Failure and fatigue life assessment of steel railway bridges with brittle material

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Summary

Some existing steel bridges have been constructed from steels with a toughness that does not fulfil the requirements in modern standards. In such a case, standards for bridges do not provide an alternative assessment route. Yet such bridges may still be fit for purpose. This paper presents an assessment method for structural safety and for the fatigue life of steel bridges constructed from material with low toughness. The method is based on the general fracture mechanics method, but accounts for bridge-specific characteristics. The method is demonstrated on parts of two railway bridges in The Netherlands that were constructed from low toughness steel. Advanced material tests have been undertaken to accurately determine the material toughness. Axle weights of passing trains have been measured and compared to the fatigue load histogram in the applicable standards. Strain gauge measurements have been undertaken to determine the actual stresses due to passing trains and these were compared with the results of finite element calculations of the bridge structures. Partial factors are proposed for the load and resistance side for a fracture mechanics assessment of bridges. The paper demonstrates that, under certain circumstances, even bridges from welded steels with lower shelf fracture toughness may be fit for purpose.

Keywords: Fatigue, Fracture Mechanics, Material toughness, Steel bridge, CTOD, Strain measurements, Dynamic amplification.

1. Introduction

A number of existing steel structures is constructed from material with a material toughness that is lower than the required toughness according to modern standards. Are the other provisions and rules in these standards, such as the unity checks, applicable in such a case? In particular, (how) does low toughness influence the fatigue life and the tolerance to cracks? This paper provides a method to determine the fatigue life and the acceptability of flaws in structures with a low fracture toughness, through the assessment of two steel railway bridges in The Netherlands.

2. Setting the scene

Many modern railway bridges in The Netherlands have channels that support the rails. The rail channel system reduces the contact noise of the bridge and is elaborated in [1], [2]. The channels consist of 20 mm thick formed plates – 30% cold straining – welded to each other and to the rest of the structure. Material S355 MC is typically applied. A typical cross-section of a bridge with rail channels is provided in Fig. 1. In two of these bridges – constructed in 2004 – it appeared after construction that the toughness of the base steel plates used for the rail cannels was significantly lower than the minimum requirement put forward in EN 1993-1-10 [3]. The Charpy impact energy was 6 J at the minimum design temperature of -20ºC, while a minimum value of 40 J is required for quality M. Cold forming and welding are generally expected to further reduce the toughness [4], [5]. The Eurocode system does not provide assessment routes if the toughness requirements are not met.

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