Lateral Drift Accommodation in Exteriors Wall Systems

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Abstract

This paper addresses the current practices for accommodating lateral building drift of nonstructural exterior systems. There are several methods of framing to accommodate the in-plane and out-of-plane lateral drift. Each framing system has its own advantages, limitations and compatibility with various building structures. Engineering judgment should be used in selecting the best framing system. Current practices to accommodate lateral drift of non-bearing light gauge stud exterior systems cannot fully isolate the exterior system to receive no damage in a seismic or high wind event.

Introduction

The 2003 International Building Code (ASCE -7 9.6.2.4) states that exterior nonstructural wall elements shall have "connections to permit movement in the plane of the panel for story drift" and that the connections "shall be sliding connections using slotted holes, connections that permit movement by bending of steel, or other connections that provide equivalent sliding or ductile capacity." The magnitude of lateral drift that needs to be accommodated is dependant on the type of lateral resisting system of the structure and the wind or seismic loads and varies considerably. For example in a moment frame design under seismic loading, the seismic relative displacement, D_p, can be as large as 2 to 3 inches per floor, whereas in a steel braced frame or concrete shear wall system under the same seismic loading, D_p can be more in the range of 0.5 to 0.75 inches. The exterior non-bearing walls must accommodate this lateral drift in two directions, in-plane and out-of-plane. In-plane lateral drift and out-of-plane lateral drift is accomplished in different ways. Both of these drifts can be achieved with various types of joints, tracks, and slotted clips. However, some of these methods of drift accommodation are incompatible at perpendicular wall intersections.

There are two general approaches to accommodating drift in exterior systems. The first is isolating the exterior system from the building structural lateral drift through sliding connections or bending of steel and the second is designing the exterior system to deform with the structural system without failure to the connections. Three common methods of framing that incorporate the isolation of exterior systems from the structural lateral drift are 1) a floor-to-floor stud system, 2) a spandrel stud system, and 3) a stud bypass system. These systems have pros and cons and each can be the appropriate framing choice depending on the geometry of the structure and the main structure lateral system.

Framing Systems

In the first method, the exterior stud wall is designed to be rigidly attached to one floor and have a joint capable of both vertical and horizontal movement at the floor above (Refer to Figure 1). This joint is typically accomplished with either a slotted slip track (Refer to Figure 3) or a track nested loosely within another slightly wider track (Refer to Figure 4). A gap is left above the studs or inner track, depending on the system used, to allow the floor above to move vertically without loading the studs below. The horizontal movement of this joint is accomplished in the slip track by slotted holes in the web of the track in which the fasteners attached to the deck above can move within. In the nested track within a track joint, the horizontal movement is achieved by the inner track fitting loosely inside of the outer track allowing the inner track to slide along the length of the outer track. Both of these joints allow a section of exterior stud wall to be attached rigidly to the slab below and be independent of the floor above, thus isolating each floor from one another for in-plane movement during a seismic or high wind event (Refer to Figure 5).

