Seismic Behavior of Precast Shear Walls with Vertical Reinforcements Overlap Grouted in Constraint Sleeve

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Abstract
Based on the existing developed type I and III sleeve with big inner diameter, simple processing and convenient reinforcement bar connector construction, the paper designed and completed pseudo static test on a piece of comparison cast-in-situ shear wall, two pieces of longitudinal reinforcement adopted on type I and type III sleeve connector pre-cast shear wall. The experimental results are as following: the main failure modes of pre-cast wall are basically consistent with that of cast-in-situ wall. However, the crack of pre-cast wall appears in latency comparatively to that of cast-in-situ wall. The initial fracture of cast-in-situ wall appears at the bottom of the wall. However, due to the vertical constraint of the sleeve, initial fracture of the pre-cast wall appears at the upper part of sleeve; the bearing capacity and energy dissipation of pre-cast wall is basically the same to the bearing capacity of cast-in-situ wall. The limiting displacement drift ratio of pre-cast wall is bigger than that of cast-in-situ wall; type I and type III sleeve can perfectly transfer reinforcement stress of pre-cast concrete shear wall. It is convenient and feasible to apply type I and type III sleeve on the pre-cast shear wall.

Key words: Reinforcement Connection, Grouted Sleeve Lapping, Precast Shear Wall, Limiting Displacement Drift ratio, Energy Dissipation

1. INTRODUCTION
Reinforcement connection is the key technology in pre-cast concrete structure. Grouting connector is an extensively applied reinforcement connector method at present. Grouting connector methods mainly include: Sleeve grouting butt connection and plug-in filling hole for steel bar lapping connector. Sleeve grouting butt connection is as shown in Fig. 1 (a) (Ling, Abd.Rahman, Ibrahim, et al., 2014; Ling, Abd.Rahman, Ibrahim, et al., 2012; Alias, Zubir, Shahid, et al., 2013). Namely after placing sleeve outside the two butt reinforcement bars, fill in grouting materials to realize connection of two reinforcement bars. It is the most commonly used reinforcement connector form at present.

Plug-in filling hole for steel bar lapping connector (Jiang, Zhang, Liu, Yan, 2011; Ma, Yin, Liu C, Liu, Pan, 2015) is to reserve holes with rough surface beside the embedded reinforcement. Insert connector reinforcement bar to the holes and fill in grouting materials. In addition, spiral hooping along the hole length direction surround the connector and embedded reinforcement bar to enhance reinforcement bar connection as shown in Fig. 1 (b).

Grouted sleeve lapping connector (Xu, Wang, Shen, 1993) is to place a sleeve outside two lapping reinforcement bar (known as type I sleeve) or four overlapping reinforcement bars (known as type III sleeve). Fill in grouting materials to realize reinforcement bar connection (Xu., Wang, Shen,1993; Xu,2016; Yu,2015) as shown in Fig. 1 (c) and 1 (d). It is a reinforcement bar connector patented technology put forward by the writer in 2014. It has been demonstrated through experiment that constraint sleeve improve the bearing capacity of overlapping and reduce the lap length of connector. The lap length of type I sleeve connector is 12.5d and that of type III sleeve connector is 20d.

Table 1 shows comparison of the connectors above. It can be seen that the grouted sleeve lapping connector is characterized of big sleeve diameter, convenient assembly construction and low cost etc.. It is a more advanced patented technology compared with existing connector technology.

Table.1 Comparison of three kinds of grouted connector

<table>
<thead>
<tr>
<th>connector form</th>
<th>Minimum connector length</th>
<th>Construction convenience</th>
<th>Construction cost</th>
</tr>
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<tbody>
<tr>
<td>Sleeve grouting butt connector</td>
<td>8d</td>
<td>Clearance between inserted reinforcement bar and sleeve interior wall is about 5~6mm. The construction is difficulty and construction period is long.</td>
<td>The materials and casting process requirements are high with high cost.</td>
</tr>
</tbody>
</table>
Plug-in filling hole for steel bar lapping connector

- Above 35d
- The lapping length is too long. Construction difficulty is high and construction period is long.
- Use reinforcement stirrup to provide horizontal restrain. The cost is low.

