete around the second row of main reinforcement.

Keywords: Fatal accidents, Demolition work, Wall, Reinforced concrete.

1 INTRODUCTION

When walls are demolished on demolition sites in Japan, they are pulled down by heavy machinery or wire rope, as shown in Figure 1. Before pulling down walls, workers cut the lower part of the column to weaken the column, as shown in Figure 1 (a). Next, the tops of walls are grabbed by heavy machinery and pulled down, as shown in Figure 1 (b). However, the necessary cutting amount of columns is unknown. When a worker cuts the wall too deeply, they run the risk of collapsing the wall and being crushed (Takahashi 2019).

(a) Cut of lower part of column. (b) Pull down of wall.

Figure 1. Demolition of a wall by heavy machinery.

Qualification programs exist in Japan (Japan Contractions Training Center 2019 and Japan Demolition Contractions Association 2019). These programs cover the duties of workers, the relevant laws, demolition methods, and the practical business of ensuring a safe work environment. Workers who complete the qualification programs become demolition site supervisors. In addition, qualification examinations exist to improve construction management ability (Japan Demolition Contractions Association 2019). The examination tests one's knowledge of demolition methods and equipment, their ability to create construction plans and quotations for demolition works, and their ability to manage demolition worksites and train workers. Workers who pass the qualification examination become technical managers of demolition works. However, these programs and examinations do not address the safety issues on column cutting.

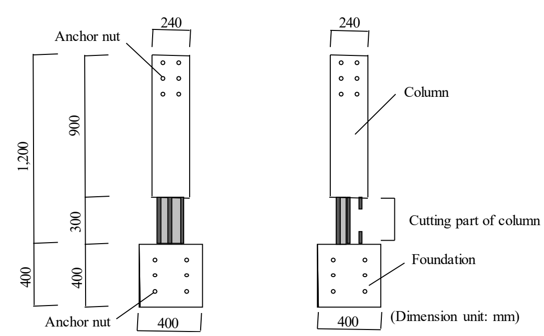
There are safety prevention guidelines (Public Buildings Association 2013), recommendations (Japan Construction Occupational Safety and Health Association 2012a, Japan Construction Occupational Safety and Health Association 2012b and Japan Construction Occupational Safety and Health Association 2016), and technical books (Study Group on Demolition Method 2017) on demolition work, but these also do not discuss the extent to which a wall and column should be cut.

There are papers pertaining to the destruction of concrete (Yuasa 2018) and studies on supporting machines on the floor by some timbering (Aoki 2018). However, there are no scholarly articles related to the cutting of walls and columns and accidental collapsing because the necessary cutting amounts of columns is unknown.

It needs to examine the relationship between the cutting amount of the lower part of the column and column stability. This study carried out the fall-down test of columns with the lower part cutting to review and ensure safe cutting of walls and columns, with the final goal of establishing safety management methods during wall demolition.

2 OVERVIEW OF THE TEST

2.1 Model of the Test



(a) Front elevation. (b) Side elevation.

Figure 2. Model of the test.

The fall-down test of columns was carried out at the National Institute of Occupational Safety and Health in Tokyo. The model of the test is shown in Figure 2, and the material property of the model is shown in Table 1. The models are full-scaled reinforced concrete columns. The strength of the steel bar, as shown in Table 1, are the results of the tension test by Japanese Industrial Standards (Japanese Industrial Standards Committee 2010).

The parameter of the test is the cutting amount of the lower part of the column. The cross sections of the lower part of the column are shown in Figure 3, and the side elevations of the lower part of the column are shown in Figure 4. Figure 3 also shows the center of gravity of the lower section. One of the models is a column without cutting, while the other four models are columns with cutting. It was examined the relationship between the cutting amount of main reinforcement and column stability. The concrete applied to the four models with cutting the same equal amount. The quantity and position of the main reinforcement were adjusted on the four models.

