BOLTED CONNECTIONS IN LARGE PANEL SYSTEM BUILDINGS

Milo Shemie
Descon/Concordia Systems Ltd.
Montreal, Quebec,
Canada

Describes the use of mechanical bolted connections to tie together the precast concrete elements of a newly developed structural system for residential multistory buildings. The new system (Descon/Concordia Structural System) was developed under an Operation Breakthrough Research and Development Award, a patent for which has been applied for.

The Descon/Concordia System for residential multistory buildings covers a wide range of assemblies including the structure, mechanical services, kitchens, bathrooms, and weather envelope. The guideline criteria developed early in the design process were that:

1. The structure should be flexible to building shape and height.
2. All precast concrete elements should be flat cast, easily manufactured, and procured.
3. The assembly of the structure should be relatively weather independent.
4. A relatively small skilled site labor should be required.

Structural system

The structure is basically a bearing wall system using prestressed concrete floor panels which span freely between precast concrete wall panels. Large panels (up to 10 ft 8 in. wide floor panels and 40 ft long wall panels) are

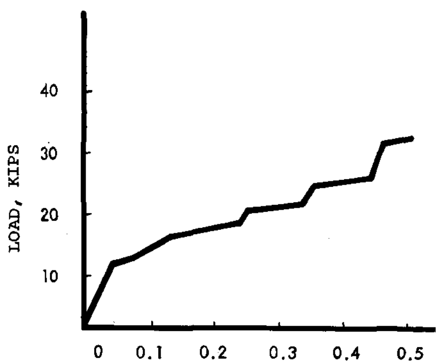


Fig. 1. Diaphragm shear test/ungrouted (¾ in. diameter A 325 friction bolted connection across slotted holes)

