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学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　博士（工学）　氏名　鄧 朋儒

学 位 論 文 題 名

Fracture Mechanics Based Fatigue Life Prediction Method for RC Slabs in a Punching Shear Failure Mode

(破壊力学に基づく鉄筋コンクリート床版の押し抜きせん断疲労寿命の予測手法)

In the last few decades, a punching shear failure model emerged as the main failure mode for RC bridge slabs subjected to repetitive moving load, which leads to an intensive study on life prediction of these RC bridge slabs. Considering that the reality load condition is too complicated to study, many studies have been conducted to predict the fatigue life of RC slab under a relatively simple cyclic moving load, because the punching shear failure mode and crack pattern of RC slabs in reality have been reproduced under this load condition in tests. However, most of the exiting life prediction approaches are either empirical equations from fitting experimental data or time-consuming finite element method based numerical methods. Therefore, it is important to develop an efficient fatigue life prediction method which can account for and reflect internal degradation mechanisms.

In this thesis, a theoretical fatigue life prediction method for RC bridge slabs subjected to cyclic moving load is developed based on fracture mechanics. Compared with the existing researches, this theoretical method can not only account for and reflect the internal degradation mechanisms of RC structures under cyclic moving loads, but also save a lot of computing time.

The proposed life prediction method for RC slabs under cyclic moving load is introduced in detail as follows.

Firstly, according to the cracking process of an RC slab under cyclic moving load and the theoretical basis for the existing empirical life prediction equations, the problem of life prediction for the RC slab is simplified into the life prediction of a critical RC beam located in the midspan of the RC slab focusing on the punching shear cracks.

Secondly, since a crack width related concrete bridging degradation was confirmed as a primary degradation mechanism for RC slabs under cyclic moving load, a crack width determination method for RC beams is proposed based on a fracture mechanics based integral equation with a bond slip model.

In the integral equation, weight functions for the crack geometry are required. As the analytical weight functions for the critical beam with punching shear cracks are unavailable, the weight functions are determined from a finite element method based virtual crack extension technique in this study.

And then, accounting for the concrete bridging degradation and the bond slip degradation in the concrete/rebar interface, cracking states of the punching shear crack after every loading cycle are determined following the idea that the effects of sectional actions and reactions are equivalent to each other. With the evolving cracking states, the fatigue failure moment, i.e. fatigue life, is determined following some brittle shear failure modes.

Furthermore, based on the developed method, the fatigue life for several loading levels are calculated and then drawn together with the experimental fatigue life and results from several empirical fatigue life prediction equations in a double-logarithmic scale. The good agreement with fatigue life from other approaches verifies the reliability of this method.

Finally, the stresses of all materials in the entire life range are computed as well, from which a more confident and straight-forward image on the degradation mechanisms that should be included in fatigue analysis is figured out. The degradations of compressed concrete and tensioned rebars are concluded as negligible under service load conditions. As a further step, the sectional forces, moments and crack openings due to different components are calculated. It is found that the compressed concrete and tensioned rebars play dominant roles in resisting sectional rotation and crack opening which is coincident with common believes. However, the contribution from cracked concrete should be included as well for an accurate analysis.

Owing to the advantages of this method compared with existing researches, this method can be applied for many purposes. For example, due to the time-saving characteristic of this method, it is suitable for conducting parametric study on some design parameters, such as slab thickness, concrete modulus and reinforcement ratio, to identify their influences on fatigue life. This information can provide advice for structural design. The effect of environment related material and concrete/rebar interface deteriorations can be analyzed as well. Besides, for the existing RC slabs reinforced with certain measures, this method can also be employed to study the improvement owing to the measure. Obviously, all these researches are very meaningful.