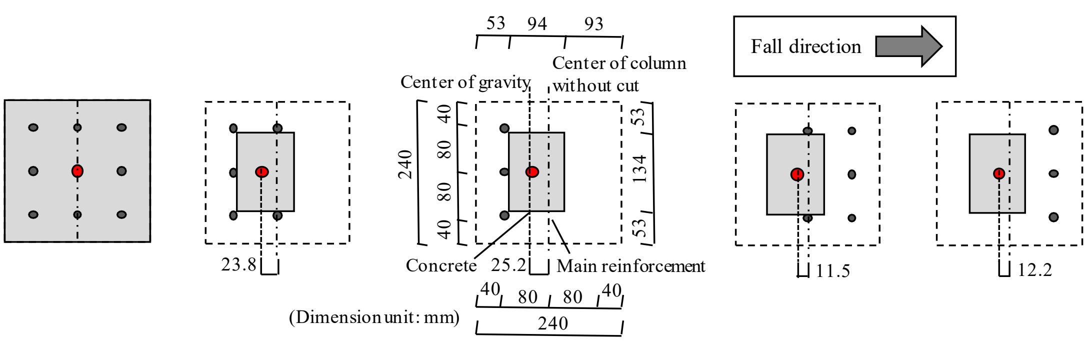
Table 1. Material property of the model.

(a) Concrete

Part of model	Compressive strenght (N/mm^2)	Slump (cm)	Maximum dimensions of coarse aggregate (mm)
Column	28.4	18	20
Foundation	—	18	20

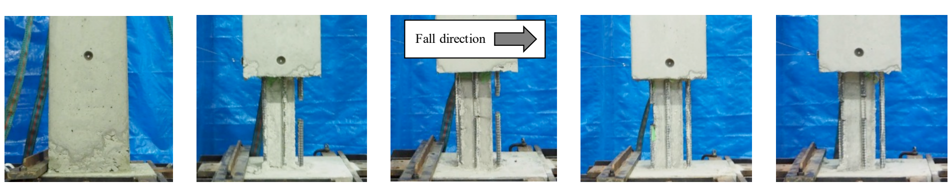
(b) Steel bar.

Part of model	Diameter (mm)	Perimeter (mm)	Cross section (mm^2)	Yield point (N/mm^2)	Tensile strength (N/mm^2)	Elongation (Percent)
Main reinforcement	12.7	4.0	1.267	353	525	23
Shear reinforcement	9.53	3.0	0.7133	374	547	19



(a) Type A. (b) Type B. (c) Type C. (d) Type D. (e) Type E.

Figure 3. Cross section of lower part of column.



(a) Type A. (b) Type B. (c) Type C. (d) Type D. (e) Type E.

Figure 4. Side elevation of lower part of column.

2.2 Setup of the Test

The setup of the test is shown in Figure 5. The model was fixed on the floor by a steel jig, as also shown in Figure 5, and a steel column was placed on the top of the model. The length from the lower end of the model to the tension point of the column was 2.9 m. The weight of the steel column was 2.76 kN, and the weight of the column without cutting was 1.18 kN.

An electric hoist was set 6.5 m away from the model and was the mechanism used to pull it down. The hook of the electric hoist was set at the tension point of the column through a load cell; a chain was rolled up by the electric hoist, and the model was pulled down.

The load and displacements, while pulling down the model, were measured. The load was measured at the tension point of the column by the load cell, and the displacements were measured at points 1 to 4 as shown in Figure 5 by wire displacement meter.

