

PUBLISHED DOCUMENT

Recommendations for the design of structures to BS EN 1993-1-9

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 20, an inside back cover and a back cover.

Foreword

Publishing information

This Published Document is published by BSI and came into effect on 30 May 2008. It was prepared by Subcommittee B/525/10, *Bridges*, in consultation with B/525/31, *Structural use of steel*, under the authority of Technical Committee B/525, *Building and civil engineering structures*. A list of organizations represented on these committees can be obtained on request to their secretary.

Relationship with other publications

This Published Document is a background paper that gives non-contradictory complementary information for use in the UK with part 1-9 of the Eurocode for the design of steel structures, BS EN 1993, and its National Annex.

Presentational conventions

The provisions in this Published Document are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

The word “should” is used to express recommendations of this Published Document. The word “may” is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word “can” is used to express possibility, e.g. a consequence of an action or an event.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a Published Document cannot confer immunity from legal obligations.

1 Scope

This Published Document gives non-contradictory complementary information for use in the UK with BS EN 1993-1-9 and its UK National Annex.

2 Material and execution tolerances and inspection [BS EN 1993-1-9:2005, 1.1(2)]

2.1 General

The safety of structures subjected to fatigue loading is generally more dependent on deviations in materials and workmanship than structures subject only to static loading. This is because fatigue life is very sensitive to local stress raisers such as joint misalignment or out-of-flatness, which cannot be discounted on the grounds of plastic redistribution (as is the case with ULS failure modes such as buckling and rupture). Fatigue life is also particularly sensitive to pre-existing crack-like imperfections close to sites of potential fatigue initiation, as they in effect eliminate much of the early propagation life. For this reason workmanship and inspection requirements for execution are generally made more sensitive as the cyclic stress levels and loading frequency increase.

2.2 Implementation with materials and specification to BS 5400-6

In BS 5400-6, four levels of quality for welds have been specified depending on the magnitude and frequency of the cyclic stresses. For low levels of cyclic stressing which would be acceptable for a curve conforming to BS 5400-10:1980 Class F2 $S-N$ ($\Delta\sigma_c = (60)$ curve (see Table 1), the lowest level is acceptable. This is termed “unspecified” because the areas of the structure which would tolerate a fatigue Class F2 $S-N$ curve or lower (G or W) do not have to be identified. Only if the degree of stressing is such that a higher fatigue $S-N$ curve than F2 is required does the minimum class requirement have to be identified on the drawings at that location in the structure. The method of doing this is by, using a “Fat” reference and an arrow on the drawings to denote the extent affected. The three minimum class requirements higher than “unspecified” are Fat F, Fat E and Fat D.

In order to derive the minimum required Fat class from the relevant $S-N$ curve in BS EN 1993-1-9, which is denoted by the reference fatigue strength $\Delta\sigma_c$, an approximate correlation has been used in the National Annex. This is shown in Table 1.

Table 1 Fatigue class requirement in BS 5400-6 corresponding to minimum required detail category in BS EN 1993-1-9

Minimum class requirement (BS 5400-6:1999)	$\sigma_r - N$ curve (BS 5400-10:1980)	σ_r at $N = 2 \times 10^6$ (BS 5400-10:1980)	$\Delta\sigma_c$ (BS EN 1993-1-9:2005)
		N/mm ²	N/mm ²
Unspecified	F2	60	56
Fat F	F	68	63
Fat E	E	80	80
Fat D	D	91	90

NOTE This correlation is nothing to do with the detail category at that point in the structure. A particular detail may be classified in BS EN 1993-1-9:2005, Table 8 as having a detail category of (say) 80. However, if the fatigue stressing at that point is so moderate that detail category of (say) 36, i.e. $\Delta\sigma_c = 36$ N/mm², would still give an acceptable life, then the minimum class requirements would be “unspecified”.

It is important not to over-specify or under-specify the minimum class requirement. The latter might lead to unsafe structures in later life.

The above principle may be applied to structures other than bridges, where fatigue needs to be considered. Alternatively, ISO 10721-2 may be applied until such time as EN 1090-2 is published as BS EN 1090-2.¹⁾

2.3 Implementation with materials and workmanship specification to BS EN 1090-2¹⁾

The same principles as described in 2.2 should be applied except that the Fat quality designation system is numerical instead of alphabetical and the term “minimum class requirement” is replaced by “quality requirement”. The levels, which are numerically different from some of those in Table 1, are as shown in Table 2.

Table 2 Fatigue class requirement corresponding to minimum required detail category in BS EN 1993-1-9

