Accommodating Building Deflections

What every EOR should know about accommodating deflections in secondary cold-formed steel systems...

Members of the ASCE-SEI Committee on Cold-Formed Steel

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ASCE-SEI Committee on Cold-Formed Steel

As the Engineer of Record (EOR) your responsibilities run far and wide. Your primary concern is the structural frame, so for many, when it comes time to worry about the building's exterior skin, very little detail is provided. Instead, a generic phrase is often included in the contract documents. For example, "Design of curtainwall and metal stud framing shall be the responsibility of the contractor and shall meet the requirements of this Specification and all applicable Building Codes." This division of labor between the EOR and a specialty sub-contractor is common for secondary cold-formed steel wall systems, and has typically been beneficial for both the EOR and the sub-contractor. However, as the primary caretaker of the building, the EOR needs to understand the ramifications of design decisions on both performance and cost with respect to secondary systems.

Indications are that the need for an EOR to understand the ramifications of their design on secondary systems will dramatically increase, not decrease, in the future. Performance-based design is the next generation of design specifications in the United States (SEAOC, 1995, FEMA, 2000). At least two heavyweights lurking in the background are indirectly motivating the movement to performance-based design: government and insurance. The mitigation of extreme events (earthquake, wind, snow) is costly both for the government (e.g., FEMA) and insurance companies. Therefore, in the future, building codes will go beyond simple "life safety" and prescribe different performance objectives for the building: operational, immediate occupancy, life safe, near collapse; under different load (event) scenarios: frequent, design level, maximum/ultimate level. Specifications with this philosophy have already been developed (FEMA 2000), and more will be forthcoming as major research effort is being expended in this direction (e.g., through the NSF funded earthquake research centers). If you think this is just a problem in "Earthquake Country", then you're missing the point. Designing for minor and moderate damage events means that you are no longer designing for the "big one" all the time. The big earthquake, the big wind, and the big snow are still important, but now the more commonly occurring earthquake, wind, snow, etc. are just as important in developing designs.

In some regards, performance-based design is not the sea of change that it first appears to be. After all, successful design of the structural frame already demands that you provide (1) ultimate strength "life safety", and (2) serviceability (control of deflections, vibrations and the like) for "operational" conditions. For minor and moderate events you ensure, with a certain level of confidence, that the structural frame will incur no damage. *Remember our primary point: for a well designed frame, the cost of damage in minor events will occur in secondary framing systems*. In fact, the majority of costs for all but the "big one" are primarily related to the ability, or lack thereof, of the secondary system to accommodate deflections of the structural frame. Adequately specifying and accommodating both lateral and vertical building deformations becomes a key component in the cost vs. risk equation for minor and moderate damage events. Engineers are accustomed to considering the importance of load path in their structure, an excellent concept for understanding strength issues. When deflections govern design a "movement path" for those deflections must be understood and monitored with the same diligence as the load path.

Vertical Building Deflections

Building codes (e.g., UBC) provide guidance on vertical deflections of the primary structural frame. The EOR is also aware of unique vertical deflection issues, including creep in the primary framing material or large stiffness changes in the primary framing between floors. Unfortunately, the awareness of Architects, much less builders, in accommodating these deflections is quite low. For example, a common problem is the simple horizontal control joint. Typically Architects abhor the large horizontal seam introduced into the building's appearance by horizontal joints. Unfortunately, in the common case of a slip track below each floor such that studs start and stop at each floor, the cladding on the wall cannot run continuously across the floors! With the exterior continuity, the load path will follow stiffness and primarily go through the studs which were probably not designed to support significant axial loads. In addition, the movement path is going to be a clear problem for the cladding. Problematic deformation is likely to result from poorly thought out, but commonly occurring, details such as this. Communication on the need to properly accommodate vertical deflection of the primary frame, between the EOR and the Architect at the earliest possible stage, is crucial to successful performance.

Not all details in current practice for CFS systems accommodate vertical deflections. Arguments about "screw movement" to accommodate deflections may be appropriate for small buildings, or where anticipated vertical deflections are small, but are quickly problematic for significant vertical movement. Is it enough for the conscientious EOR to prescribe slip clips to accommodate the vertical deflections? Not in general. Here, communication between the EOR and the cold-formed steel system subcontractor is critical. At a minimum, if the EOR is prescribing slip clips, anticipated floor-to-floor movement should be discussed; however, more importantly, the EOR should be aware that industry-standard "slip clips" do not exist and many of the products are proprietary. (The example detail on page 18 provides additional discussion on "slip" clips.) In this case, the experience of the CFS sub-contractor can help communicate the cost/risk scenario of the possible details: from simple friction-held clips that trap one flange to more robust solutions. The design of the CFS system cannot be isolated from the design of the primary structure, and review of wall sections and details is essential in order to ensure adequate intended movement paths. If, instead, these details are left to the builder, they may either: (1) not be incorporated - leading to a future problem, or (2) a builder may raise the initial estimate due to uncertainty about a potentially problematic connection detail.

