STEEL INDUSTRY GUIDANCE NOTES

Fracture Toughness

All materials contain some imperfections. In steel these imperfections take the form of very small cracks. If the steel is insufficiently tough, the 'crack' may propagate rapidly without plastic deformation and result in brittle fracture. The toughness of steel and its ability to resist brittle fracture are dependent on a number of factors that should be considered at the design stage. Some of these factors are described below.

Charpy V-notch test

A convenient measure of toughness is the Charpy V-notch impact test. This test measures the impact energy required to break a small notched specimen at a specified temperature by a single impact blow from a pendulum. In the material standards tests are specified typically to achieve a minimum energy value of 27 Joules at a given temperature. This determines the sub-grade (or "quality") of the steel.

BS 5950 Part 1

Clause 2.4.4 of BS 5950-1: 2000 describes the requirements to avoid brittle fracture by using steel with adequate notch toughness, taking account of:

- The minimum service temperature
- The material thickness
- The steel grade
- The type of detail
- The stress level
- The strain level or strain rate

In the UK the minimum service temperature T_{min} is normally taken to be -5°C for internal steelwork and -15°C for external steelwork. For applications where the steel is exposed to other temperatures T_{min} should be taken as the minimum temperature expected to occur in the steel within the intended design life of the structure.

The steel specification for each component should be such that the thickness t satisfies the equation:

$t \leq Kt_1$

Where

K is a factor that depends on the type of detail, the general stress level, stress concentration effects and strain conditions as tabulated below.

t_1 is the limiting thickness at the appropriate minimum service temperature Tmin for a given steel grade and quality when the factor K=1 as tabulated below for values for steels in common use in the UK.

Who should specify the steel sub-grade

Provided that the frame designer has specified typical connection details, he is in the best position to specify the steel sub-grade and should take responsibility for ensuring the appropriate steel is used. Unless steelwork contractors are designing the structure they will need the sub-grade at tender stage to prepare a quotation. To leave the steelwork contractor to choose the sub-grade is not satisfactory, as for example it may not be clear from the arrangement drawings if the steel is exposed or if it is highly stressed.

Note that changes in the construction details could affect the choice of sub-grade. For example a member may have welded attachments, or only have holes for bolted connections. If a welded fabrication were changed to one only with drilled holes, the K factor would increase, and a less tough steel may be permitted. It would normally be wise to assume that the steelwork is "welded generally", according to the K value table given over the page.

Steel used in internal and external conditions

Specifiers should note that unstiffened thick flanged columns in S 275 could generally have a K value of 3 and sub-grade JR can be used externally for columns with flanges up to 60mm thick. (i.e. all universal columns except the three heaviest 356x406UC in sub-grade JR could be used in such circumstances).

Thin column flanges with welded stiffeners will generally have a K value of 1 which means that most universal columns above 203x203 would then need to be specified as sub-grade J0 and the three heaviest universal columns 356x406 would need to be specified as sub-grade J2 for external use.

For beams where tension and welding are expected, K=1 is the common default assumption and it is possible to say that internally all but a very few members can be sub-grade JR. For external use J0 is required for beam sections above 533UB and column sections above 203UC as a broad generalisation.

K-Factor

Type of detail or location	Components in tension due to factored load Stress ≥ $0.3Y_{nom}$	Components not subject to applied tension
Plain steel	2	4
Drilled holes or reamed holes	1.5	3
Flame cut edges	1	2
Punched holes (un-reamed)	1	2
Welded, generally	1	2
Welded across ends of cover plate	0.5	1
Welded connections to unstiffened flanges	0.5	1

Maximum thickness t_1 for K=1.0

Steel grade and quality to BS EN 10025-2	Maximum thickness t1 (mm) when K=1 according to minimum service temperature	
	Normal temperatures	
	Internal	External
	-5°C	-15°C
S 275 JR	36	20
S 275 J0	65	54
S 275 J2	94	78
S 355 JR	25	14
S 355 J0	46	38
S 355 J2	66	55

Key Points

1. A convenient measure of toughness is the Charpy V-notch impact test
2. BS 5950-1 gives the requirements to avoid brittle fracture.
3. Provided the frame designer has specified typical connection details he is in the best position to specify the steel sub-grade
4. The Steelwork Contractor will need the sub-grade at the tender stage
5. Changes in construction details can affect the choice of sub-grade

Further sources of Information

1. **National Structural Steelwork Specification for Building Construction, 5th Edition, BCSA & SCI publication No. 203/07**
2. **Steel Buildings, BCSA publication No. 35/03**