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# A comparison of the fatigue behavior between S355 and S690 steel grades

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ABSTRACT

The use of higher strength steels allows the design of lighter, slenderer and simpler structures. Nevertheless, the increase of the yield strength of the steels does not correspond to a proportional increase of fatigue resistance, which makes the application of high strength steels on structures prone to fatigue, a major concern of the design. This paper presents a comparison of the fatigue behavior between the S355 mild steel and the S690 high strength steel grades, supported by an experimental program of fatigue tests of smooth specimens, performed under strain control, and fatigue crack propagation tests. Besides the cyclic elastoplastic characterization, the fatigue tests of smooth small size specimens allow the assessment of the fatigue crack initiation behavior of the materials. Results show that the S690 steel grade presents a higher resistance to fatigue crack initiation than the S355 steel. However, the resistance to fatigue crack propagation is lower for the S690 steel grade, which justifies an inverse dependence between static strength and fatigue life, for applications where fatigue crack propagation is the governing phenomenon. Consequently, the design of structural details with the S690 steel should avoid sharp notches that significantly reduce the fatigue crack initiation process.


## 1. Introduction

The use of high strength steels allows the design of lighter, slenderer and simpler structures with high structural performance. The economic factors are decisive concerning the choice of the steel for a structural application. In general, the use of high strength steels contributes to weight reduction which compensates the higher cost of the high strength steels [1]. High strength steels are gaining competitiveness with respect to the mild structural steels.

The application of high strength steels on steel bridges is becoming attractive. According to Miki et al. [2] and Jensen and Bloomstine [3], the number of new bridges made of high strength steels is increasing significantly in the last decades. New applications of high strength steels are also being considered, such as windmill tower production [4]. The use of high strength steels allows the construction of taller windmill towers with simple and cost effective joining systems for tower assembling, contributing to the increase of the competitiveness of the wind energy generation.

Despite the important advantages of the increased yield strength provided by the high strength steel grades, the use of these steels faces important challenges. The weldability of the high strength steels is lower than the weldability of mild steels, and decreases with strength increasing [5]. The carbon and alloy element contents are, therefore, limited to ensure weldability. Ductility, toughness and corrosion resistance are also desired characteristics for the high strength steels. A particular group of high strength steels is the high performance steels (HPS) that combine high strength with enhanced ductility, toughness, weldability and improved weathering ability [6].

Fatigue resistance of the high strength and HPS is a major concern, since it is well known that fatigue resistance does not increase proportionally to the static strength of these steels. This is very often the case for welded components [7]. The fatigue resistance of welded joints made of high strength steels may be even lower than for welded joints made of mild steels [2]. Nevertheless, S–N curves proposed in design codes (e.g. Eurocode 3 [8]) do not show dependency on material, which implies significant safety margins. In general, high strength steels and HPS are still less investigated than construction mild steels, leading to a deficient understanding of the fatigue behavior of the high strength steels and HPS. However, this topic has been gaining much interest in the last decade [9,10]. Many fatigue studies are focused on testing structural details rather than investigating the plain material, which limits the extent of the findings to the specific geometries under investigation. The investigation on plain material allows the assessment of the basic fatigue properties of the materials, which are required to model the fatigue behavior of structural components. Particularly, the assessment of the fatigue crack

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