STRENGTH OF EXISTING R/C COLUMNS USING INSTALLED SIDE WALLS

Daisuke Kato[1] and Yoshimasa Honda[2]

[1] Faculty of Engineering, Niigata University, Japan
Email:dkato@eng.niigata-u.ac.jp
[2] Graduate Student, Niigata University, Niigata, Japan
Email: kinzo@pop16.odn.ne.jp

SUMMARY

Effects of installed side walls on shear strength of R/C columns were examined experimentally. Static loading tests of four R/C columns with side walls were conducted. 250 mm square R/C columns, the height of which was 1000mm, were commonly used for all specimens. Main variables were construction methods of side walls, i.e. (i)monolithically cast with columns, (ii)post cast in site and (iii)installing precast side wall to column.

1. INTRODUCTION

In order to avoid pancake type collapse of R/C buildings during severe earthquakes, it is necessary to enhance shear strength of columns. One of effective methods to enhance shear strength of columns is strengthening by side walls. In this paper effects of installed side walls on shear strength of R/C columns were examined experimentally.

For this purpose static loading tests of four R/C columns with side walls were conducted. 250 mm square R/C columns, the height of which was 1000mm, were commonly used for all specimens. Main variables were construction methods of side walls, i.e. (i)monolithically cast with columns, (ii)post cast in site and (iii)installing precast side wall to column. Finally evaluating methods of shear strength of columns with installed sidewalls was discussed.

2. OUTLINE OF TEST

Table 1 shows properties of specimens. Four column specimens with a sidewall were examined. Two of four specimens were tested in 2003 [1] and other two were tested in 2004 [2]. Main variables were construction methods of side walls, i.e. (i)monolithically cast with columns, (ii)post cast in site and (iii)installing precast side wall to column. Figure 1 shows reinforcement of four specimen. Table 2 shows strength of materials.

The sidewall of specimen RCSW-1 was postcast in site, which was a traditional and popular method to install sidewalls to bare frames. Single D10 steel bars with a space of 100mm were used as anchor steels to connect the sidewall to the column and footings. Top portion of the sidewall, the height of which was 100mm, was postcast using high strength concrete for grouting.

Sidewalls of specimens RCSW-2 and RCSW-3 were precast walls with the same reinforcement as that of specimen RCSW-1. The precast sidewall of specimen RCSW-2 was connected to column and top and bottom footings using equal leg angle steels and mechanical anchors with a space of 100mm. The detail of connecting method between sidewall and column of specimen RCSW-2 is shown in Figure 2(a). Epoxy resin was injected to the space between sidewall and surrounding frame. On the other hand the connecting method of specimen RCSW-3 was revised for simplification because the connecting method of specimen RCSW-2 was somewhat complicated. Horizontal angle steel plates connecting between sidewall and column were replaced by four D13 bars, the total area of which was almost comparable with that of horizontal reinforcement of the sidewall. Those D13 bars were arranged at the same time with other sidewall reinforcement. The holes of existing column were drilled to anchor those D13 bars. Vertical angle steel plates connecting between sidewall and footings of specimen RCSW-3 were replaced by four plates located at extreme end of the sidewall. The detail of connecting method between sidewall and footings of specimen RCSW-3 is shown in Figure 2(b). Epoxy resin was also injected to the space between sidewall and surrounding frame in specimen RCSW-3. Specimen CSW-H was cast monolithically for comparison.

Figure 3 shows loading setup. All specimen were subjected to constant axial load of 300 kN. The lateral load was subjected maintaining the top steel loading girder parallel to the base using two vertical jacks on the left and right side of the specimen. The lateral load was reversed at every scheduled drift angle twice.

3. TEST RESULTS

Figure 4 shows relationship between lateral load and lateral drift angle and relationship between axial strain and lateral drift angle of all specimens. Lateral drift angle was defined as lateral deformation divided by column height and axial strain was defined as axial deformation of the column divided by column height. Horizontal dashed lines of these figures represent 80% of maximum strength. Figure 5 shows crack patterns of all specimens at the maximum strength and at final stage. Figure 6 compares envelope curves of four specimens.

Among two specimens with same material strength tested in 2003 maximum strength of specimen RCSW-2 with a precast sidewall connected using angle steel was higher than that of specimen RCSW-1 with a post cast sidewall. This reduction of shear strength was caused by early separation of column and side wall. As shown in Figs. 5(a) and (b) crack patterns show that failure occurred along the joint between column and sidewall in specimen RCSW-1 although failure occurred a little bit far from joint in case of specimen RCSW-2 due to confinement of angle steel.