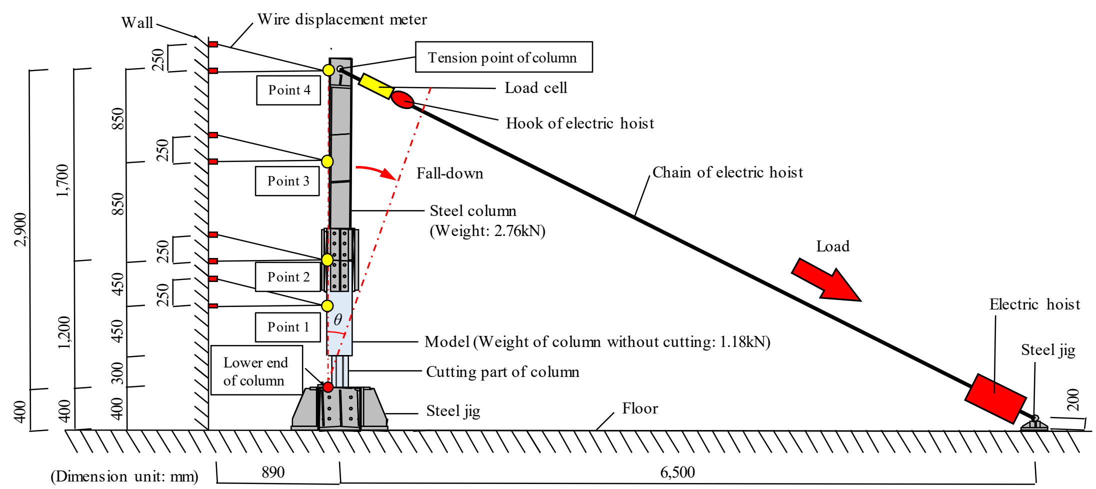


Figure 5. Setup of the test.

3 RESULTS OF THE TEST

3.1 Relationship between Moment and Rotation Angle

The relationship between the moment M and the rotation angle θ while pulling down the model is shown in Figure 6. The vertical axis of Figure 6 is the moment at the lower end of the column. The moment was calculated by the load of the tension point, the weight of the model, and the steel column. The weight of the model and the steel column was to be at the center of each member. The horizontal axis of Figure 6 is the rotation angle of the model. The black line in Figure 6 is the moment from the load of the tension point of the column, and the red line is the moment from the weight of the model and the steel column.

Figure 6 depicts Type D and Type E without concrete on the compression side of the fall-down, and therefore they had lower strength. Type E with one row of main reinforcement was also of low strength. The moment of Type E is 5 % of that of Type A without cutting. In the case of cutting with no concrete on the compression side of the fall-down and one row of main reinforcement, the wall is easily collapsible and dangerous. Type E was of low strength because the position of the neutral axis is on the main reinforcement. It is generally concluded for a different-sizing column.

From Figure 6, Type B and Type C are of about same strength. However, Type B, with more rows of main reinforcement, had a higher deformation capacity. Type B also required less cutting than Type C, and the wall was difficult to collapse. In demolition sites, workers should leave two rows of main reinforcement, and leave concrete around the second row of main reinforcement as was the case with Type B. A buckling of main reinforcement was prevented by the concrete.