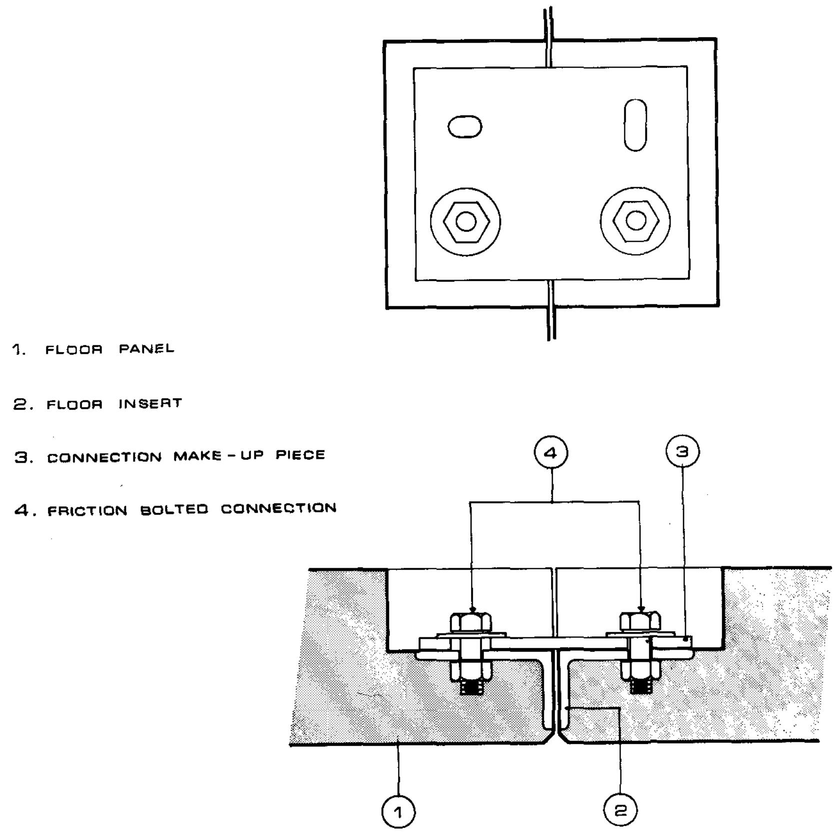


Fig. 2. Floor-to-floor connection

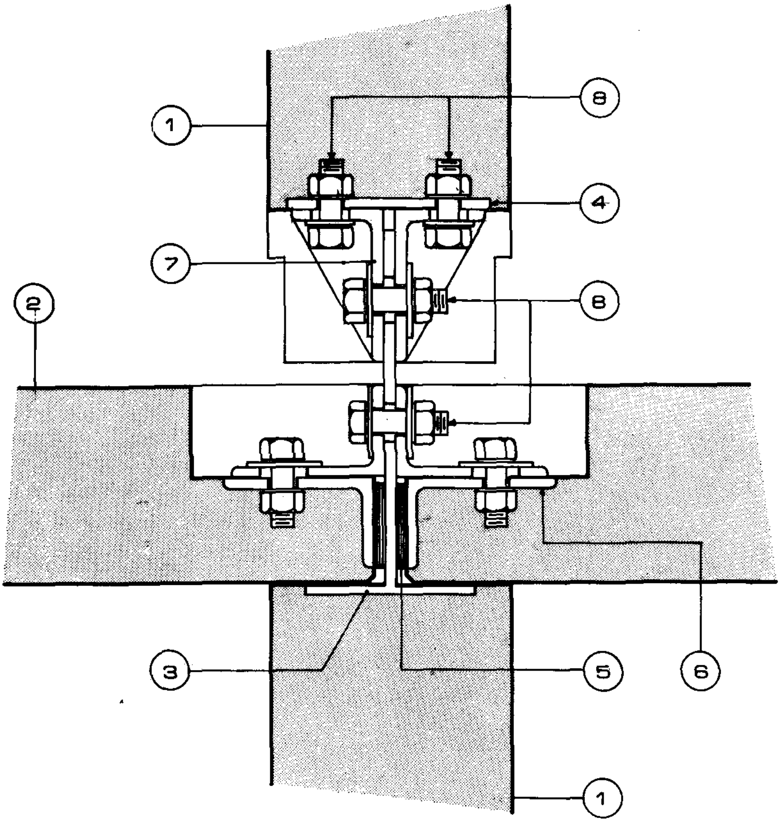
used to minimize the number of crane lifts and connections.

The various elements are interconnected by mechanical joints, and are friction bolted together on the site to provide permanent connections. The finite number of connections are designed to transform the floors and walls into semicontinuous horizontal diaphragms and vertical cantilevers, capable of resisting wind, earthquake, and local explosion loading.[1,2]

Connections are generally composed of steel inserts embedded in the concrete panel. These are held in place by stud-welded anchor bars which are used to develop the required strength by friction-shear.[3] During erection when two such inserts are placed adjacent to each other, a third element (a steel makeup piece) is friction bolted onto the embedded inserts, thus completing the connection. The makeup pieces are preslotted[4] to take up manufacturing and erection tolerances.

Earthquake response

The behavior of a friction bolted connection across slotted holes is similar to the plastic behavior of ductile mate-