On the other hand maximum strength of specimen RCSW-3 with a precast sidewall using a simplified connecting method was comparable with that of monolithic specimen CSW-H. This is because separation of column and side wall was not observed at maximum strength due to epoxy resin glue used in this specimen.

4. EVALUATING METHOD OF STRENGTH

Figure 7 shows models to calculate shear strength of columns with installed sidewalls. Figures 7(a)and (b) show models to calculate shear strength of monolithic columns with sidewalls［3］. Figure 7(a) shows irregular section model, in which shear strength of column is evaluated added by side wall contribution considering strut action shown in the figure. The shear strength of columns is evaluated by strut and truss analogous model proposed by AIJ［4］. On the other hand Figure 7(b) shows rectangular section model, in which convex section of column are neglected and shear strength is evaluated as a rectangular section shown in the figure. The shear strength of the rectangular section is also evaluated by strut and truss analogous model proposed by AIJ. It is noted that the shear strength of monolithic columns with sidewalls can be obtained as the larger value of these two models.

In case of columns with installed sidewalls if slip does not occur in the joint between column and sidewall, the shear strength can be evaluated just like monolithic specimens. However if slip occurs in the joint, which means the sidewall is separated from the column, the shear strength should be calculated using separated model shown in Fig. 7(c). In the separated model the shear strength can be calculated as the summation of strength of the column and sidewall calculated separately. Judgment of slip depends on the construction method of installed sidewalls.

Table 3 shows comparison of strength between calculation and experiment. In this table values of strength calculated using models shown in Figs.7(a),(b) and (c) are listed in the second, third and fourth columns, respectively. In the fifth column of this table flexural strength, which means shear load at flexural yielding of top and bottom sections, are listed showing that flexural strength is much higher than shear strength in all specimens.

The final answer of calculated strength is listed in the sixth column of this table. Proposed evaluating equation for shear strength of columns with monolithically cast side walls overestimated the observed shear strength of specimen RCSW-1 with a post cast side wall. This reduction of shear strength was caused by separation of column and side wall. From this view point separated model should be used for columns with traditional post cast sidewalls the value because little effect was expected to prevent the joint between column and sidewall from slipping. Consequently in specimen RCSW-1 with a traditional post cast sidewall the value using separated model was adopted as a final answer.

On the other hand values using monolithic models were adopted as final answers in other three specimens because effects to prevent slip of joints were expected in these specimens. In these cases the larger values of irregular and rectangular section models can be taken as shear strength.

The seventh and last columns of Table 3 represent observed maximum strength during the test and the ratio of experimental data to calculation, respectively. Observed shear strength of a column with installed precast side wall was found to be comparable with those of columns with monolithically cast side walls. This is because separation of column and side wall was not observed due to epoxy resin glue used in this specimen. Consequently proposed evaluating equation of shear strength of R/C columns with monolithically cast side walls was found to be effective for columns with installed precast side walls. However in specimen RCSW-1 with a traditional post cast sidewall calculated value by separated model is too conservative and the model should be examined furthermore.

5. CONCLUSIONS

(1)Static loading tests of four R/C columns with side walls were conducted. Main variables were construction methods of side walls, i.e. monolithically cast with columns, post cast in site and installing precast side wall to column.
(2)Evaluating equation of shear strength of R/C columns with installed sidewalls was proposed based on truss and arch analogy model.
(3)Proposed evaluating equation for shear strength of columns with monolithically cast side walls overestimated the observed shear strength of a column with post cast side wall. This reduction of shear strength was caused by separation of column and side wall. From this view point separated model should be used for columns with traditional post cast sidewalls the value because little effect was expected to prevent the joint between column and sidewall from slipping.
(4)Observed shear strength of a column with installed precast side wall was found to be comparable with those of columns with monolithically cast side walls. This is because separation of column and side wall was not observed at maximum strength due to epoxy resin glue used in this specimen. Consequently proposed evaluating equation of shear strength of R/C columns with monolithically cast side walls was found to be effective for columns with installed precast side walls.