Grouted sleeve lapping connector

- Type I: 12.5d, Type III: 20d.
- The sleeve is characterized of big diameter and convenient construction.
- Use grouting material which is low in cost.

Note: d refers to diameter of reinforcement bar in connector. The unit is mm;

The paper performed pseudo static test on a cast-in-situ shear wall and two pieces of pre-cast shear wall by using type I and III reinforcement bar connectors. The paper carried out comparative study on cracking load, failure mode, displacement angle, ductility, energy dissipation and seismic performance of the two.

2. EXPERIMENTAL PROGRAM

2.1. Specimen Design and Production

Three shear wall specimens are XW1, YW1 and YW2. XW1 is cast-in-situ wall and YW1 is pre-cast shear wall that vertical reinforcement of restrained edge members and the shear wall body adopts type I sleeve connector. YW2 is restrained edge members vertical reinforcement which adopts type III sleeve connector and the shear wall body vertical reinforcement adopts type I sleeve connector. The specimen is composed of test wall, loading beam at the wall top and pant and at the bottom of the wall. The test wall is of rectangular section. The overall dimensions are the same, 2700mm of wall height, 200mm of thickness and 1300mm of wall length. The wall height and length are the same to storey height and wall length between two windows respectively. The specimen facade is as shown in Fig. 2. The vertical distance between loading beam center to base surface is 2900mm. The shear span ratio of wall is 2.23.

![Figure 1. Forms of grouted connection joints of reinforcement bars](image1)

![Figure 2. Elevation of shear wall specimen](image2)
Specimen manufacturing method and connector mode are as shown in Table 2. Pre-cast wall vertical reinforcement adopts new type of sleeve invented by Yuqiong for connection. The sectional dimensions and reinforcement bars of shear wall are as shown in Fig. 3. The vertical and horizontal distribution reinforcement of shear wall is D8@200. Set edge members 400mm in length. Set 6D16 vertical reinforcement and D8@100 reinforcement stirrup. The volume-stirrup ratio is 0.0136. XW1 is cast-in-situ wall specimen, loading beam and pattand pouring assembly. The reinforcement distribution is as shown in Fig. 3 (a). YW1 is pre-cast shear wall. 6 type I sleeve grouting anchor lapping 60mm in inner diameter, 3mm in wall thickness and 175mm in length are adopted for connection. The length of reinforcement bar protruding to sleeve is 175mm; 6D10 vertical reinforcement distribution in the wall adopts indirect splicing: 2D18 reinforcement bars are used to substitute for 6D10 distributed reinforcement bars. The actually measured tensile yield bearing capacity of 2D18 reinforcement bar is 205.35kN and that of 6D10 reinforcement bar is 232.42kN. Two sleeves( type I) welding with 2D18 reinforcement bar prefabricated in pre-cast wallbody with an inner diameter of 70mm, 3mm of wall thickness and 225mm in length, and 2D18 reinforcement bars embed in pattand are inserted in sleeve to realize reinforcement bars connection. The length of reinforcement bar protruding to sleeve is 225mm. 6 vertical reinforcement distribution bars with a diameter of 10mm and 2 reinforcement bars with a diameter of 18mm are used for indirect splicing (lap length is 945mm). The YW1 reinforcement is as shown in Fig. 3 (b).

YW2 is pre-cast shear wall. 6D14 at each end of embedded column and 6D14 reinforcement bar embedded in pattand are connected by 3 type III sleeve grouting anchor lap connection 60mm in width, 130mm in length, 3mm in wall thickness and 280mm in length. Place four reinforcement bars in each sleeve. The length of reinforcement bar protruding to sleeve is 280mm; the 6D10 vertical distribution connection in the wall is the same to that of YW1. The YW2 reinforcement is as shown in Fig. 3 (C).

