Experimental Testing of a Rotational Friction Connection for use in Precast Concrete Panels in Metal Building Systems

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Metal Building Systems with Hard Walls

- MBS commonly used in low-rise non-residential structures
- Optimized design, quick construction, low-cost
- Often include concrete panels or masonry walls (hard walls) to enhance aesthetics
- Connections between the hard walls and metal building frame serve a critical load path
- Failure of brittle connections has been observed during seismic events
2011 Christchurch, NZ
Post EQ Reconnaissance
Stiffness Incompatibility

• Heavy, stiff wall elements connected to light, flexible steel framing

• Connections must sustain forces at the interface

• Forces result from in-plane and out-of-plane inertial effects and compatibility effects at the interface

• Connection strength and ductility are questionable
Rotational Friction Connection: A New Approach

• Bridges the interface between the hard wall and the metal building system frame
• Provides large displacement capacity and minimal damage to surrounding elements
• Energy dissipation geared in the in-plane horizontal direction
• Maintains out-of-plane strength and provides compliance for vertical deformations

Elevation View
Experimental Setup

A concrete wall panel with steel embedded plates was post-tensioned to the strong floor.

Five identical RFCs were connected to the embedded plates.

Horizontal actuator attached to spandrel beam imposes displacement in the in-plane horizontal direction.
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Overhead actuator with steel cables applied out-of-plane force.
Testing Sequence

1. Monotonic Pushover
2. Unidirectional Quasi-static Cyclic Testing
3. Biaxial Testing
4. 100-cycle Testing
Monotonic Pushover

Testing Procedure:
- Imposed an in-plane horizontal displacement of 4.5 inches

Results:
- RFC exhibited elastic-perfectly plastic behavior
- Testing stopped when spandrel beam began bearing into the angles

Monotonic Pushover Curve
Unidirectional Cyclic Testing

Testing Procedure:
- FEMA 461 Protocol I
- Two trial runs per test specimen

Results:
- Loops are Rectangular and Stable
- RFCs experienced drop in bolt tension
- Hardening behavior observed especially in Run 2
- Surface roughening effects more than compensates for loss of bolt tension

Hysteresis Loops for RFC750 Specimen 1
Biaxial Testing

Testing Procedure:
- Applied a constant out-of-plane force
- Two in-plane cycles with amplitude of 2-in.

Results:
- P-Delta effects account for the post-slip stiffness of the connection
- Tensile force results in positive geometric stiffness
- Compressive forces result in negative geometric stiffness

Hysteresis Loop under Biaxial Condition (Tensile)
100-Cycle Testing

**Testing Procedure:**
- 100 constant amplitude cycles
- Followed by 10 cycles at twice the original amplitude

**Results:**
- Hardening behavior clearly present
- Loss of bolt tension more than compensated for through roughening of contact surface

![Hysteresis for 100-Cycle High Displacement](image)
Conclusions

- RFC is a **viable prototype** that resolves the compatibility issues between concrete hard walls and metal building systems while providing a ductile fuse element in the longitudinal direction of the building.

- RFC has **stable energy dissipating capabilities** and **would not require component replacement** or adjustments following a seismic event.

- The hysteresis loops were **rectangular** and **stable** for first trial run.

- **Hardening behavior** was observed during the second run and 100-cycle tests.

- The only damage to the connection was the wearing of the contact surfaces. There was **no observable damage to surrounding elements**.

- Biaxial testing confirmed that **P-Delta effects are significant** and cannot be ignored.

- Testing results proved that the RFC can undergo **large displacements without losing strength** and **maintain the crucial load path** between the wall panel and the spandrel beam.
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