REFERENCES

［1］Daisuke KATO and Yuji Otsuka; Static Loading Tests of R/C Columns with a Post Cast Side Wall, Proceedings of the Japan Concrete Institute, Vol.25, No.2, 2003, pp.1471-1476 (in Japanese)
［2］Yoshimasa HONDA, Daisuke KATO, Atsushi HONMA and Masataka NANBU; Static Loading Tests of R/C Columns with a PCa Side Wall, Proceedings of the Japan Concrete Institute, Vol.26, No.2, 2004, pp.253-258 (in Japanese)
［3］Daisuke KATO and Hao Yang SUN: Evaluating Method of Post Peak Behavior of R/C Columns with Side Walls, Journal of Structural and Construction Engineering, Architectural Institute of Japan, No.566, pp.97-103, April, 2003 (in Japanese)
［4］Architectural Institute of Japan, Design Guidelines for Earthquake resistant Reinforced Concrete Buildings Based on Inelastic Displacement Concept,1999 (in Japanese)

Table 1 Properties of specimens

<table>
<tr><th>specimen</th><th>column (mm)</th><th>side wall(mm)</th><th>height (mm)</th><th>main bar of column</th><th>hoop (%)</th><th>side wall reinforcement (%)</th><th>axial force (kN)</th><th>construction method of side wall</th><th>connecting bar between column and side walll</th><th>test year</th></tr>
<tr><td>RCSW-1</td><td rowspan="4">250×250</td><td rowspan="4">500×75</td><td rowspan="4">1000</td><td rowspan="4">4-D13</td><td rowspan="4">2-D6@100 (0.26)</td><td rowspan="4">2-D6@100 (0.85)</td><td rowspan="4">300</td><td>post cast</td><td>D10@100</td><td rowspan="2">2003</td></tr>
<tr><td>RCSW-2</td><td>precast</td><td>angle steel</td></tr>
<tr><td>RCSW-3</td><td>precast</td><td>4-D13</td><td rowspan="2">2004</td></tr>
<tr><td>CSW-H</td><td>monolithic</td><td>-</td></tr>
</table>

Table 2 Strength of material (N/mm^2)