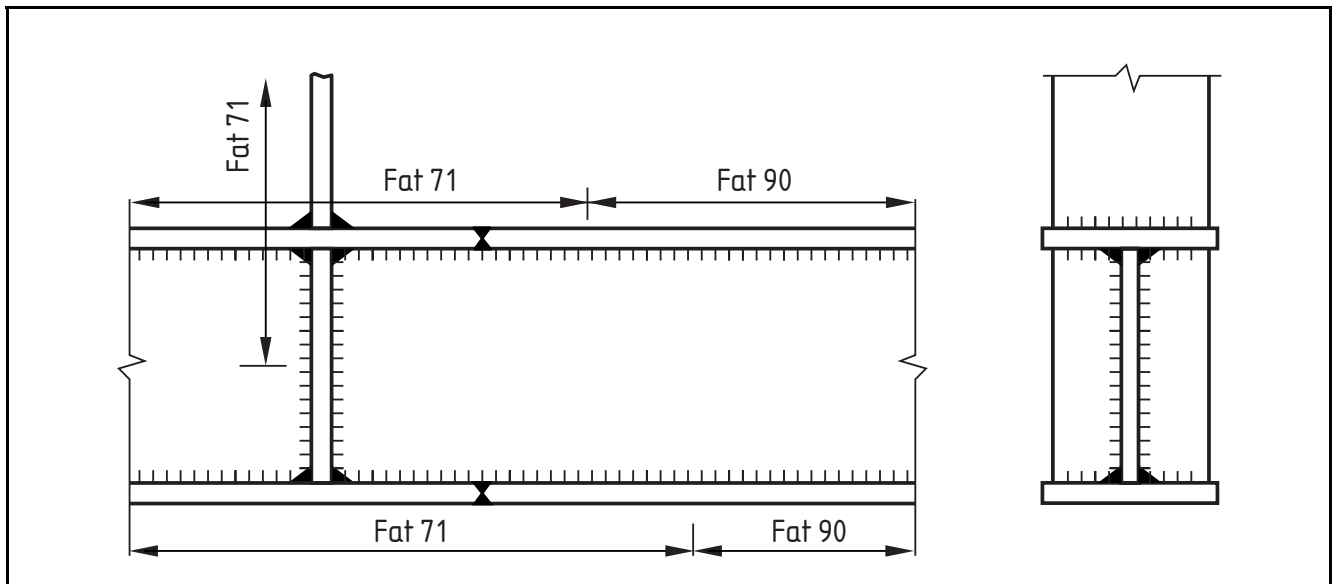
Quality requirement	Required value of reference fatigue strength $\Delta\sigma_c$	Indicate on drawings (see Figure 1)
Fat 56	$\Delta\sigma_c \leq 56$ N/mm ²	No
Fat 71	$56 < \Delta\sigma_c \leq 71$ N/mm ²	Yes
Fat 90	$71 < \Delta\sigma_c \leq 90$ N/mm ²	Yes
Fat 112	$90 < \Delta\sigma_c \leq 112$ N/mm ²	Yes
Fat 140	$112 < \Delta\sigma_c \leq 140$ N/mm ²	Yes

The above quality designations are in alignment with those in ISO 10721-2 and assume that full static stressing will be applied as permitted by BS EN 1993-1-9.

¹⁾ At the time of publication of this part of PD 6695, EN 1090-2 is still in preparation. The equivalent British Standards should be used until BS EN 1090-2 is published.

Fat 56 is the new “unspecified” level. All zones of the structure requiring quality levels above Fat 56 should be indicated on the relevant drawings according to the method shown in Figure 1. The directions of the arrows are parallel to the direction of the relevant stress fluctuation.

Figure 1 **Method of indicating quality requirements higher than Fat 56 on drawings when using BS EN 1090-2 for execution**



2.4 Assurance of quality

Fracture mechanics calculations confirm that when the cyclic stressing is sufficiently high that the minimum class requirement exceeds 80 N/mm^2 or thereabouts, the acceptable sizes of planar fabrication flaws such as cracks or lack of fusion, when orientated normal to stress direction, are generally no more than about 1 mm to 2 mm in height. For higher stress levels the acceptable sizes rapidly reduce to fractions of a millimetre. Such sizes are not detectable by eye, even if surface breaking, and are close to the threshold of reliable detection and evaluation by normal commercial non-destructive testing techniques. They are also of a size which many welding processes operated under normal commercial shop (or site) conditions cannot be relied upon not to leave in the weld. In joints with difficult access (both for welding and NDT) the sizes of flaws which are likely to occur and which might not be detected might be two or three times the above size. This leaves a problem of how the quality required to sustain these high cyclic stress levels in a safe life design can be assured.

The above problem can be overcome by restricting the detail category for certain details to a level where there is an improved probability of attainment of the required quality and a high probability of detection and correct evaluation. This applies not only to certain high category transverse and longitudinal welds, but also to flame cut edges and plain surfaces. The latter can be susceptible to corrosion pitting and very minor accidental damage.

Where safe life design applies and fatigue stressing is very high, and where higher categories have to be used, it is recommended that the special acceptance criteria and methods of fabrication control and inspection are agreed with the relevant experts at the design stage. Alternatively the damage tolerant method might have to be applied.

3 Derivation of specific fatigue loading models [BS EN 1993-1-9:2005, 2(2)]

Loading for fatigue should normally be described in terms of a design load spectrum, which defines a range of intensities of a specific live load event, the method of application, and the number of times that each intensity level is applied during the structure's design life. If two or more independent live load events are likely to occur, the sequence and phasing between them should be specified.

Where no published data for live loading exist, load history data should be obtained from existing structures subjected to similar effects. Alternatively, loading data can be inferred by analysis of the response of continuous strain or deflection measurements over a suitable sampling period. Dynamic magnification effects where loading frequencies are close to one of the natural frequencies of the structure should be taken into account.

In this situation the partial safety factors for fatigue load intensity for safe life design should take into account the degree of confidence in the prediction of the design load spectrum from the available data. Recommended values of γ_{ff} are given in the National Annex to BS EN 1993-1-9.

4 Determining fatigue strengths from tests [BS EN 1993-1-9:2005, 2(4)]

4.1 General

The guidance given in 4.2 to 4.7 is based on BS EN 1999-1-3:2006, Annex C.

4.2 Test specimens

Test specimens should represent the intended application detail as closely as practicable, with regard to material, dimensions, manufacturing procedures and workmanship quality limits allowed by BS EN 1090-2 and BS EN 1993-1-9. These features should be measured using the methods specified in BS EN 1090-2.²⁾

4.3 Testing conditions

The loading mode should represent the most likely loading mode expected to be applied to the detail in the structure.

Any environmental conditions outside the scope of BS EN 1993-1-9 should be simulated.

²⁾ At the time of publication of this part of PD 6695, EN 1090-2 is still in preparation. The equivalent British Standards should be used until BS EN 1090-2 is published, and any other agreed alternative methods should be specified for the individual projects.