YW1 and YW2 are obtained to vertical structure reinforcement D8 within sleeve height range at each end of embedded column. More reinforcement stirrup and horizontal distribution are obtained within sleeve height range. The reinforcement bar is applied to improve the compressible deformation ability of wall root concrete and avoid early falling off of sleeve covering layer. The grouting layer thickness between YW1 and YW2 pre-cast wall and pattand is 20mm.

Table 2 Specimen manufacturing method and vertical reinforcement connector mode

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Manufacturing method</th>
<th>Embedded column</th>
<th>Sleeve form</th>
</tr>
</thead>
<tbody>
<tr>
<td>XW1</td>
<td>Cast-in-situ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>YW1</td>
<td>Prefabrication</td>
<td>Type I (φ60, 175mm in height)</td>
<td>Type I (φ70, 225mm in height)</td>
</tr>
<tr>
<td>YW2</td>
<td>Prefabrication</td>
<td>Type III (60 in width and 130 in length, 280mm in height)</td>
<td>Type I (φ70, 225mm in height)</td>
</tr>
</tbody>
</table>

(a) Elevation of XW1 specimen (b) Elevation of YW1 specimen (c) Elevation of YW2 specimen
2.2. Sleeve Design

The detailed drawing of various types of sleeves required on the shear wall are as shown in Fig. 4. The diameter in the diagram refers to inner diameter. The sleeves in the paper are improved based on those in Yuqiong experiment. The sleeve invented by Yuqiong et al. is only applied on pull-out test. Perform grouting directly on the upper part of sleeve. Since the sleeve in the paper needs to be applied on the wall, the sleeve invented by Yuqiong et al. has been improved as following: Add a cover plate at the top of sleeve to prevent concrete entering the sleeve at concrete pouring; drill on the edge of the cover plate. The diameter is 2mm greater than that of reinforcement bar so that the upper part of reinforcement bar can enter the sleeve; set grouting hole and vent hole on the upper part of sleeve and lower part of the side wall. The inner diameters are 14mm and 27mm respectively. The distance between the upper edge of grouting hole and vent hole and the lower edge is 20mm. The wall thickness of various sleeve is 3mm.

2.3. Mechanical Property of Material

Table 3 lists the measured values of reinforcement bar yield strength $f_y$ and tensile strength $f_u$. The measured value is the average value of three reinforcement bars.
The cube compressible strength of concrete wall and base of the test specimen are 30.9MPa and 42.4 MPa respectively.

<table>
<thead>
<tr>
<th>Diameter (mm)</th>
<th>( f_y ) (MPa)</th>
<th>( f_u ) (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>549.24</td>
<td>650.88</td>
</tr>
<tr>
<td>8</td>
<td>470.70</td>
<td>650.63</td>
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<tr>
<td>10</td>
<td>493.28</td>
<td>655.10</td>
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<tr>
<td>14</td>
<td>492.08</td>
<td>624.15</td>
</tr>
<tr>
<td>18</td>
<td>404.49</td>
<td>614.05</td>
</tr>
</tbody>
</table>

Grouting material adopts H-40 with 28 compressible strength manufactured by Shanghai Huanyu Architectural Engineering Material Co., Ltd.. Test specimen fracture resistance and compressive strength are 10.77 MPa and 77.98 MPa. Test specimen splitting tensile strength is 4.33MPa.