<table>
<tr><th>specimen</th><th>column concrete</th><th>side wall concrete</th><th>grouting concrete</th><th>D6</th><th>D10</th><th>D13</th><th>angle steel</th><th>bolt</th></tr>
<tr><td>RCSW-1</td><td rowspan="2">26.0</td><td rowspan="2">29.8</td><td>43.4</td><td rowspan="2">322</td><td rowspan="2">373</td><td rowspan="2">365</td><td>-</td><td>-</td></tr>
<tr><td>RCSW-2</td><td rowspan="3">-</td><td>235</td><td>362</td></tr>
<tr><td>RCSW-3</td><td>21.7</td><td>21.7</td><td rowspan="2">353</td><td rowspan="2">382</td><td rowspan="2">383</td><td>240</td><td>240</td></tr>
<tr><td>CSW-H</td><td colspan="2">21.7</td><td>-</td><td>-</td></tr>
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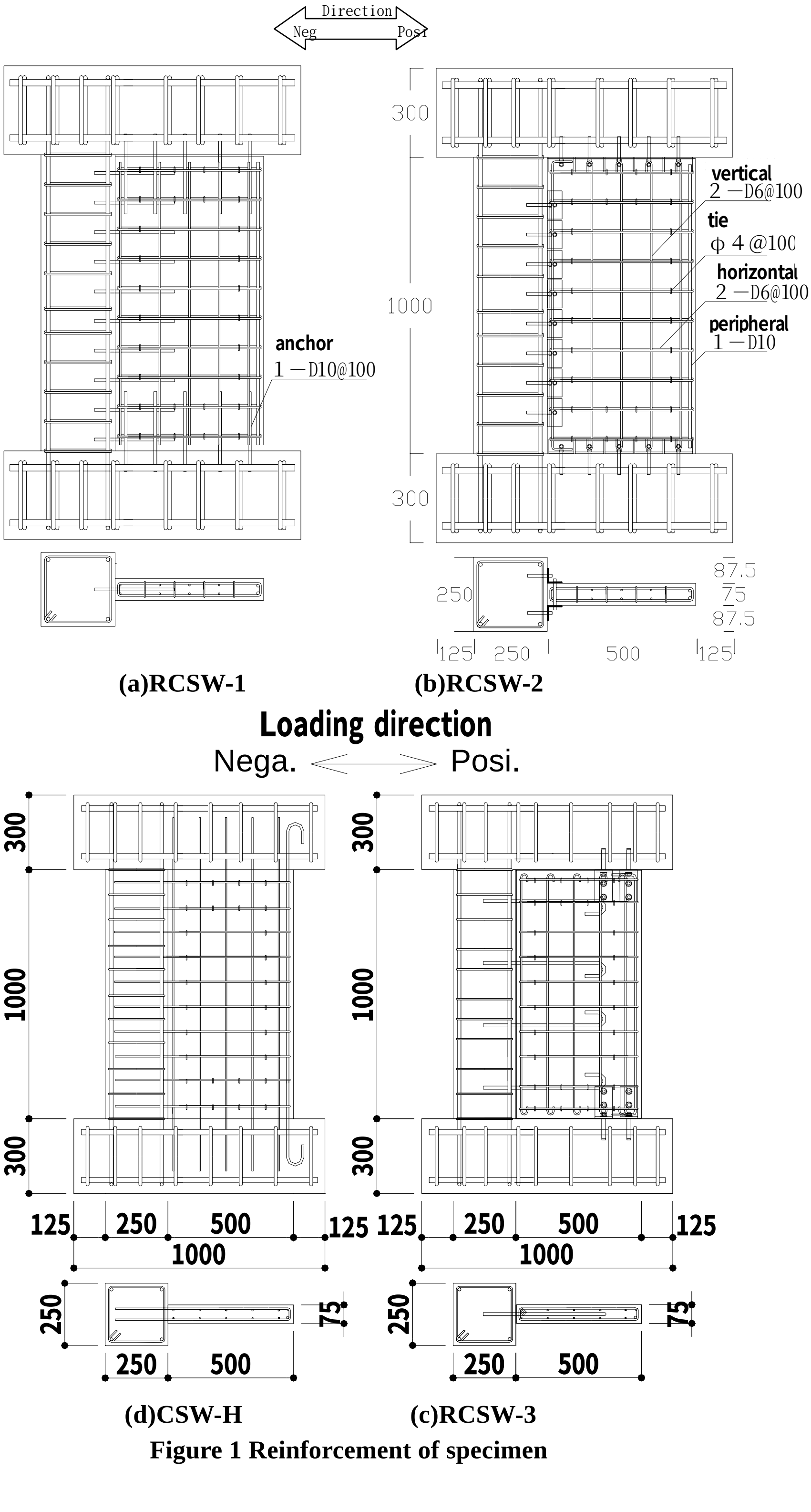
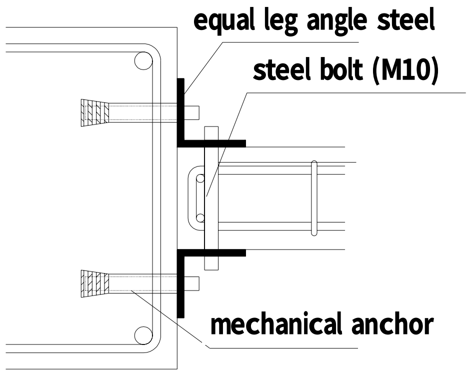
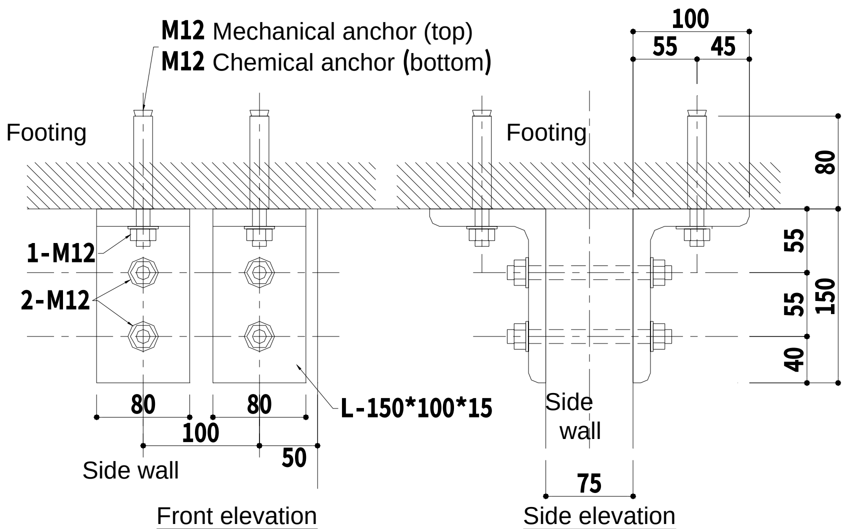


