



Fatigue assessment of highway steel bridges in presence of seismic loading

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ABSTRACT

In this study a LEFM (Linear Elastic Fracture Mechanics) approach is used in a probabilistic context to evaluate the fatigue reliability of steel girder highway bridges in the presence of seismic loading. In the first part the fatigue damage is related to the traffic load produced by heavy trucks crossing the bridge; the second part deals with the fatigue damage related to seismic loading. Both damage typologies are analyzed using linear elastic fracture mechanics principles, and the time required for an initial crack propagation is calculated. Taking into account that the correlation between fatigue effects and seismic actions is not usually considered in the literature, this method could enable a better understanding of progressive damage phenomena due to fatigue related problems, and could give some new insights for increasing the remaining fatigue life of a large number of steel bridges in seismic zones.

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1. Introduction

The ASCE Committee on Fatigue and Fracture Reliability [1] reported that 80%–90% of failures in steel structures are related to fatigue and fracture, and this data is confirmed by Byers et al. [2]. Steel girder bridges are very common and are expected to be vulnerable to fatigue and fracture-related problems, as mentioned by Raju et al. [3]. The problem of fatigue assessment [4–7] becomes further complicated if the deteriorated conditions of existing steel need to be considered: defects of superstructures represent the 20.5% of the causes for the replacement of steel highway bridges [8], while each year about 1200 bridges reach the end of their design life [9]. Most of them must be strengthened, repaired or rebuilt to ensure an acceptable level of safety considering present and future traffic conditions. Flaws are expected to be present in steel structures, in terms of defects in welds, notches, dents, etc. Cracks originating from these inherent flaws could propagate under a time-varying random load process and the structural integrity is expected to degrade with time. When a fatigue crack grows to a critical size, the structure fails [10]. These effects could be more significant when a seismic event strikes the structure during its service life. In this context, to authors' best knowledge a correlation between fatigue effects and seismic actions has not been extensively analyzed in the literature: this is a crucial argument in bridge engineering, especially to estimate the precise cumulative effect of the total damage and assess the remaining life of historical infrastructures. Other existing approaches to the problem of lifetime performance prediction, for example in the field

of concrete structures affected by corrosion are shown in [11,12]. Moreover, interesting considerations on safety assessment under multi-hazards can be found in [13].

In this paper, a method for fatigue damage estimation of highway steel bridges in presence of seismic loading is presented. As a matter of fact, fatigue safety generally depends on the following three main parameters:

- the *stress range* due to traffic load (related to the structural behaviour of the bridge);
- the *geometry of the construction details* which leads to a more or less pronounced stress concentration and may trigger or accelerate fatigue crack propagation;
- the *number of stress cycles* due to the past traffic which directly influences the remaining fatigue life of the structure.

A rational procedure for the examination of fatigue safety which proceeds by step levels using both deterministic and probabilistic methods is appropriate in most cases. Probabilistic methods enable the explicit consideration of the scatter of the parameters that influence the fatigue strength and the fatigue damaging effect.

The main objective of this paper is to introduce an innovative method that allows examination of the fatigue safety and determination of the remaining fatigue life based on a step-by-step procedure referring to LEFM (Linear Elastic Fracture Mechanics).

The first part of the work deals with the fatigue analysis using crack propagation law based on LEFM, coupled with a reliability method involving heavy traffic loads; the second part deals with the fatigue damage caused by seismic loading and analyzed with the same LEFM theory. Results are finally discussed in relation to a case study.

The first assumption of this work is that fatigue and seismic hazards are not considered to interact in probabilistic terms, as

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