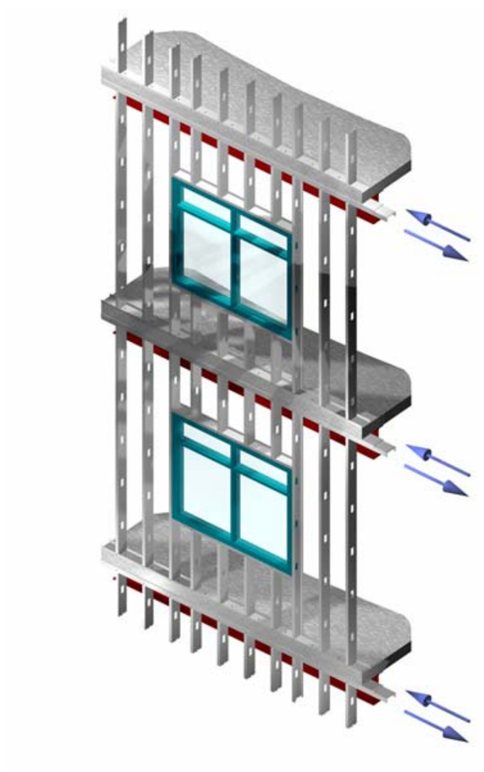

Figure 1: Typical Floor-to-Floor Framing with Joint Below Floor Line

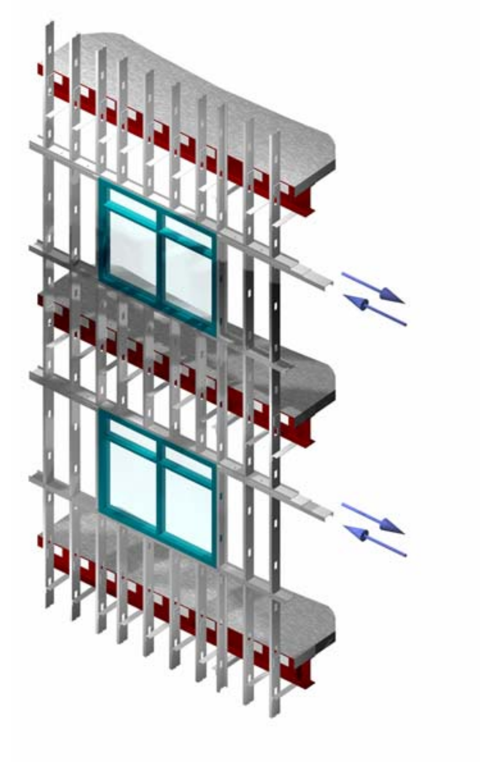

Figure 2: Typical Spandrel System with Joint at Head of Window

The lateral drift accommodation capability of these slip systems is large due the fact that the wall is not directly fastened to the primary structure but is moving loosely within a track system or slot. The rigid connection at the base of the walls must be designed to transfer the inertial force of the wall during a seismic event to the primary structure. For out-of-plane movement during such an event, the wall will rotate in the top and bottom tracks at each level without bending the studs. Since the studs are framed floor to floor, each floor can rotate independent of one another (Refer to Figure 7 left).

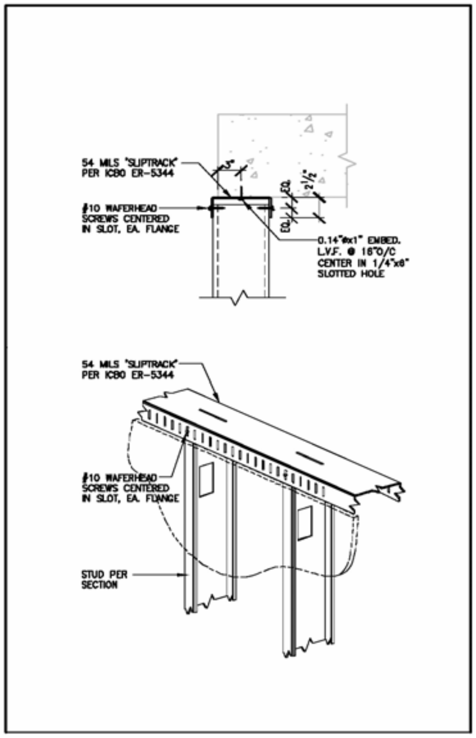

Figure 3: Slotted Slip Track Joint Detail

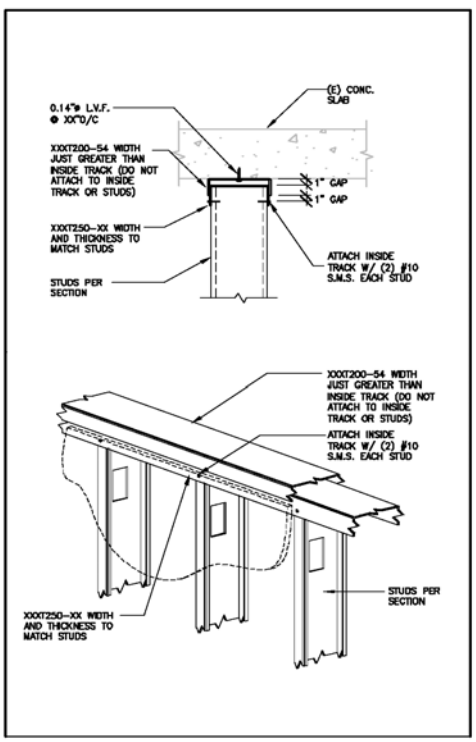

Figure 4: Track Within a Track Joint Detail

In the second method, the spandrel stud system, the exterior studs bypass the floor and attach rigidly to the edge of the floor to form a band around each level. Between these bands are either windows or in-fill studs with a joint capable of vertical and horizontal movement, similar to that discussed in the paragraph above, at the top of the windows or in-fill studs (Refer to Figure 2). This method of framing is commonly used in office buildings where there are long bands of windows that are uniform in height. In this system, the in-plane lateral drift is accommodated through sliding of the joint at the top of the window. Each band of studs will move independent from the band above and below when subjected to lateral drift (Refer to Figure 6).

