Tolerance

By Greg Schindler, P.E., S.E.

We all could use more tolerance in our lives. Tolerance can have different meanings – tolerance of others' ideas, tolerance of mistakes, tolerance for unanticipated events. It can mean acceptance of the actions or attitudes of other people. In that context, and relating to our business, we should all be tolerant of the actions and decisions of our clients, colleagues and coworkers – up to a point. I think structural engineers are normally very tolerant, some might say too tolerant, of the quirks and vagueness of our architectural friends.

Another, and possibly more important, aspect of tolerance has to do with the ability to accommodate the unexpected. That may mean leaving enough space on the highway so that when the idiot in the next lane cuts you off, it doesn't cause an accident. But it is also making sure that that embedded connection plate is wide enough to still work when the contactor gets it off location by a couple inches. Of course that rarely happens!

If there is one thing that I try to consistently instill in the young engineers I work with, it is the importance of thinking about how their designs will actually be accomplished by the contractor and how tolerant the details are of things not being built in exactly the correct location. It is always an eye opener when young engineers see their work in real life for the first time, and realize how things have to fit in 3D space. And, not only do the pieces have to physically fit, but the sequence or timing of installation of each piece can have a great impact on how they fit, or even if it is possible to be assembled at all. That group of number 11 bars looks a lot more impressive in person than those small dots on the drawing.

It is extremely important that engineers, both the young and the experienced, get out in the field as much as possible. Site visits are indispensible in developing a good sense of how construction actually happens, and how easy it is for structural elements to not be in the place that you intended them to be. This is particularly the case in concrete construction where everything, including forms, rebar and concrete, is assembled in place and not fabricated in the shop. All structural elements have industry accepted position tolerances. When those tolerances combine, they often can result in dimensions or locations being different than planned. This is usually what the Φ factor is for. But, engineers should always be aware of how the allowed tolerances can affect the strength of the element. For instance, a rebar ½-inch out of place makes a larger difference in an 8-inch slab than a 36-inch beam. When designing different structural elements, you should consider the impact of the rebar being at the maximum allowed distance out of place. In most cases you may rely on the Φ factor, and in others you may need to revise the rebar location in your design in order to ensure adequate strength.

Another issue with tolerances in concrete is the real space taken up by rebar versus the single lines and dots that appear on the drawings. Designers should take the time more often to sketch the actual rebar sizes with the correct bends, layering and cover. This can reveal congestion problems before they become field problems.

Steel construction has similar but slightly different tolerance issues. In steel, the fit-up of fabricated pieces is often the main issue. Because connection interfaces of the mating elements are shop fabricated separately and assembled in the field, assembly tolerances must be accounted for in the design. With any connection, the designer should consider which of the three dimensions may require field adjustability in order to allow accuracy in the most important direction. For instance, it may be better to use slotted holes or field welded lap connections in one direction or another to accommodate inaccuracies in fabrication or fit-up.

Structural drawings don't often show actual tolerance indicators, but I believe we should do that more often. One place that such dimensions are sometimes shown is with cladding connections. Cladding elements often have tighter tolerance requirements than general structural construction. Sometimes the mating position of connection faces is indicated with tolerance dimensions such as + ¼ inch, - ½ inch, or + ⅜ inch, - 0 inches, for instance. It may be appropriate to include such dimensional tolerance information on other structural connections as well.

In general, we all should just be more conscious of the fact that, for many of reasons, things often are not built exactly as we planned. Sometimes this can be avoided by more information on the documents. Sometimes it just takes better communication with the contractor. But, most often, it just happens and we need to tolerate the need for real world tolerances.▪

Your Turn Do you have any great examples of how things didn't fit in the field, either due to inaccurate construction or inadequate attention to tolerance in design? Do you have any thoughts on good ways to convey to young engineers the importance of thinking about construction tolerances? How do we teach the "real world" versus the "design world"? Please submit you responses and see what others have to say by clicking on the "Your Turn" button at **www.structuremag.org**.

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