1. BEARING WALL PANEL

2. FLOOR PANEL

3. WALL INSERT - TOP

4. WALL INSERT - BOTTOM

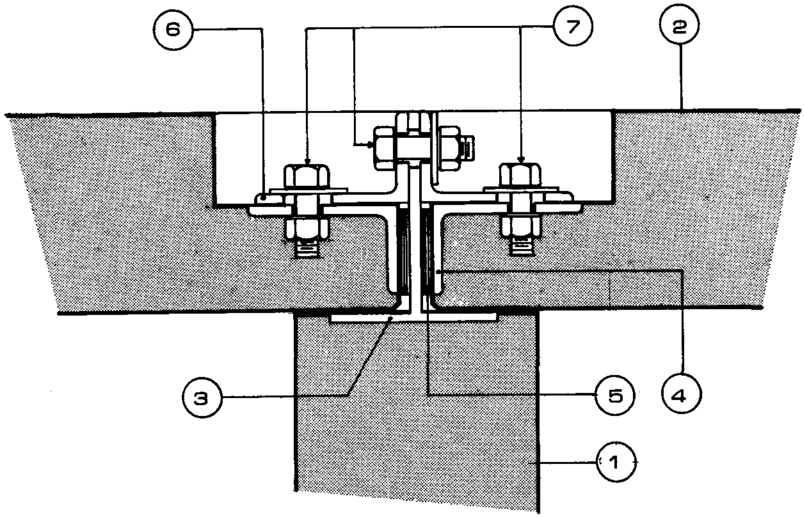
5. METAL SHIMS

6. FLOOR INSERT

7. CONNECTION MAKE-UP PIECES

8. FRICTION BOLTED CONNECTION

Fig. 3. Wall-to-wall connection



1. WALL PANEL

2. FLOOR PANEL

3. WALL INSERT

4. FLOOR INSERT

5. METAL SHIMS

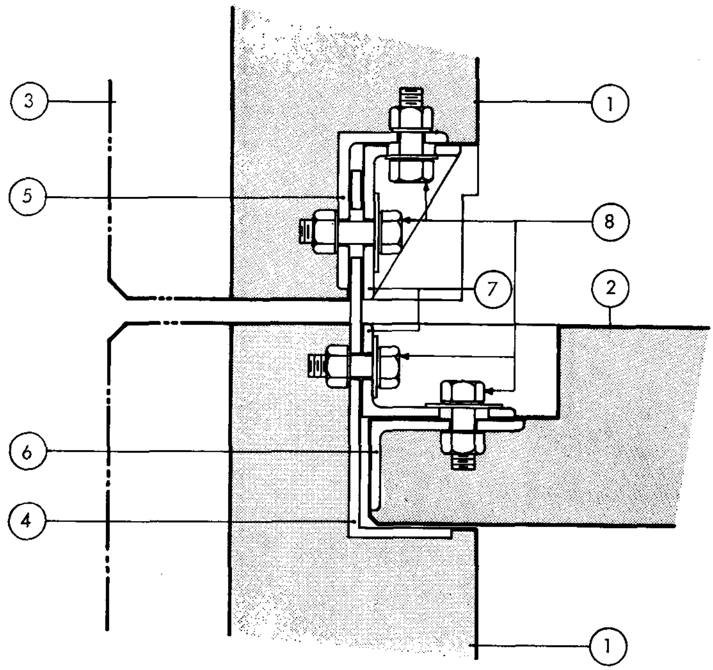
6. CONNECTION MAKE-UP PIECES

7. FRICTION BOLTED CONNECTIONS

Fig. 4. Wall-to-floor connection

rials. Thus, the connection is suitable for building response to a seismic input.

Tests made beyond the ultimate slip load indicate that the newly developed, friction bolted joints (see Fig. 1) have a capacity for energy absorption when a connection slips. These tests were made at the National Bureau of Standards in Gaithersburg, Maryland. The results of the tests show that the capacity of the connection is not impaired. In fact, when the connection eventually transforms into a bearing connection, its capacity is increased and it remains ductile. Not enough tests are made yet to study the behavior of a connection on reversal of load beyond the slip capac-



1. Exterior bearing wall panel
2. Floor panel
3. Cladding
4. Wall top insert
5. Wall bottom insert
6. Floor insert
7. Connection make-up pieces
8. Friction bolted connections