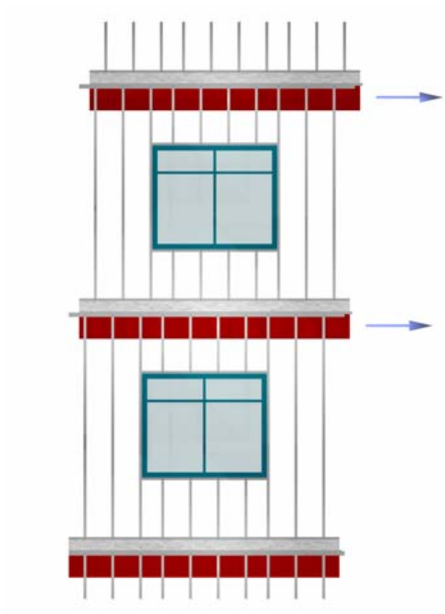

Figure 5: In-Plane Movement of Floor-to-Floor Framing System

Similar to the floor-to-floor system, the spandrel system can accommodate large lateral drifts due to the wall moving loosely within a track system or slot. As with any of these systems the inertial force of the wall during a seismic event must be transferred to the primary structure. The clips attaching the spandrel band to the deck must be designed to transfer this force from the spandrel band as well as the windows or in-fill studs above. Out-of-plane lateral drift is accomplished in a similar way as the floor-to-floor method. The studs rotate in the top and bottom track connections between the spandrels (Refer to Figure 7 right side).

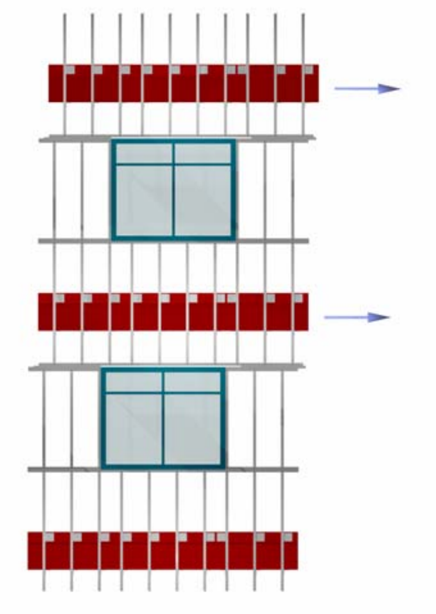

Figure 6: In-Plane Movement of Spandrel Framing System

Figure 7: Out-of-Plane Drift for Floor-to-Floor System (left) and Spandrel System (right)