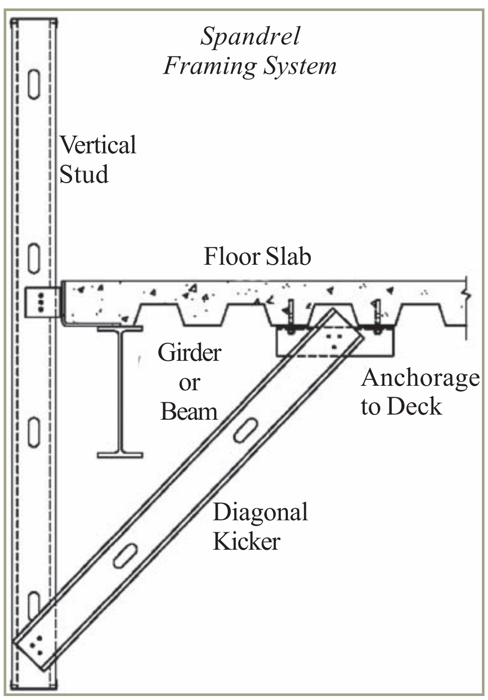
The ASCE-SEI Committee on Cold-Formed Steel is charged to "disseminate and interpret information on the behavior and design of structural steel members, cold-formed to shape from flat materials..." The committee consists of both practitioners and educators. Over the last several years, the focus of the committee's ongoing discussions has been on deflections in cold-formed steel systems. The opinion of the committee is that a variety of issues related to deflections in secondary cold-formed steel systems are poorly understood by key parties involved in building construction. This lack of understanding negatively impacts building performance, as well as initial cost and operating cost. Further, current conditions indicate these issues are growing, rather than lessening, importance. Therefore, the committee set out to provide a brief article of interest to the Engineer of Record (EOR), who may subcontract out secondary cold-formed steel (CFS) systems. The article concentrates on problems, ramifications and hopefully some solutions and guidance when dealing with how CFS systems should be designed to properly accommodate building deflections: both vertical deflections and lateral drifts. The phrase, secondary cold-formed steel system, is used here to describe cold-formed structural members that support exterior finishes, but are not considered part of the primary structural frame. These cold-formed members may support a variety of exterior finishes: metal panels, exterior insulation and finish systems (EIFS), concrete masonry units (CMU), brick etc. The committee's focus is on accommodating the primary building movements, i.e., in-plane lateral and vertical deflections.

Lateral Building Deflections

Problems with vertical deflections are minor compared to those with accommodating lateral building deflections. Here, the disconnect between the involved parties (EOR, CFS subcontractor, Architect, and Builder) is the greatest. Currently, this disconnect is felt most strongly on the West Coast as codes (e.g., UBC 1997) generally require (1) larger drift demands and (2) prescribe the performance of the secondary CFS systems. For example, under extreme events, deflection demands are as high as 2.5% of the story height. Although secondary systems supporting exterior finishes may be damaged, the finish (e.g. masonry) should not fall off the building during the event. As discussed previously, future building codes are likely to put more emphasis on accommodating lateral deflections, not less.

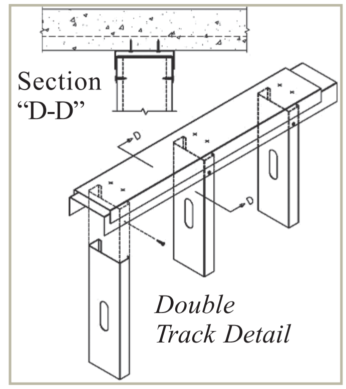
In the rush to get contract documents out to bid, it is likely that the EOR may choose to be relatively vague about the lateral deflection requirements. This situation is likely to result in one of the following: (1) increased operating costs due to a finished building that does not have an adequate movement path, and will thus incur significant damage when even minor lateral deflections are imposed; (2) increased initial cost due to the uncertainty introduced into the bid process, as reflected by bids placed by the Builders; or (3) increased construction costs, added as costly design changes are made during the construction process to accommodate the lateral movements.

Fully accommodating lateral drifts can be a costly endeavor. An EOR should assign building drifts based on the actual building stiffness and an understanding of the cost vs. risk tradeoffs that occur in accommodating lateral deflections in secondary systems. You should be aware that accommodating large lateral deflections in CFS wall systems can add significant costs to traditional systems.



Example Details

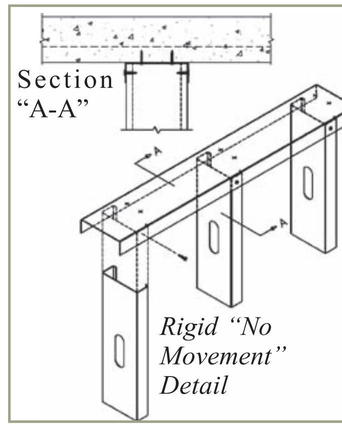
In the on-line version of this article (www.structuremag.org), five details are selected to illustrate our discussion of accommodating vertical and lateral building deflections: rigid detail, slotted "slip" clip detail, slotted track detail, single deflection track detail, and a double deflection track detail. The provided details are not "standard" details, and are not meant to be used as such. The details are for illustrative purposes only. The provided costs are subjective estimates for comparison purposes based on the experience of the members of the committee. Connection costs can vary significantly.



