Serviceability of reinforced concrete beams under high-cycle fatigue loading

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Summary

Serviceability requirements of concrete structures often deal with control of crack widths and deflections. It is well known that such variables increase with number of cycles, but the currently available models assume some simplifications to include this cyclic increase. The estimation is usually made by affecting the monotonic response of the element by long term factors. Although this methodology usually yields conservative results, it does not actually account for the realistic cyclic behaviour of reinforced concrete in tension and may be unsafe under the permanent load level. In the paper, the progressive degradation of the bond properties in the tension chord with number of cycles is included in a cycle-dependent model. In addition, the fatigue damage of concrete in the compression zone is accounted for. The paper presents how both degradation mechanisms of the tension and compression zones are coupled. The proposed model allows the estimation of crack widths and deflections of flexurally loaded elements under cyclic loads. The model results are compared in the paper with experiments on cyclically loaded reinforced concrete beams. The study allows understanding the different interaction played by the degradation mechanisms in lightly and heavily reinforced concrete beams.

Keywords: fatigue; serviceability; reinforced concrete beams; cracking; repeated loading.

1. Introduction

Serviceability verifications of concrete structures often deal with control of crack widths and deflections. It is well known that such variables increase with number of cycles, which should be accounted for in structures subjected to repeated loading. Many civil structures are actually subjected to repetitive loads due to traffic, wind or waves. Regarding the serviceability verifications, the consideration of this type of loading in the currently available codes of practice for structural concrete is based on simplified long term factors. These factors mainly take into account the decay of tension stiffening contribution in the long term and they are based on empirical results [1,2]. Moreover, these simplified factors do not consider whether the long term effect is due to sustained or repetitive loads. The realistic cyclic behaviour of the concrete or the bond-slip interaction are not taken into account.

Existing experimental results on reinforced concrete beams tested in the high cycle fatigue domain show that crack widths and deflections increase with the number of cycles [3-5]. The increase is observed under both maximum load and minimum load. The employ of code-based factors to determine the cyclic increase seems overly simplistic and it usually fails to reproduce the cyclic behaviour. This is due to the fact that simplified models do not consider the two main degradation mechanisms developed in reinforced concrete under repeated loading: cyclic damage of the concrete in compression and cyclic reduction of the bond properties at the steel-concrete interface.

In this paper the influence of repeated loading within the high-cycle fatigue domain is studied. First of all, the main effects of repeated loading are highlighted from the experimental evidence obtained

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