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Mechanical behaviour of hot dip galvanized steel connection under cyclic loading

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Abstract

This short technical note summarizes some recent data from hot dip galvanized steel bolted connections under fatigue loading. In particular the effect of a galvanizing coating on the fatigue strength of S355 structural steel is analyzed in detail showing that the decrease of the fatigue life is very limited if compared with that of uncoated joints and the results are in good agreement with Eurocode detail category, without substantial reductions. The procedure for the preparation of the specimens is systematically described in this note providing a useful tool for engineers involved in similar practical applications. The results are compared with previous data from notched galvanized specimens weakened by a central hole and not treated specimens characterized by the same geometry.

Keywords: galvanized steel, high cycle fatigue, notch effect, stress concentration factor

1. Introduction

Different kinds of structural joints such as welded joints, bolted joints, rivet joints and adhesive joints are widely used in various industries, however, according to specific geometry of these joints, they are commonly considered as the most critical components in structures. (Khoramishad and Razavi 2014; Ayatollahi et al. (in press); Razavi et al.

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2017; Ayatollahi et al. (in press); Esmaeili et al. (in press)). Dealing with structural steel members, bolted connections are one of the most widely used methods for joining. It is advantageous for its versatility and reliability. Among the main advantages of bolted connections over those obtained by welding and riveting the following can be summarised: the economy of the process, the speed and ease of assembly, the reliability of service; the easiness of inspection, the performance under variable applied stresses. It is also worth of mentioning that for bolted connections pre-heating and heat damage to the coating on hot dip galvanized can be avoided as well as weld cracking or induced internal stresses.

Nomenclature

$\Delta\sigma$	Nominal stress range due to tensile loading
$\Delta\sigma_C$	Reference value of the fatigue strength at N_C = 2 million cycles
k	Inverse slope of the fatigue curves
N	Number of loading cycles to failure
R	Nominal load ratio
T_σ	Normal stress-based scatter index (for 10-90% probabilities of survival)
HDG	Hot Dip Galvanized
Ps	Probability of survival

It is well known that the durability of structural components is strongly influenced by the degree of corrosion encountered in service operative conditions and due to the external environment or aggressive factors (Espallargas et al. (2013a), Espallargas et al. (2013b), Espallargas et al. (2015), Haugan et al. (2017)). Deterioration due to corrosion usually leads to the seizure of fasteners and premature failures, in the form of corrosion fatigue. A proper protection of bolted connections is, therefore of paramount importance if the overall integrity of a structure is considered a key point in the design. Hot-dip galvanizing is a surface treatment that allows the protection from corrosion and environmental aggressive agents. It can be successfully used in a large range of applications. Among them steel wires for bridges (Jiang et al. (2009), Yang et al. (2012)), automotive industries (Berchem and Hocking (2006a), Berchem and Hocking (2006b)), steel structures (James (2009)) can be mentioned.

Some authors correlated the fatigue strength to the coating thickness of the zinc layer (Bergengren and Melander (1992)) while other authors did not support any specific correlation of loss in the fatigue properties due to the coating thickness (Nilsson et al. (1989), Browne et al. (1975)). Vogt et al. (2000), by appropriately employing the Kitagawa–Takahashi diagram were able to identify a threshold value of the coating thickness not affecting the fatigue behaviour of unnotched components made of structural steels. Dealing with hot dip galvanized structural components it is worth of mentioning a recent contribution by the same authors (Berto et al. (2016)). The only preliminary study carried out on hot dip galvanized bolted connections was published by Huhn and Valtinat in a conference held in 2004. The available data on this topic are the very few and the present technical note is aimed to partially fill this gap of the recent and past literature providing also a clear explanation for the preparation and final assembly of the specimens. The paper is structured in the following way: in section 2 the geometry of specimens is briefly described, in section 3 the procedure for fabrication and assembly of the specimens is clearly provided and in section 4 the new fatigue data are summarized and compared with those taken from the standard in force for the same detail category. Finally a comparison between the present data and some recent data by the same authors from notched galvanized specimens weakened by a central hole is carried out.

2. Material and geometry of the specimens

The test specimens, made of S355 structural steel, for the bolted connection are shown in Fig. 1. Preloaded M12 bolts of class 10.9, system HR, were used in drilled holes. Hot dip galvanized coatings of fasteners according to UNI EN ISO 10684. The dimensions of the test samples were designed primarily to produce a net section fatigue failure of the middle main plate, and not in the bolts or cover plates (EN 1993-1-8). All the samples were hot-dip galvanized for an immersion time of 14 minutes which is typical in the application. The result was a zinc layer of about 400 µm. This layer is commonly employed in practise in large structures.

Subsequently, the joint surfaces were treated according to a light sandblasting process (sweep blasting). In the