Shear behaviour of reinforced concrete members without stirrups and subjected to fatigue loads

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Summary

The shear fatigue behaviour of reinforced concrete elements without stirrups is a complex process that involves a large number of variables. Because of its brittle nature, a better understanding of shear fatigue is convenient, so that practical recommendations with mechanical basis can be proposed. Experimental evidence indicates that shear fatigue failure starts with the formation of a diagonal crack from the inclination of a flexural crack in one of the shear spans. This diagonal crack then propagates with load cycles, both upwards to the load application point and downwards to the support. Final shear fatigue failure takes place by the destruction of the compression zone when its depth is too small to resist the compression force acting on it. In addition, it is also possible an unstable propagation of the diagonal crack as soon as it forms. A critical point of the process is therefore the formation of the diagonal crack. In this paper, the capabilities of a predictive model to estimate the number of cycles to diagonal cracking are explored. A comparison is carried out with first experimental results on haunched reinforced concrete beams without stirrups, which are typical of cantilever slabs of bridge decks.

Keywords: Beams; fatigue; reinforced concrete; shear strength; bridge deck slabs.

1. Introduction

Concrete structures may suffer fatigue when they are subjected to cyclic loads. Despite of the fact that typical fatigue failure of reinforced concrete elements is due to the brittle fracture of the longitudinal reinforcement, experimental works have shown that shear fatigue failure is also possible. This failure mode was unexpectedly obtained by the Structural Engineering Group of the Technical University of Madrid (UPM) in a previous experimental campaign [1], which motivated the launching of a specific research project on the topic. Shear fatigue failure is undesirable because of its brittle nature and the interest of a deeper understanding relies on the large number of concrete elements designed without shear reinforcement (for example bridge deck slabs, retaining walls, wind towers or maritime structures). A RILEM report already put in evidence the necessity of studying the shear fatigue behaviour [2].

Previous experimental works carried out in reinforced concrete elements without stirrups have shown that different fatigue failure mode may be developed according to the type, position and magnitude of applied loads, geometry, reinforcement ratio and material properties of tested specimens [1]-[14]. In general, the shear fatigue failure appears as a consequence of the formation and progressive development of a diagonal crack from an existing flexural crack. After diagonal cracking, the crack propagates into the compression zone until failure takes place due to the destruction of the compression zone when its depth is too small to resist the applied force acting on it (failure mode referred to as ‘shear-compression failure’). The propagation of the diagonal crack can also be instantaneous, leading to an even more brittle failure mode (referred to as ‘diagonal-cracking failure’).

According to previous experimental results, a critical point of the shear fatigue process is the formation of a diagonal crack. Therefore, the availability of a predictive tool for diagonal cracking seems very interesting. In this paper, the capabilities of a predictive mechanical model to estimate the number of cycles to diagonal crack are analyzed. Diagonal cracking strength is obtained as a function of the stress state at the tip of a critical flexural crack, from which is supposed to develop

https://doi.org/10.2749/222137814814027602
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