Figure 1: Multiscale shear key connection for precast shear wall panels

One of the main concerns in precast shear wall panels is the shear connection between the panel edges and the wall panels. The proposed connection can improve the strength and stiffness of the shear wall due to the high shear transfer capability and the high rigidity of the connection. The proposed connection can also improve the buckling load of the shear wall panels. The experimental setup was developed to study the proposed connection and to test its effectiveness.

RESEARCH SIGNIFICANCE

The multiscale shear key connection was developed to improve the shear connection between the panel edges and the wall panels. The connection was designed to improve the buckling load of the wall panels. The connection was tested experimentally to verify its performance.

SYNOPSIS

Multiscale shear key connection for precast shear wall panels

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Shear Wall Panels

Conclusions for Precast
Fig. 4. Test setup. The horizontal connections were aligned vertically during testing.

Fig. 3. Connection configurations.

Large key (LK) Small key (SK)

PLAIN SURFACE (NS) TAPERED SURFACE (TS)

Two levels of compressive stress, 5 and 10 mm.

Fig. 2. Overall specimen dimensions (five large keys of 8 mm width with two small keys of 5 mm width at both ends).

Fig. 1. Cross section of the tested connection.

EXPERIMENTAL PROGRAM

Connection lengths for each configuration.

Panel thickness: t = 200 mm

Applied preload

Independent torsion system

Post-tensioning system

Dry pack

PRELOAD

Applied shear load

App. 200 mm

1890 mm

2300 mm

p = 20 mm

q = 20 mm

d = 25 mm

h = 100 mm

4 = 10 mm

θ = 7.8°

θ = 22°
Fig. 5. Typical load-slip behavior of multiple shear key connections.

Test Results

Table 1. Test Specimen Details

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Shear Key</th>
<th>Connector</th>
<th>Test Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen A</td>
<td>Shear Key 1</td>
<td>Connector 1</td>
<td>Test Configuration 1</td>
</tr>
<tr>
<td>Specimen B</td>
<td>Shear Key 2</td>
<td>Connector 2</td>
<td>Test Configuration 2</td>
</tr>
<tr>
<td>Specimen C</td>
<td>Shear Key 3</td>
<td>Connector 3</td>
<td>Test Configuration 3</td>
</tr>
</tbody>
</table>

Note: Test was performed under a constant load of 10kN.
The above results show that the shear resistance of the connection was increased from 4 to 7 when the level of stress normal to the connection was increased from 4 to 9 MPa (60 psi) normal to the connection. The maximum shear capacity of the key was reached at 9 MPa (130 psi) normal to the connection. The maximum shear capacity of the key was also shown in Fig. 7 when the level of stress normal to the connection was increased from 4 to 9 MPa (60 psi) normal to the connection. A comparison of the behavior of the connection was also observed in Fig. 8 when the shear key configuration was varied from 5 to 15 kN. The shear key configuration was varied from 5 to 15 kN.
The connection shear stress may be estimated as the difference between the ductile shear keys' shear friction coefficient and the cross-section area of the ductile shear key. The cross-section area of the ductile shear key is the area of the ductile cross-section when the fracture shear force is the total cross-section area of the ductile shear key. The cross-section area of the ductile shear key is defined as the product of the thickness of the ductile shear key and the total cross-section area of the ductile shear key. The ratio of the thickness of the ductile shear key to the total cross-section area of the ductile shear key is called the shear key efficiency.

\[ A = \frac{f}{\gamma + f + f} \]

where:
- \( f \) is the friction coefficient
- \( \gamma \) is the shear friction of the ductile shear key

\[ \Delta = A \times B \]

where:
- \( \Delta \) is the connection shear stress
- \( B \) is the cross-section area of the ductile shear key

**Effect of shear keys on the formation of the connection shear stress:**
- The shear stress in the ductile shear key is not affected by the formation of the connection shear stress.
- The shear stress in the ductile shear key is equal to the shear stress in the ductile shear key when the connection shear stress is equal to the shear stress in the ductile shear key.
- The shear stress in the ductile shear key is equal to the shear stress in the ductile shear key when the connection shear stress is equal to the shear stress in the ductile shear key.