Double Track Detail

All of the details shown are appropriate in certain situations. Standardization of testing and performance of many of these details does not currently exist. It is not the committee's intent to provide an opinion on the definitive detail to use for accommodating deflection. Rather, it is our goal to provide guidance on the cost vs. risk ramifications of a representative sample of the types of connections in current use.

The Committee hopes that the discussion of the details and their estimated costs provides some preliminary means to weigh the cost to risk ramifications for accommodating vertical and lateral deflections in a building. Unfortunately, at this time, the process is by no means fine-tuned nor overly quantitative. Although we may speak of moderate demands or large demands, these numbers are not quantified. As the EOR, it is important to realize that many questions still remain for accommodating vertical and lateral deflections. The answers to these questions influence the decisions that you and your CFS sub-contractor might make.



Rigid "No Movement" Detail

Conclusion

When must vertical deflection be explicitly accounted for? A rigid detail may perform fine, even for a non-load bearing wall, if the difference in stiffness between the secondary and primary systems is large enough that the load path remains in the primary system; but where is the limit to this notion? How stiff must the primary system be? If the demands are small enough that the non-load bearing secondary wall could bear the load, then a rigid detail may be sufficient. Otherwise, it generally seems prudent to provide for vertical movement in all non-load bearing secondary CFS walls.

When are the lateral deformation demands large enough that they must be explicitly addressed? No definitive guidance currently exists. Some rules of thumb may be used, (e.g., 1/16th of an inch), but they certainly are open to debate. However, little is available to replace them at this point. It is clear that 2.5% of the story height is a large lateral demand and must be considered, but what about 0.5%? Should this automatically require an expensive double-track detail such as the one given in the examples? Definitive experimental data does not exist, and both the EOR and the CFS sub-contractor must apply their best judgment in this case.

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In addition to knowing when deformation demands are large enough that movement must be considered, other difficult questions remain: How much racking can a cold-formed system sustain without losing all or part of the finish elements? What is the stiffness of a CFS wall system with different details and finishes? Our lack of knowledge of these systems promotes the concept of disconnecting the primary and secondary systems under moderate and large events if damage is to be minimized. Of course, this is a costly decision and is thus not always provided for.

It is clear that there is much work to be done in developing secondary CFS systems, but good details exist. Conscientious designers who consider load path and movement path for both the primary and secondary systems will find they will be able to insure a better performing and lower cost building, if these considerations are made early in the project and communicated explicitly to the Architect and Builder.

Visit www.structuremag.org for an on-line, full length version of this article, which incorporates additional details, examples and references. Graphics in this article are representative of the many example details included in the on-line version.

Slotted or "Slip Clip" Detail

The following is one of the Example Details included in the on-line article:

Cost*:
$ - $$$ typical cost ratio ~ 1.3, additional cost of slab edge angle brings the total cost ratio for the illustrated system to 2.3. ("Slip" clip systems that accommodate both lateral and vertical deflections also exist, but are not shown here. Costs of such systems vary, but a typical cost ratio would be 1.7 alone, or 2.7 with the slab edge angle included.)

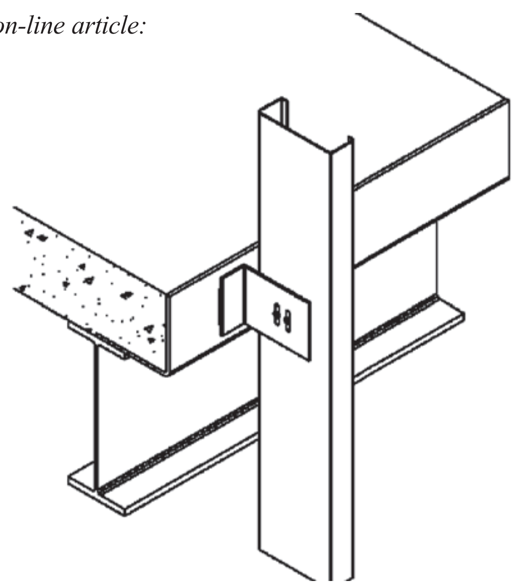
Description:
A special slotted (often proprietary) clip is used to connect the stud to track as shown.

Advantages:
Provides for vertical deformation at clip location; allows for offset of stud and structure (e.g. edge of slab) to provide straight, plumb walls

Disadvantages:
No accommodation of lateral deformations

Load Path/Movement Path:
For vertical deformation the movement in the clip allows the load path to avoid the stud and thus ensure the secondary nature of the CFS system. However, under lateral demands the clip will engage the wall; some slip may occur, but under moderate or large lateral demands the secondary wall system will be in the load path for lateral movement. This potentially changes the lateral stiffness of the primary system and increases the forces in the secondary system.

Comment:
Details of this kind are common, with many different varieties available. Successfully employed, the detail ensures that under gravity loads the wall is "non load bearing" however, under lateral demands the wall system will be engaged in a manner similar to the rigid detail. Adequate performance anticipated when vertical deformation is of primary concern, problematic otherwise.



**Costs can vary particularly widely for this connection detail, therefore contact manufacturers.*