2.4. Loading System and Measuring Contents

The pseudo static test of shear wall is performed at the structural static lab of Tongji University. The test loading device is as shown in diagram 6. The applied axial pressure calculated is 800KN. First of all, apply a 800kN vertical force and remain unchanged during test process. Horizontal load is to be applied according to loading test scheme. Horizontal load is applied by adopting force control and displacement control: The previous three stages loading force is to be controlled by force. The horizontal forces are 50kN, 100kN and 150kN respectively for circulation and the actuator is subject to circulation for once. Subsequently adopt displacement control mode, respectively as 4mm, 8mm, 12mm, 16 mm, 20mm and 24mm. The actuator displacement is subject to circulation for twice. After 24mm, each grade of displacement increase by 8mm until specimen failure. Stop loading until the wall bearing capacity initially drops to 85% of the peak load.

![Test loading device diagram](image)

Figure 6. Test loading device diagram

Paste strain gauge at the vertical reinforcement 20mm above the patand top of YW1 and YW2 sleeve connector, and 20mm above the sleeve. Compare the strain of vertical reinforcement bar of the upper and lower sleeve, and evaluate whether the reinforcement bar for sleeve connector can effectively transfer the internal force. For distributing reinforcement D10 and D18 at YW1, YW2 indirect splicing, Distribute reinforcement bar strain gauge at 490mm above the patand. In addition, arrange reinforcement bar strain piece 20mm above the sleeve and 20mm at patand top to determine the connection performance of D18 reinforcement bar for sleeve connector.
3. TEST RESULTS AND ANALYSIS

3.1. Failure Process and Failure Pattern

In case of 4mm of horizontal displacement, tiny horizontal crack will appear at the right root of XW1 wall. In case of 8mm of horizontal displacement, tiny cracks will appear at both ends of shear wall; with increasing of horizontal force, the shear wall will show multiple horizontal cracks from bottom to upper of the shear wall. In case of 16mm of horizontal displacement, the right side of the horizontal crack will extend 45 degree inclined down and compression vertical cracks appear for the first time at the left bottom of wall; in case of 24mm of horizontal displacement, crack width of wall bottom will further increase with small amount of concrete dropping. In case of 40mm of horizontal displacement, the concrete at the bottom right corner of wall will start peeling and dropping; in case of 64mm of horizontal displacement, the wall reaches to bearing capacity.

In case of 8mm of horizontal displacement, a horizontal crack will occur at the left and right side of YW1 about 500mm in height; in case of 12mm of horizontal displacement, the original crack will extend to the left bottom with an inclination of 30 degree; in case of 16mm of horizontal displacement, a crack will extend to 45 degree inclined to the lower right; in case of 32mm of horizontal displacement, compression vertical crack will occur at the left bottom of the wall, and the bottom right grouting layer and wall combination surface will crack; in case of 56mm of horizontal displacement, the concrete above the left sleeve will be crushed partially; the concrete at the bottom right corner of the wall will drop off. After that, the wall crack will not show obvious development; in case of 64mm of horizontal displacement, the concrete outside the corner of sleeve will be subject to more serious crushing. And the concrete will continuously drop off; in case of 72mm of horizontal displacement, the wall reaches to bearing capacity.

In case of 12mm of horizontal displacement, horizontal crack will occur at the left and right side of YW2 wall at a height of 300mm; in case of 16mm of horizontal displacement, the crack will develop to the center and present 45 degree inclining to the lower left corner; in case of 24mm of horizontal displacement, the crack will develop to the center and present 45 degree inclining to the lower right corner. In case of 40mm of horizontal displacement, multiple vertical cracks will occur at the left bottom corner of the wall; in case of 56mm of horizontal displacement, concrete crushing damage phenomenon will deteriorate at both ends of the wall and the concrete will be crushed on the left side above the sleeve; in case of 64mm of horizontal displacement, the concrete outside the sleeve both corners of the wall will drop off; in case of 72mm of horizontal displacement, the wall reaches to bearing capacity limit.

