STEEL INDUSTRY GUIDANCE NOTES

Tolerances in structural steelwork

This note explains the importance of tolerances in structural steelwork – what they cover, and when designers should think carefully about providing means of adjustment. Strictly, "tolerances" are permitted deviations – allowances from perfection. Tolerances are specified in documents such as the National Structural Steelwork Specification (NSSS).

Tolerances

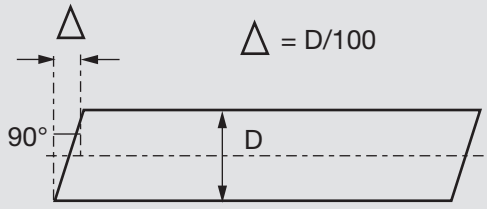
Tolerances in the NSSS represent the accuracy which is generally appropriate for normal structures. Whilst more onerous tolerances may be specified, this should only be undertaken with caution. Compliance with onerous tolerances will be more expensive, and in some circumstances practically impossible to measure or achieve. In general, provision for adjustment between the primary frame and whatever demands more onerous tolerances is a more appropriate approach.

The two types of tolerance in structural steelwork are those after fabrication, and those after erection.

Fabrication tolerances

Issues such as straightness of members, length, position of holes and position of fittings are described as fabrication tolerances. With modern machinery and process control the tolerances specified in Section 7 of the NSSS are all readily achievable. It should be noted that perfection is not needed – for example, bearing surfaces needn't be absolutely square or smooth.

Tolerance on end prepared for bearing



Plan or Elevation

Erection tolerances

Erection tolerances are covered by Section 9 of the NSSS. The most common source of dispute arises from a failure to appreciate that erection tolerances for the frame are generally less onerous than those demanded by such items as lifts, cladding, or glazing. The most appropriate approach is for these interface requirements to be resolved early, and to ensure the connections at the interface allow for adjustment.

Provision for Adjustment

Adjustment may be provided by the connections themselves – some cladding fixings cater for adjustment in three directions. Simple solutions may also be possible, including connections with slotted holes, and bolted brackets that allow packs to be inserted or removed. If such measures are required, the critical points must be identified and highlighted in the project specification. Discussion with specialist sub-contractors is advised.

Survey points

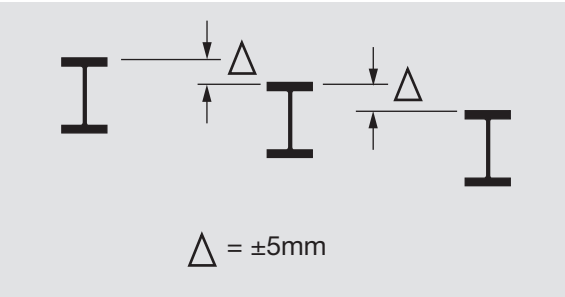
Erection tolerances are generally measured at "node" points – at connections for example, where the level of the beams is specified.

Measuring position at node points is eminently sensible – they are the points where some adjustment may be possible, and are not subject to the unpredictable manifestation of deflection. Deflection is unpredictable – member inertia will differ from that assumed, as will connection stiffness. Between fixed locations, the relative positions of beams and columns are important, so permitted deviations in relative position are given. For beams, the assumption is that beam deflection will be the same, and the relative position of adjacent beams should be controlled. Clearly this principle becomes more challenging if the stiffness of the beam supports change (connections, continuity, column size etc), or the beams have different spans.

Similar provisions are made for the position of adjacent columns on the building perimeter.

BCSA corus

Deviation from relative horizontal levels (measured on centreline of top flange)



Frame Survey

It is most unlikely that the erected frame can be surveyed in a complete, but unloaded state. Usually, as soon as one area is complete, following trades complete the floors, roof and elevations. On large structures, the frame may only be partially constructed before areas are loaded with materials, even whilst erection of the frame continues elsewhere. The frame itself is subject to a changing loading regime, with consequent changes to the deflected form. Early agreement on when the frame is to be surveyed is essential.

Practical limits of surveying accuracy should be borne in mind – combined with the difficulty of measuring a large, three-dimensional frame.

Cumulative tolerances

Erection tolerances must be achieved, whatever deviations are permitted at the fabrication stage. It is not reasonable to suggest that a fabrication tolerance is a reason to exceed the permitted deviations at the erection stage. Similarly, the sum of any individual tolerances cannot exceed that given for the overall structure.

The simple approach to erection tolerances is that they can be cumulative. Thus a base can be out of position, a column can be out of plumb, holes can be out of position and a beam need not be perfectly straight – leading to the possibility of a significant deviation from a theoretical position in space. In practice, it is unusual for all the deviations to conspire to produce the "worst case". A more likely scenario can be calculated by considering the root "sum of squares" value.

Key Points

1. Tolerances in the NSSS are primarily to ensure that design assumptions are not invalidated. In particular, they do not allow for the fixing of other components, which frequently demand more onerous tolerances.
2. More onerous tolerances than the NSSS are possible, but may be expensive and increasingly difficult to achieve. Onerous tolerances should not be specified without careful thought, and preferably in discussion with the specialist sub-contractors.
3. If onerous tolerances are essential, a cost effective approach is to ensure that the connection details at the interface allow for adjustment.
4. Frame deflections are not covered by the tolerances within the NSSS. Deflections are inevitable, are difficult to calculate precisely, and the calculations are unlikely to be mirrored by the real structure. In really critical situations, a clearance for the deflected shape should be allowed for, and secondary fixings should have provision for adjustment.
5. Where deflections or deviations would be highlighted by some visual feature, allow for adjustment.
6. The NSSS should be taken as the default specification.
7. Modern construction programmes often mean that the frame must be surveyed in a partially complete state, possibly with partial loading. Early agreement on when the frame must be surveyed is essential.
8. Permitted deviations are cumulative, but unlikely to always occur in the same direction in practice.

Further sources of Information

1. National Structural Steelwork Specification for Building Construction, 4th Edition. BCSA and SCI Publication No. 203/02, 2002.
2. Commentary on the National Structural Steelwork Specification for Building Construction, 4th Edition. BCSA and SCI Publication No. P 209/03, 2003.
3. Steel Designer's Manual, Blackwell Scientific Publications.
4. Design for Construction, SCI publication No. P 178.

References 1 and 2 are available on www.steelconstruction.org while references 1, 3 and 4 can be found on www.steelbiz.org