Fig. 5. Exterior wall-to-floor-to-wall connection

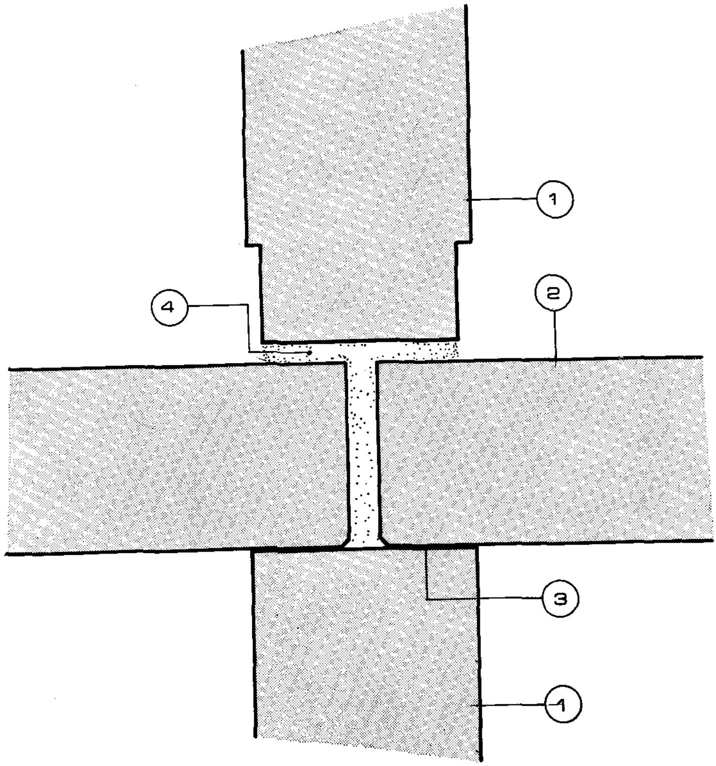
ity, or on the nature of joint degradation after several cycles of slip. However, it appears likely that discrete movements in such a joint would exhibit similar charactersitics of ductility to metals in their plastic range.

Connections

There are two basic connections used from which several variations are developed to suit different conditions:

1. The floor-to-floor connection, and
2. The floor-to-wall connection

The floor-to-floor connection (Fig. 2) is used at the free interfacing edges of floor panels. Its two principal functions are to provide an in-plane shear connection and to level the two adjacent



1. BEARING WALL PANEL
2. FLOOR PANEL
3. NEOPRENE STRIP
4. DRY PACK

Fig. 6. Bearing wall joint

floor panels. The slip capacity of each connection is 20 kips for four ¾ in. diamter A 325 bolts. A minimum of two connections or as many as required by earthquake analysis are provided at each free edge of a floor panel. Since the connection makeup plate is very stiff relative to its short span, the two floor panels are brought level with each other on torquing the bolts. Access to the connection is from the top and is relatively simple.

The floor-to-wall connection (Fig. 3) is used at the joint between interior wall panels and the adjacent floor panels. Its principal function is to provide shear and direct force capacities in the planes of the floor and wall panels. As the floor panels are installed, metal shims are driven to close the indeterminate tolerance gap between the wall insert and the floor panels. Angle makeup pieces are bolted on as shown before the next wall is installed. The next wall is subsequently supported on cement-asbestos shims, which is then bolted to the connection assembly. The wall uplift and in-plane shear capacity at slip is 40 kips for four ¾ in. diameter A 325 bolts, the source of which is earthquake shear and overturning. For explosion loads, a 5 psi ultimate pressure level is assumed to act over a maximum width of 18 ft.[5] The wall is held in place by direct pressure across the shims or by the bolted floor connection. A minimum of two such connections is used for each wall panel or as many as required by analysis.

The connections shown on Figs. 4 and 5 are variations of the above, wherever required. They use the same erection process and achieve substantially the same results.

Erection

As can be seen from the above, the connections are reasonably fast and repetitive. The level of skill required to achieve a connection is similar to that required from an erection crew handling, guiding and placing the precast panels. Dry pack is required in the bearing joints (Fig. 6) for completion of the erection process. This is made into a separate process independent of crane time with an optional delay of three floors to offset bad weather conditions.

Two prototype projects in St. Louis, Missouri, and Jersey City, New Jersey, are near completion. The projects include six buildings of which two are 11 levels high. (The precast manufacturers are Nelsen Concrete Products, Centralia, Illinois, and Eastern Schokbeton, Bound Brook, New Jersey).

From the prototype experience, it can be concluded that the onus of tolerances is much better on the makeup plates or angles than on the precast elements themselves. Makeup pieces are easy to handle, rework or to reject and replace. It is an awesome decision to reject a 40 ft wall panel and wait for another one because of bad fit.

Conclusion

A system of mechanical bolted connections for large panel construction is presented which optimizes the erection process and transforms it into a time-predictable cycle. Manufacturing requires an industrialized process and a high degree of quality control. The system is flexible and adaptable to building shape. Additionally, it has characteristics of ductility in its response to earthquake loads.

References

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Discussion of this article is invited.
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