Figure 1 Reinforcement of specimen



(a)Connection between sidewall and column (and also footing) of specimen RCSW-2



(b)connection between sidewall and footing of specimen RCSW-3

Figure 2 Details of connecting method of sidewall to column or footing

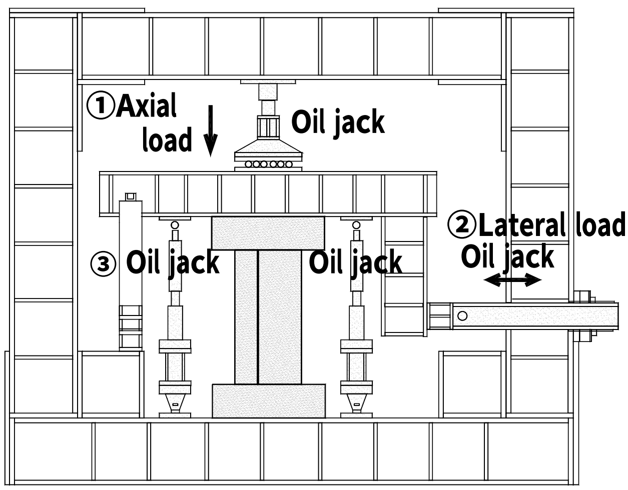
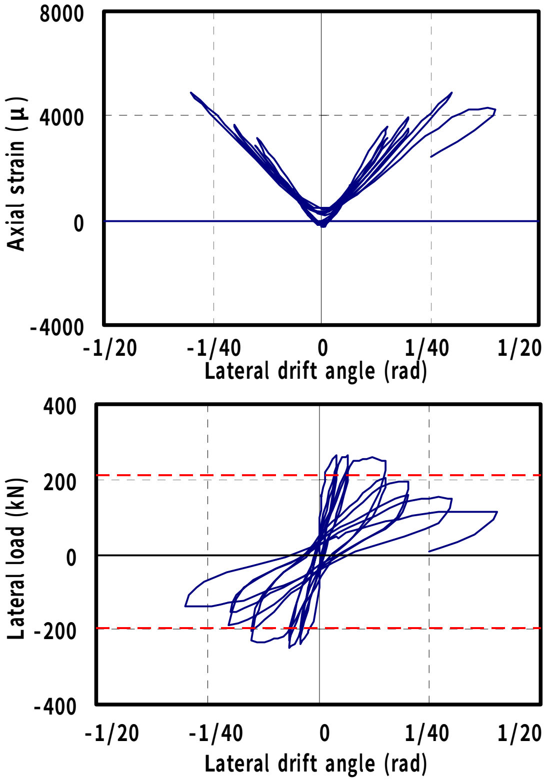
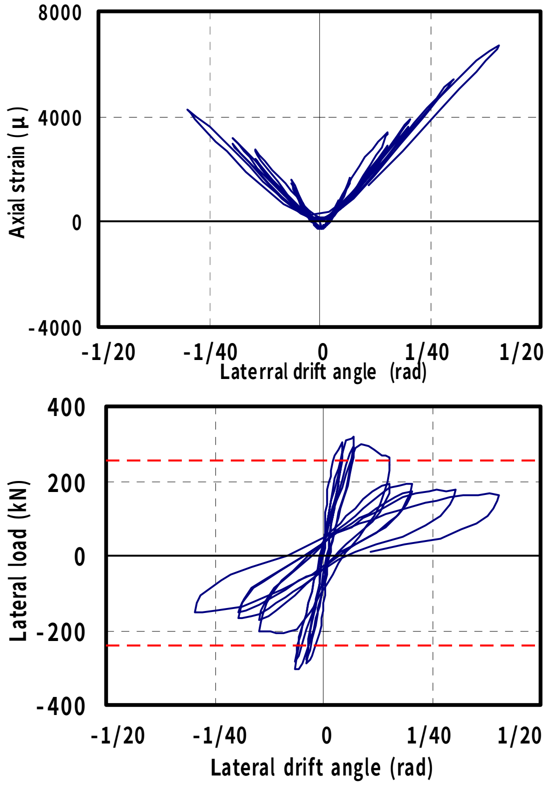