Fig. 7 shows failure sketch of XW1, YW1 and YW2 specimen at ultimate load. It can be seen that the development law of prefabrication and cast-in-situ shear wall crack are basically the same. The failure mode of specimen is basically the same. The edge components vertical steel tensile yield and crushed concrete are subjected to bending destruction. The different point is that the crack of pre-cast wall appears in latency comparatively to that of cast-in-situ wall. It is mainly due to the existence of vertical restraint of the sleeve to concrete on the wall edge and latency of concrete cracking; the surface cracking of pre-cast wall and base shows latency to the crack of the cast-in-situ wall bottom. Cast-in-situ wall concrete crushing refers to concrete crushing damage on both root of the wall. The concrete at the upper part of sleeve of pre-cast wall will be damaged. Subsequently, the concrete protective layer outside the sleeve will drop off. Chisel the upper and lower end of the sleeve after the experiment. It has been detected that no slipping will occur on reinforcement bar comparatively to grouting materials.

3.2. Hysteretic Curve and Skeleton Curve

The hysteretic curve and skeleton curve of top horizontal force-displacement is as shown in Fig. 8. Due to existing of hysteretic curve of XW1, YW1 and YW2 specimen, as well as pinching approach, the curve is comparatively full with good energy dissipation capacity. It can be seen from the skeleton line contrast figure, three types of wall will basically coincide with the situation of the early stage. It distinguishes slightly at later period. The general difference is not big. In case of positive loading, XW1 curve is at the outer side. In case of reverse loading, YW1 is at the outer side. The difference among the three envelope lines is not big.
3.3. Bearing Capacity

Table 4 lists the cracking load, yield load and peak load of wall. Yield load refers to the horizontal load of vertical reinforcement outside the wall tension zone reaches to yield strain; the peak load refers to the maximum horizontal load that can be withstood by the wall.
In general, the cracking load of pre-cast wall is higher than that of cast-in-situ wall. In addition, the crack load of YW2 is the maximum. The existence of sleeve restrains the vertical deformation of external concrete. YW2 sleeve type III is the longest. The cracking load is the maximum.

The average bearing capacity of pre-cast wall is consistent with that of cast-in-situ wall which indicates that the reinforcement bar adopts sleeve connector can effectively transfer the internal force. The indirect grouting anchor connection of vertical distributed reinforcement can effectively transfer the internal force and are equivalent to that of cast-in-situ wall.

### Table 4 Horizontal force comparison of specimen under different states (unit: kN)

<table>
<thead>
<tr>
<th>Specimen</th>
<th>$F_{ox}$</th>
<th>$F_{oy}$</th>
<th>$F_{p}$</th>
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<tbody>
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<td>188.77</td>
<td>139.48</td>
<td>164.13</td>
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<tr>
<td></td>
<td>164.01</td>
<td>139.48</td>
<td>128.81</td>
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<tr>
<td>YW1</td>
<td>185.58</td>
<td>206.07</td>
<td>195.83</td>
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<tr>
<td></td>
<td>206.07</td>
<td>195.83</td>
<td>130.76</td>
</tr>
<tr>
<td>YW2</td>
<td>196.39</td>
<td>251.79</td>
<td>224.09</td>
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<tr>
<td></td>
<td>251.79</td>
<td>224.09</td>
<td>166.74</td>
</tr>
</tbody>
</table>