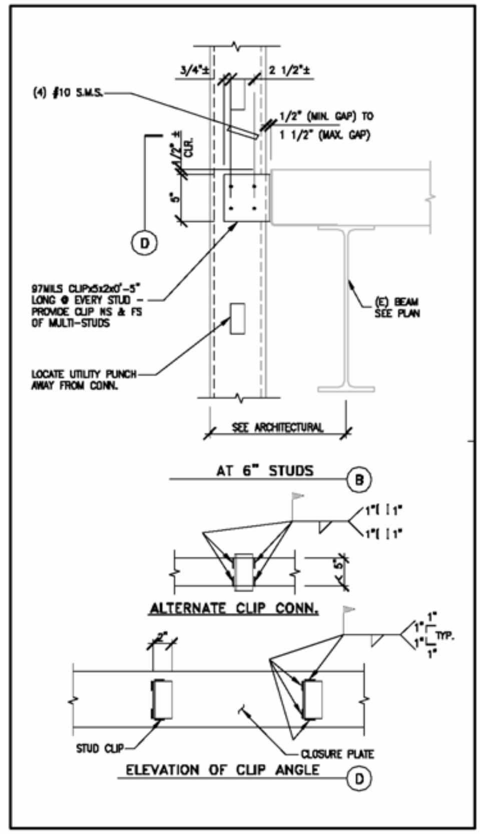

Figure 8: Typical Clip Connection at Deck Edge

In the third method, the stud bypass system, the studs bypass each floor with a rigid clip connection to one floor (Refer to Figure 8) and a vertically and/or horizontally slotted clip connection to the floor(s) above. In this system, the in-plane lateral drift is taken in bending of both the rigid and slotted clips or slipping of the horizontal slotted clips. When the drift is taken by bending of the clips the gap between the back of the stud and the deck edge as well as the ability of the stud to rotate about its weak axis should be evaluated.. The connection of the clip to the deck edge should be strong enough to allow yielding of the clip prior to connection failure. This method of accommodating in-plane lateral drift can be acceptable due to the ductile nature of the clip bending and the repetitive number of clips. The amount of lateral drift accommodated by this type of system can be limited by the deflection capability of the clips and the gap between the studs and the deck edge. This type of system is generally used when the expected lateral drifts are low, as would be the case in a steel braced frame or concrete shear wall structure. For this method, the out-of-plane lateral drift is accomplished by rotating the stud at the clip connections.

In any of the above methods it is important to consider the whole movement path of the isolated framing. Changes in joint heights or inclusion of building frame components into the exterior system may prevent the intended isolation.

The other approach to accommodating drift is to rigidly tie the exterior wall system to the building structure and allow the wall system to rack with the lateral drift of the building. In this method a slip joint is not provided. For this method to be used correctly two conditions must be met. The first is that the connections of the wall system to the structure be capable of safely transferring the force required to deform the exterior wall system to meet the building lateral drift. This will assure that the wall system connections will not fail and thus not create a hazard of falling wall segments. The second is that the wall system itself be capable of racking the required amount without creating a hazard or unacceptable performance.

In general this method of accommodating drift would be well suited to relatively stiff buildings with relatively flexible exterior wall systems. This method would not be particularly well suited for flexible buildings with brittle finishes or any finishes that can result in falling hazards when subjected to lateral racking. Exterior wall systems with stone or brick veneer would not be well suited to this method.

Currently the data available to determine the flexibility and strength of exterior wall finishes is limited. Engineering judgment must be used. The few tests that have been conducted appear to support the conclusion that a significant amount of lateral racking of EIFS and Stucco systems can be accommodated without failure. One reasonable way to estimate the lateral racking strength and stiffness of these systems is to compare them to the many comparable tests performed on timber framed systems with similar finishes. In general the racking stiffness in cold formed steel framed systems is less than a comparable timber framed system due to the lack of fixity in the sheathing fasteners in the light gauge steel.

In light of the currently incomplete data on racking strength and stiffness of the exterior wall systems conservative designs are warranted in using this method. As more data becomes available, this method may grow in use even in buildings with relatively high drift requirements. The performance of exteriors using this system can be compared to the performance of exterior walls that are part of the structural system (bearing wall systems) and can not be divorced from the lateral drift. However, lateral drifts in some building frame systems can be larger than bearing wall systems and may not be directly comparable.

Corner Condition

If the general approach of accommodating drift by isolation of the exterior system is chosen the wall intersections can be incompatible. For in-plane drift, the movement occurs at a discrete joint location either at the bottom of the slab or top of the window. For out-of-plane drift the movement occurs over the height of the wall with rotation at the top and bottom. When these two drift accommodation methods meet at building corners the walls will separate from one another or impact each other (Refer to Figures 9 and 10).

If the drift is accommodated by deforming or racking of the exterior wall system then the building corners would be compatible and concentrated damage at the building corners would not be expected.