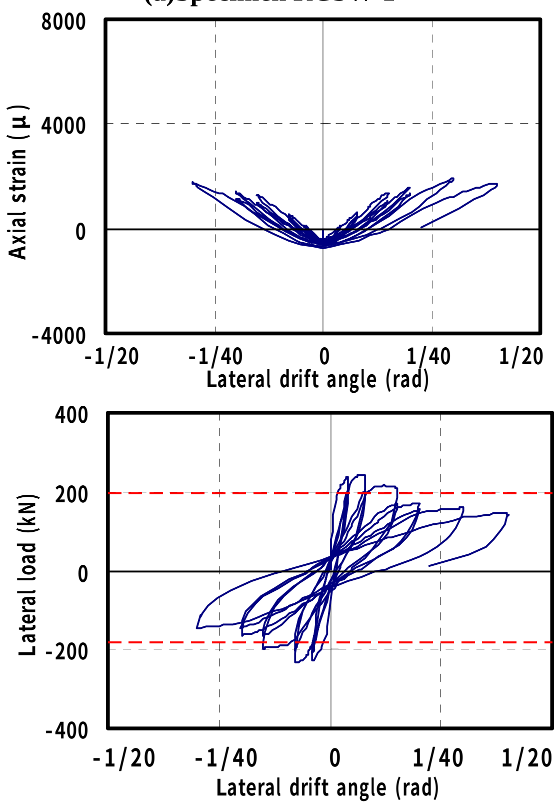
Figure 3 Loading set-up



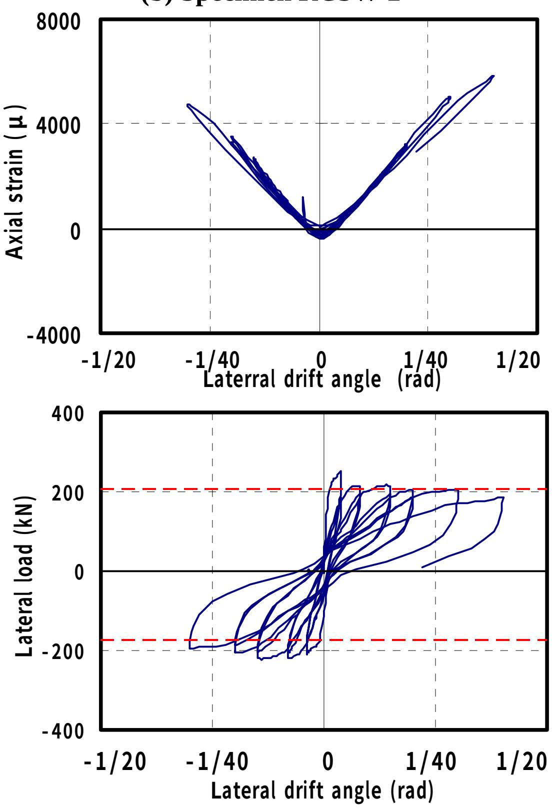
(a)Specimen RCSW-1



(b) Specimen RCSW-2

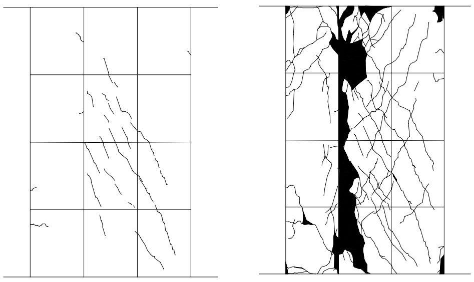


(d)Specimen CSW-H



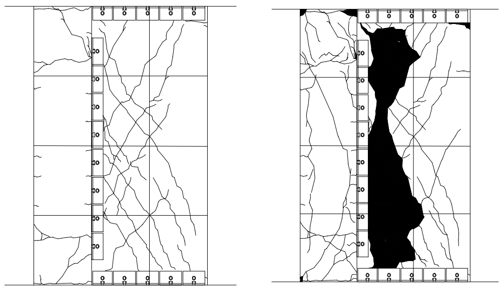
(c) Specimen RCSW-3

Figure 4 Lateral load or axial strain – lateral drift angle relationship



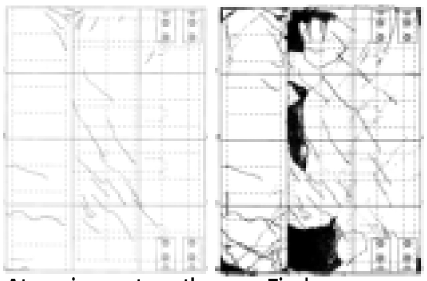
at max strength(1/250rad) final (1/25rad)