### Table 5 Horizontal displacement (unit: mm) and displacement angle of specimen under different status

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<thead>
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<tbody>
<tr>
<td>XW1</td>
<td>Dis. angle</td>
<td>3.8-7</td>
<td>6.43</td>
<td>4.94</td>
<td>7.34</td>
<td>4.07</td>
<td>5.71</td>
<td>13.91</td>
<td>9.97</td>
<td>11.94</td>
<td>46.31</td>
<td>47.13</td>
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<td>64.08</td>
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<td></td>
<td>Dis. angle</td>
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<td>1/713</td>
<td>1/508</td>
<td>1/208</td>
<td>1/291</td>
<td>1/243</td>
<td>1/63</td>
<td>1/62</td>
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<td>1/45</td>
<td>1/49</td>
<td>3.8-7</td>
<td>6.43</td>
<td>4.94</td>
<td>7.34</td>
<td>4.07</td>
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<td>13.91</td>
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<td>46.31</td>
<td>47.13</td>
<td>46.72</td>
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<tr>
<td>YW1</td>
<td>Dis. angle</td>
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<td>3.98</td>
<td>3.68</td>
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<td>7.65</td>
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<td>9.97</td>
<td>11.94</td>
<td>46.31</td>
</tr>
<tr>
<td>YW2</td>
<td>Dis. angle</td>
<td>2.99</td>
<td>2.70</td>
<td>2.85</td>
<td>10.92</td>
<td>12.54</td>
<td>11.73</td>
<td>25.67</td>
<td>23.56</td>
<td>24.62</td>
<td>53.86</td>
<td>39.01</td>
<td>46.44</td>
<td>76.76</td>
<td>63.66</td>
<td>70.18</td>
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<td>Dis. angle</td>
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<td>1/231</td>
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<td>1/247</td>
<td>1/111</td>
<td>1/111</td>
<td>1/111</td>
</tr>
</tbody>
</table>

Note: Dis. refer to Displacement, Dis. angle refer to Displacement angle.

### 3.5 Energy Dissipation

The energy dissipation of shear wall is generally measured by horizontal force-displacement hysteretic curve area, namely energy dissipation $E$ and equivalent viscous damping coefficient $D_e$. 

$\Delta \theta_p$, ultimate displacement $\Delta u$ (displacement angle $\theta_p$), peak displacement $\Delta p$ (displacement angle $\theta_p$), ultimate displacement $\Delta u$ (displacement angle $\theta_p$) and displacement ductility factor. Peak displacement is the corresponding displacement of wall peak load; the ultimate displacement is the displacement while the wall bearing capacity dropping to 85% of the peak bearing capacity.

It can be seen from Table 5 that: The cracking displacement of XW1 is minimum. And the cracking displacement of YW2 is maximum. The cracking displacement of pre-cast wall is higher than that of cast-in-situ wall since sleeve restrains the vertical deformation of external concrete. The sleeve type III of YW2 is the longest. The reinforcement effect can be high. Therefore, the cracking displacement will be the maximum.

The peak displacement of three shear walls is basically consistent. The ultimate displacement of pre-cast wall is greater than that of cast-in-situ wall. Namely after reaching to the maximum bearing capacity, the deformation capacity of pre-cast-situ wall is greater than that of cast-in-situ wall. Under the sleeves contraction effects to concrete at the compressible zone after concrete crushing, the bearing capacity of shear wall will decrease slowly. The ultimate displacement angle of pre-cast wall (1/41) is greater than that of cast-in-situ wall (1/49). Although the ultimate displacement of precast shear wall is greater, the yield displacement of precast shear wall is much greater compared with the cast-in-situ shear wall. Such phenomenon induced smaller displacement ductility coefficient of precast shear wall.
Fig. 9, 10 are wall energy dissipation and viscous damping coefficient curve. The energy dissipation of the wall is the average value of the two circulations. It can be seen from the figure that: Pre-cast wall $E_c$, $D_c$ at the front of 56mm is basically equivalent to that of cast-in-situ wall. The cast-in-situ wall $E$ after 56mm will increase slowly, while the pre-cast wall $E$ almost presents linear growth; the cast-in-situ wall $D_c$ basically will not increase after the displacement of 56mm. And the pre-cast wall $D_c$ will increase consistently to 72mm. At the later period of loading, the energy dissipation $D_c$ of pre-cast wall is better than that of cast-in-situ wall.