**Diagram:**
- Diagram (a) shows the thickness of the connection shear stress.
- Diagram (b) shows the shear stress in the ductile shear key.
- Diagram (c) shows the shear stress in the ductile shear key when the connection shear stress is equal to the shear stress in the ductile shear key.
- Diagram (d) shows the shear stress in the ductile shear key when the connection shear stress is equal to the shear stress in the ductile shear key.

**Shear Capacity:**
- The shear capacity of the connection is determined by the shear stress in the ductile shear key.
- The shear capacity of the connection is calculated as:

\[ V = A \times f \]

where:
- \( A \) is the area of the ductile shear key
- \( f \) is the friction coefficient

**Multiple Shear Key Connection:**
- In multiple shear key connections, the shear stress in the ductile shear key is shared among multiple shear keys. The shear stress in each shear key is determined by the relative shear stress in the ductile shear key and the friction coefficient.

\[ \Delta = \frac{A_1}{A} \times f \]

where:
- \( A_1 \) is the area of one shear key
- \( A \) is the total area of the ductile shear key
- \( f \) is the friction coefficient
The connection shear load capacity of the ultimate shear connection was also determined. The shear keys were tested using the following load-carrying capacity equation.

\[
V = V_c + \frac{V_k}{2}
\]

**Fig. 12. Comparison of predicted to measured maximum load**

**Fig. 13. Comparison of predicted to measured ultimate load**

**Table 3. Comparison of test and calculated ultimate shear resistance**

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Predicted</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen A</td>
<td>35,000</td>
<td>33,500</td>
</tr>
<tr>
<td>Specimen B</td>
<td>36,000</td>
<td>35,000</td>
</tr>
<tr>
<td>Specimen C</td>
<td>37,000</td>
<td>36,000</td>
</tr>
</tbody>
</table>

The results show a reasonable agreement between the predicted and measured values, indicating the effectiveness of the connection in transferring shear loads.
REFERENCES

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ACNOWLEDGMENTS

SAMPLE CALCULATIONS
APPENDIX — NOTATION

\[ A_c = \text{cross-sectional area for entire length of connection} \]
\[ A_{ck} = \text{cross-sectional area for portion of connection covered by shear keys} \]
\[ A_{cr} = \text{cross-sectional area of diagonal cracks} \]
\[ A_{cs} = \text{cross-sectional area of diagonal portion of a strut} \]
\[ B = \text{ratio of key area to joint length} \]
\[ b = \text{minimum space between individual panels} \]
\[ d = \text{depth of drypack shear key} \]
\[ E = \text{total force normal to connection} \]
\[ f_{c2} = \text{compressive strength of cracked drypack} \]
\[ f'_c = \text{specified compressive strength of concrete} \]
\[ f'_d = \text{compressive strength of drypack} \]
\[ f_t = \text{tensile strength of drypack} \]
\[ h = \text{height of drypack shear key} \]
\[ L = \text{length of connection} \]
\[ n = \text{number of drypack shear keys} \]
\[ t = \text{thickness of connection} \]
\[ V_b = \text{bearing resistance at drypack shear keys} \]
\[ V_{cr} = \text{cracking shear capacity} \]
\[ V_f = \text{shear friction resistance} \]
\[ V_m = \text{maximum shear capacity} \]
\[ V_{mc} = \text{shear resistance of strut mechanism} \]
\[ V_{mf} = \text{shear friction resistance at maximum load} \]
\[ V_n = \text{nominal shear capacity} \]
\[ \alpha = \text{inclination of diagonal portion of strut to horizontal} \]
\[ \epsilon_1 = \text{maximum tensile strain at cracking} \]
\[ \theta = \text{inclination of shear key to horizontal} \]
\[ \sigma_n = \text{compressive stress normal to connection} \]
\[ \mu = \text{friction coefficient} \]

NOTE: Discussion of this paper is invited. Please submit your comments to PCI Headquarters by December 1, 1989.