

# AD 352

## Fatigue assessment of crane supporting structures to Eurocode 3

This Advisory Desk note offers advice on fatigue assessment of crane girders (described in the *Eurocodes* as “runway beams”) and other crane supporting structures, in particular on the purpose of paragraph (2) of clause 9.1 of BS EN 1993-6 (*Eurocode 3 – Design of steel structures – Crane supporting structures*) and how it should be interpreted.

Clause 9.1(2) states: “Fatigue assessment need not be carried out for crane supporting structures if the number of cycles at more than 50% of full payload does not exceed  $C_o$ .” The UK National Annex confirms that  $C_o$  should be taken as  $10^4$ .

The purpose of 9.1(2) of BS EN 1993-6 is to provide a simple preliminary check to see whether a detailed fatigue assessment is necessary. It was intended to avoid detailed calculations when the total number of operating cycles over the design life is modest. To achieve a simple rule it is necessary to make assumptions about the load spectrum, the design for strength at ULS (STR limit state) and the class of fatigue detail.

The first problem arises because of the use of the term “full payload” in clause 9.1(2). What is meant is the maximum value of the lifted load; it does not mean the crane capacity. It has mistakenly been suggested that if the crane capacity (“Safe Working Load”) were double the maximum lifted load, this would avoid the necessity for a fatigue assessment of the crane supporting structure. This is a misinterpretation, leading to an unsafe conclusion.

It has also mistakenly been suggested that if a crane supporting structure were designed for double the actual loads applied by the crane, it need not be checked for fatigue. This is also a misinterpretation, leading to an unsafe conclusion.

The second problem is that there is no statement about the number of cycles at less than “50% of the payload”. Although there was an assumption (in drafting the rule) that the total spectrum, of which the  $10^4$  cycles is part, has a normal (Gaussian) distribution, this is not explicitly mentioned. From the wording of the clause, it might be inferred that the number of cycles at less than 50% could be unlimited, but that would be an incorrect interpretation.

It also appears to have been assumed that the steel grade would not be higher than S275, that the span of the crane girder would be sufficient to avoid two load cycles for each pass of the crane and that the resistance of the supporting structure would be fully utilized under the ULS combination of actions. Taken with a further assumption about the relative magnitudes of

crane self weight and lifted load, these assumptions imply a particular stress level under fatigue loading. Finally it appears to have been assumed that constructional details requiring the use of stress concentration factors will be avoided. None of these assumptions is stated.

It is therefore concluded that the rule, as expressed in clause 9.1(2) of EN 1993-6, is open to misinterpretation and potentially to an unsafe conclusion that a detailed fatigue assessment is not needed. This situation will be taken up with the relevant committees but in the meantime, the following modified version of the rule may be used.

“Fatigue assessment need not be carried out for crane supporting structures if the following criteria are all met:

1. the required steel grade for the structure is not greater than S275;
2. constructional details requiring the use of stress concentration factors are avoided;
3. the load on the structure due to the self weight of the crane does not exceed 70% of that due to the maximum lifted load ;
4. the span of the runway beams (crane girders) is at least 70% more than the crane wheel spacing (centre-to-centre of the first and last wheels in each end carriage);
5. either:
  - a) the crane loading spectrum has a ‘normal’ (Gaussian) distribution, in which not more than 10,000 cycles impose a load exceeding 50% of the maximum load in the spectrum;
  - b) the total number of cycles of loading on the structure, each cycle comprising of one traverse of the loaded crane and one traverse of the unloaded crane, does not exceed 10,000.”

This modified rule is conservative; failure to comply with all five criteria does not necessarily indicate that a particular structure will fail a fatigue assessment, only that a full fatigue assessment should then be made.

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# AD 353

## Execution class for bridge steelwork

With the switch to Eurocodes for the design of bridges, project specifications are now being drawn up based on the use of the execution standard BS EN 1090-2 and the Steel Bridge Group’s Model Project Specification (MPS) document (SCI publication P382). The Advisory Desk has become aware that, in adopting the MPS, specifiers have in some cases chosen to select Execution Class 4 (EXC4) as the ‘default’ for the project, rather than EXC3, as recommended in the MPS. The purpose of this AD Note is to explain the consequence of making that more onerous choice.

BS EN 1090-2 sets out four execution classes, EXC1 to EXC4, EXC4 being the highest class. For the reliability level appropriate to most bridges, EXC3 will ensure the necessary quality of workmanship throughout the structure - in

practice EXC2 might be sufficient for many parts of a bridge but it is easier and safer to adopt the same level of requirements generally, rather than try to differentiate between one part of the structure and another.

The differences in requirements between EXC3 and EXC4 arise in only a few clauses of BS EN 1090-2 but have a significant effect upon certain acceptance criteria and levels of inspection. The most notable changes are: thickness tolerance (5.3.2); quality of cut surfaces (6.4.3); acceptance criteria (7.6); extent of supplementary NDT (Table 24).

In detail the increased requirements are:

Thickness tolerance (5.3.2): The default thickness tolerance for EXC4 is Class B, which is more onerous than the Class A normally used at present for

both highway and railway bridges. Specifying Class B will result in an increase of 0.5 to 0.7 mm in the thickness of most plates and material cost is directly related to the weight of the plates. The increase in self-weight due to positive tolerance should be allowed for, where appropriate (in lightweight structures of thin plated elements).

Quality of cut surfaces (6.4.3) – The cutting processes used in normal production are not capable of producing the 'Range 3' quality of surface required by EXC4. To achieve this quality the cut surface would need to be ground, which would frustrate the efforts that fabricators are making to avoid all manual grinding because of health and safety concerns over tool vibration and eye injury. The additional operation would add to cost. Range 3 quality is not usually assumed when carrying out fatigue assessment of free edges

Acceptance criteria (7.6) – Fabrication shops using mainly manual welding methods will struggle to achieve some of the additional acceptance criteria for level B+, particularly if the design calls for complex joints where access is poor and the welder may be working in an uncomfortable position. The additional requirements of EXC4 are only really achievable if there are simple, relatively straight joints where mechanized processes can be applied or the welder has good access and visibility.

Extent of NDT (12.4.2) – a greater extent of inspection clearly invokes greater time and cost.

The requirements for EXC3 in these clauses correspond to current practice in bridge fabrication, which has offered a quality that has generally been acceptable. Class EXC3 is adequate to ensure that the fatigue reference stress level is for the detail category in the Tables in BS EN 1993-1-9 or, where listed in Table NA.1 in the UK National Annex, the minimum strength level in that Table. Specifying EXC4 would meet the requirements for "special inspection and testing requirements" noted in NA.2.1.2 – for example allowing the detail category to increase from 125 to 140 for free edges – but the increase will rarely have any practical effect for fatigue, as lower category details at or near the specific location will usually govern.

In summary, if the more stringent requirements of EXC4 are specified, the requirements can be met but they are more onerous, will result in increased fabrication cost but will achieve very little benefit.

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