Table 6 indicates the comparison of energy dissipation and equivalent viscous damping coefficient $D_c$ under ultimate bearing capacity of the wall. Under ultimate load, pre-cast wall $E$ is greater than cast-in-situ wall: $E$ of pre-cast wall is 1.41~1.43 times of that of cast-in-situ wall. And $D_c$ is 1.22~1.27 times of cast-in-situ wall. Under the ultimate load of pre-cast shear wall, the energy dissipation is greater than that of cast-in-situ wall. It is related to the increasing of inner reinforcement stirrup and horizontal reinforced bars within the scope of sleeve. Furthermore, due to the constraint of sleeve, the energy dissipation of pre-cast wall will be slightly improved. Consequently, the energy dissipation of pre-cast wall is similar to that of cast-in-situ wall.

### Table 6. Energy dissipation and equivalent viscous damping coefficient under ultimate load of specimen

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Energy dissipation ($E$, kN*mm)</th>
<th>Viscous damping coefficient ($D_c$, $10^{-6}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XW1</td>
<td>18.71</td>
<td>1.00</td>
</tr>
<tr>
<td>YW1</td>
<td>26.47</td>
<td>1.41</td>
</tr>
<tr>
<td>YW2</td>
<td>26.75</td>
<td>1.43</td>
</tr>
</tbody>
</table>

3.6. Strain of the Reinforcement Bar YW1 and YW2

Fig. 11 and 12 show the vertical bar (embedded column) strain hysteresis curve and spine curve comparison chart of YW1 and YW2 on the upper and lower side of sleeve under the horizontal force. When the strain is a positive value, the reinforcement bar is pulled; and when the strain is a negative value, the reinforcement bar is pressed.

![Figure 11. Comparison of the strain hysteresis curve and spine curve of the reinforcement bar on the lower and upper part of YW1 sleeve.](image-url)
It can be seen from the Figure that the hysteresis rule of strain of the reinforcement bar on the upper and lower side of sleeve are basically the same: The hysteresis curve will be full when the reinforcement bar is pressed and it will become narrow when the reinforcement bar is being pulled. It can be seen from the spine curve that the spine curves on the upper reinforcement bar of the sleeve and that on the lower part are basically consistent with each other, which indicates that the upper and lower reinforcement bar strain can be effectively transferred by adopting type I and III sleeve constraint overlapping vertical reinforcement.

Figure 12. Comparison of the strain hysteresis curve and spine curve of the reinforcement bar on the lower and upper part of YW2 sleeve.

Fig. 13 illustrates the YW1 and YW2 hysteresis curve of horizontal force and strain in indirect splicing reinforcement bar and vertically distributed reinforcement at the position 490mm away from the patand top. It can be seen from the Figure that the hysteretic curves on the upper and lower part of sleeve are basically consistent with each other. It is feasible to adopt indirect splicing at the center vertical reinforcement of shear wall.

Figure 13. Hysteresis curve comparison of indirect splicing reinforcement bar and vertically distributed reinforcement

4. CONCLUSION

1) Type I and type III aregrouted sleeve lapping connectors. The inner diameter of sleeve is much higher than that of butt sleeve commonly used. It is convenient to insert the reinforcement bar to sleeve. And the assembly speed of pre-cast wall is quick.

2) The crack of pre-cast wall appears in latency comparatively to that of cast-in-situ wall. It is mainly due to the existence of vertical restraint of concrete on the wall edge of the sleeve and latency of concrete cracking.

3) At ultimate limit state, the concrete crushing of cast-in-situ wall is from both sides of the wall bottom. The concrete at the upper part of sleeve of pre-cast wall will be initially damaged. Subsequently, the concrete protective layer outside the sleeve will drop off.

4) The energy dissipation competence of pre-cast wall is similar to that of cast-in-situ wall. The ultimate bearing capacity of pre-cast wall is consistent with that of cast-in-situ wall. The ultimate displacement angle of pre-cast wall is 1/41 which is greater than that of cast-in-situ wall 1/49. The difference between peak displacement and cast-in-situ wall is not significant.

5) Type I and type III sleeve can perfectly transfer the vertical bar stress of precast concrete shear wall.
References