(a)CSW-1



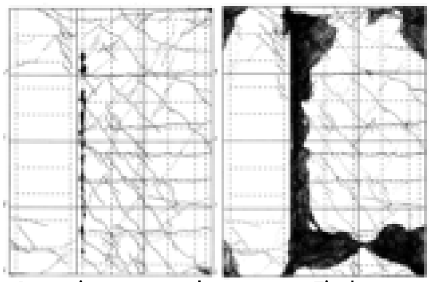
at max strength (1/150rad) final(1/25rad)

(b)CSW-2



At maximum strength (1/250rad) Final (1/25rad)

(c)CSW-3



At maximum strength (1/125rad) Final (1/25rad)

(d)CSW-H

Figure 5 Crack pattern

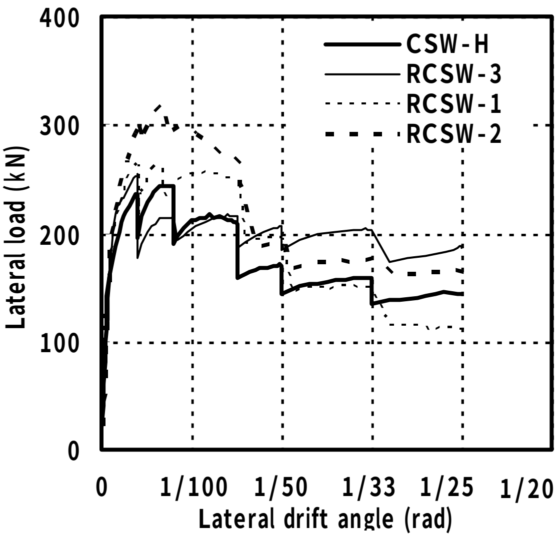
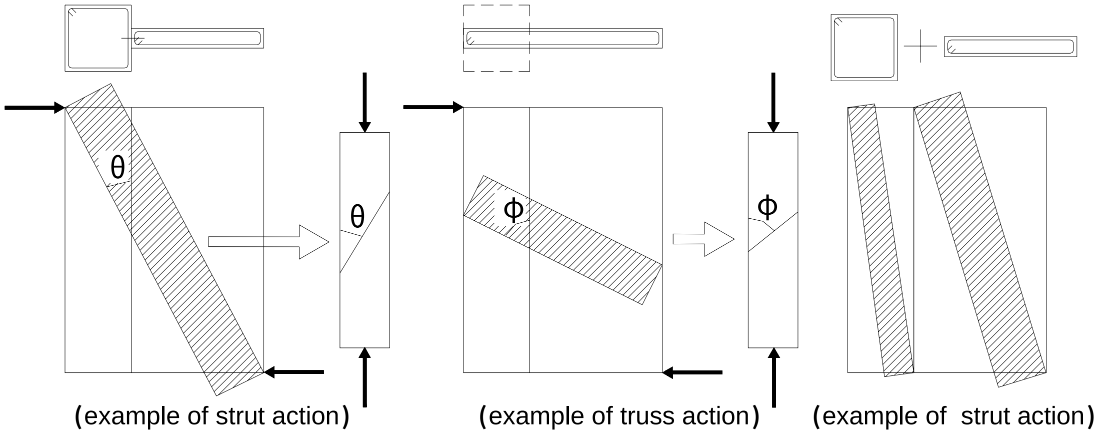


Figure 6 Envelop curve of lateral load – lateral drift angle relationship



(example of strut action) (a) Irregular section model

(example of truss action) (b) Rectangular section model

(example of strut action) (c) Separated model

Figure 7 Models for shear strength of columns with installed sidewall

Table 3 Comparison of strength between calculation and experiment

specimen	calculation (kN)					experiment (kN)	(exp/cal)
	shear strength			flexural strength	final answer of calculated strength		
	monolithic		separated model				
	irregular section model	rectangular section model					
RCSW-1	245	265	161	351	161	264	(1.64)
RCSW-2					265	318	(1.20)
RCSW-3	204	227	167	355	227	244	(1.07)
CSW-H					227	254	(1.12)