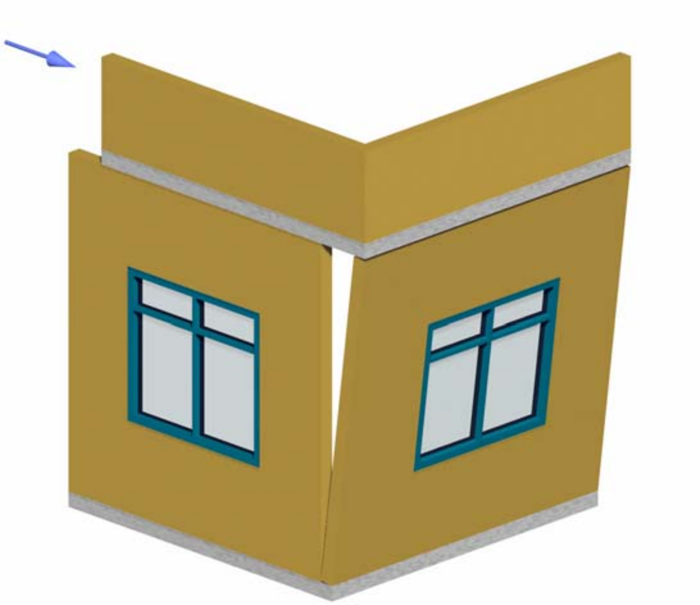

Figure 9: Corner Incompatibility at Floor-to-Floor System

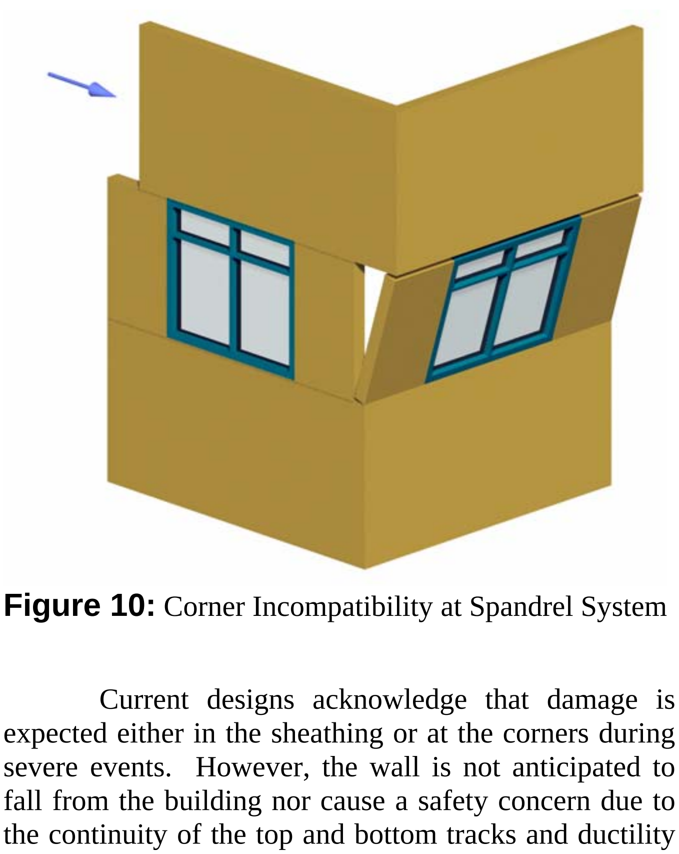

Figure 10: Corner Incompatibility at Spandrel System

Current designs acknowledge that damage is expected either in the sheathing or at the corners during severe events. However, the wall is not anticipated to fall from the building nor cause a safety concern due to the continuity of the top and bottom tracks and ductility of the light gauge framing. This design philosophy is consistent with the stated objectives of national building codes. According to section 101.3 of the 2003 International Building Code, the purpose of the code is to establish the minimum requirements to safeguard the public health, safety, and general welfare… and safety to life and property from fire and other hazards attributed to the built environment and to provide safety to fire fighters and emergency responders during emergency operations.

To limit damage at wall intersections when lateral slip joints are provided in the design, large vertical joints would need to be provided at all wall intersections. The required width of these joints would be the expected seismic relative displacement or maximum expected deflection under wind loading. Depending on the type of structural system and demand on the structure the vertical joints could need to be anywhere from 0.5 to 3 inches wide. Since such vertical joints are generally undesirable, they are rarely specified. Frequently, this corner condition is not considered nor well understood, and expectations of the performance of the exterior wall lateral drift accommodation system may not be realistic. This is especially true in buildings with short lengths of walls and numerous corners. In structures with long lengths of walls and few corners the damage is expected to be limited to a small percentage of the total exterior system, but should the building contain short walls and numerous corners the percentage of damage could be very large. In fact, the damage to the exterior framing by attempting to accommodate lateral drift in the above manners may be larger then if the exterior system was rigidly attached for lateral movement and the studs and sheathing were forced to rack from floor to floor in a seismic or high wind event. In recent years, the industry has been detailing more carefully to accommodate lateral drifts. This increased attention to drift accommodation can result in an unreasonable expectation of expected damage. Current design methods accomplish the task of accommodating lateral drift in a reasonable manner by limiting the expected damage to corners. Complete elimination of damage may not be possible without unacceptable measures. Special care should be taken when designing for drift in structures with numerous wall intersections.

Conclusions

A significant amount of effort is being incorporated into exterior wall designs with the intent of accommodating building drift. Accommodating drift is not synonymous with elimination of non structural damage for all circumstances. Damage can be minimized for service level events. Complete isolation or elimination of damage in a major seismic or high wind event may not be possible without unacceptable measures. The safeguard of public health, safety and general welfare, is achievable through thoughtful design using good engineering judgment.

References

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