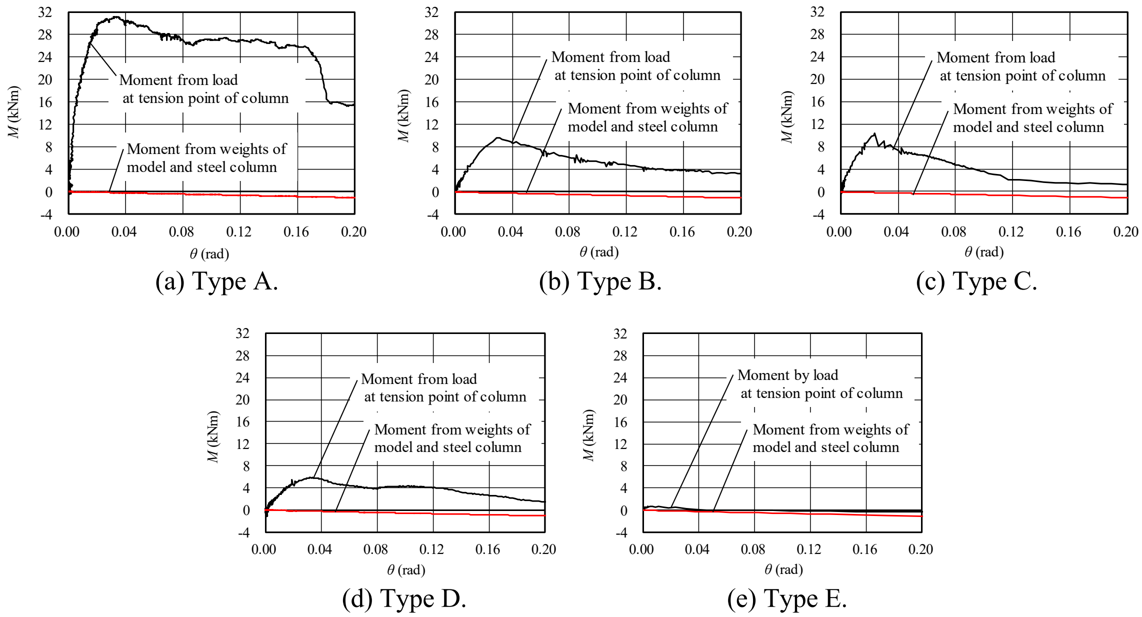


Figure 6. Relationship between moment M and rotation angle θ of the model.

3.2 Stability of the Column

The stability of the column with the lower part cut was examined from the results of the tests. The rough figure of the relationship between the moment M and the rotation angle θ was shown in Figure 7. The maximum of the moment from the load at the tension point of the column was M_u, as shown in Figure 7. When the rotation angle θ is to M_u, the rotation angle θ is θ_u. When the moment from the weights of the model and the steel column is to θ_u, this moment is M_{uw}. When the moment reaches M_u, the column is in danger of collapsing as this is the point of maximum strength. The area formed from the moment M and the rotation angle θ until M_u is W_u, as shown in Figure 7. The area formed from the moment M and the rotation angle θ until M_{uw} was W_{uw}. Table 2 shows $W_{uw} / (W_u + W_{uw})$, which is the effect of the dead load of the column when the column is in danger of collapsing. The closer $W_{uw} / (W_u + W_{uw})$ is to 1, the more the column is in danger of collapsing.

From Table 2, the biggest $W_{uw} / (W_u + W_{uw})$ is 0.141 of Type E. The effect of the dead load of Type E is 14.1 percent. All models become independent because the effect of the dead load to fall-down the column is small. Type E, however, may collapse due to the tension of the wire rope at the top of the column at demolition sites because the strength of Type E is low.

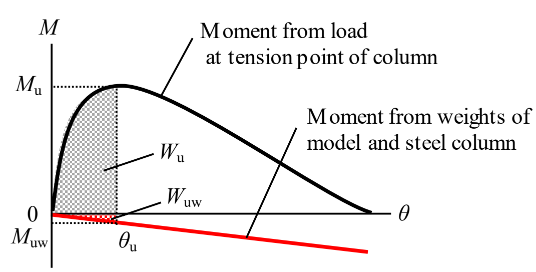


Figure 7. The rough figure of the relationship between moment M and rotation angle θ of model.

Table 2. Results of the test.

Model	W_u	W_{uw}	$W_{uw} / (W_u+W_{uw})$
Type A	0.767	0.003	0.004
Type B	0.185	0.006	0.029
Type C	0.148	0.004	0.025
Type D	0.130	0.004	0.033
Type E	0.003	0.001	0.141

4 CONCLUSION

In this study, the strength and stability of the columns were examined by the fall-down test of columns with the lower part cut. The summary is as follows.

1. The model without concrete on the compression side of the fall-down was of low strength. Expressly, the model with one row of main reinforcement was of low strength. This model may collapse due to the tension of the wire rope at the top of the column. Future columns in demolition sites should not be cut as displayed in the model.
2. In demolition sites, workers should leave two rows of main reinforcement and leave concrete around the second row of main reinforcement.
3. All models become independent because the effect of the dead load to fall-down the column is small.

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