



STEEL INDUSTRY
GUIDANCE NOTES

Through-thickness Properties

Although not easily detectable to the eye, rolled steel does not have a homogeneous structure. This is because the process of rolling squeezes the alloy grains in the microstructure such that they overlap by becoming long and thin in the direction of rolling. In most applications the principal stresses and strains imposed on a steel product will be in this beneficial lengthwise direction. Occasionally, however, loads will be imposed in the transverse “through-thickness” or “Z” direction. Then the ability of the grains to adhere to each other is crucial.

The situation when the through-thickness properties of the steel are most likely to be important is in heavily-welded “cruciform” type joints. This is because when welds shrink on cooling the locally imposed strains can reach yield and the parent material must be ductile enough to redistribute these strains. This requires the steel to have an appropriate “Z-quality”.

Z-quality

BS EN 10164 *Steel products with improved deformation properties perpendicular to the surface of the product – Technical delivery conditions* defines three Z-quality classes – Z15, Z25 and Z35. As a through-thickness specimen cut from the steel product is stretched it reduces in area by ductile “necking” before fracture. To meet Z35 quality, three specimens must average at least 35% reduction in area in this test with no individual value below 25%.

The principle reason why a steel product would not meet this requirement is because impurity elements, in particular sulfur, are precipitated along grain boundaries, thus reducing inter-granular adhesion. Also, if steel products are rolled from ingots (as opposed to the continuous casting method used mainly today) “dirty” non-metallic inclusions are more likely and these will provide obvious weakness in the through-thickness direction. Hence, specifying a “clean” steel with low sulfur content is often used as a “proxy” for Z-quality. Having identified adverse welded joint configurations that cannot be avoided, it is generally more practical to ensure that Z35 quality steel is used in the relevant joint component that is subjected to the through-thickness strains from weld shrinkage (the “through” material as opposed to the “incoming” material).

Recommendations in standards

In terms of design and specification, there are provisions in the National Annex for BS EN 1993-1-10 *Eurocode 3: Design of steel structures – Material toughness and through-thickness properties* which in turn invokes PD 6695-1-10 *Recommendations for the design of structures to BS EN 1993-1-10*. The advice in the PD is congruent with that given in Annex F of BS EN 1011-2 *Welding – Recommendations for welding of metallic materials – Arc welding of ferritic steels* informative Annex F *Avoidance of lamellar tearing*.

The focus of these recommendations is the risk of lamellar tearing arising during fabrication (or welding on site obviously). The NA limits the need to take steps to avoid risk to thicker tee (T), cruciform (X) and corner (L) joints. These joint configurations can arise during the design of main members (eg welded box girders and other built-up or compound sections) or the design of complex connections. The “high” risk limits given in the PD for the thickness of the “through” material (t_z) are:

- T (tee) joints with $t_z > 35\text{mm}$;
- X (cruciform) joints with $t_z > 25\text{mm}$;
- L (corner) joints with $t_z > 20\text{mm}$;

Fabrication

The steelwork contractor's welding coordinator has a key role to play in reviewing the configuration of welded joints shown on fabrication and erection drawings to avoid lamellar tearing occurring during fabrication. Assuming suitable Z-quality material has been specified for "through" material in "high" risk joints, there are further steps in

the PD and BS EN 1011-2 Annex F that can be taken to mitigate or avoid risk in other joint configurations that might be "medium" risk. Steps would include possible change of weld details, inspection of "through" parent materials before welding in the local zone to be welded, and inspection of the "through" material in the joint during or after completion of welding.

Key Points

Steel material with enhanced through-thickness properties generally only needs to be specified for thicker tee (T), cruciform (X) and corner (L) joints.

The risk of lamellar tearing arising during fabrication can be avoided or reduced by:

1. Reconsideration of adverse member design configurations (welding details arising from the need to manufacture main members as welded profiles);
2. Review of welding details arising during design detailing of welded joints in connections;
3. Procurement of suitable Z-quality material, in terms of both purchase order and checking of the inspection documents for delivered materials;
4. Inspection of "through" parent materials before welding in the local zone to be welded;
5. Control of the welding processes;
6. Inspection of the "through" material in the joint during or after completion of welding.

Further sources of Information

1. PD 6695-1-10 Recommendations for the design of structures to BS EN 1993-1-10, BSI
2. Steel Buildings, BCSA Publication No. 35/03