学 位 論 文 内 容 の 要 旨

DISSERTATION ABSTRACT

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Fatigue analysis of RC slabs with plain bars and FRP strengthening based on bridging stress degradation concept

(架橋応力劣化に基づく丸鋼鉄筋床版と FRP 補強効果の疲労解析)

The safety of construction in the long-term performance is the main goal of structural designers. An example is seen in reinforced concrete (RC) bridge deck slabs that have been subjected to a large number of load repetitions. Therefore, many numerical and experimental studies have been conducted to predict the fatigue life of these slabs. Most of these studies focused on the modeling of fatigue behaviors of RC slabs reinforced with deformed bars. Until 1965, plain bars were used for reinforcing RC bridge slabs in a part of Japan. The fatigue damage of those slabs is more significantly observed than that of slabs reinforced with deformed bars. Moreover, old slabs were economically designed by small thickness without considering the fatigue resistance. Until 1965, plain bars were used for reinforcing RC bridge slabs in a part of Japan. The fatigue damage of those slabs is more significantly observed than that of slabs reinforced with deformed bars. Therefore, it is important to predict the fatigue behaviors of these slabs to decide a suitable repairing method.

For the main goal of this research, a numerical method based on the bridging stress degradation concept is presented in this study to simulate the fatigue behaviors of RC slabs reinforced with plain bars under a moving load. Moreover, this study provides a numerical investigation to understand the fatigue failure and the improvement mechanism of fiber reinforced polymer (FRP) strengthening.

Finite element method (FEM) is used to solve a slab model of smeared crack elements. The cracked elements are modified according to the bridging stress degradation concept. This concept can be defined as the reduction of transferred stress across a crack plane under repetitive loading due to crack opening and closing process. Reinforcing bars are modeled as a smeared reinforcement according to its ratio in all directions. For plain reinforcing bars, the bond-slip effect between a reinforcing bar and its surrounding concrete is taken into consideration by adding equivalent bond strain to plain bar strain. To verify the numerical method, this study will be divided to three parts as follows.

In the first part, plain concrete beam is analyzed under static and fixed pulsating load. Moreover, RC beams are analyzed using this numerical method under fixed pulsating and moving load. The numerical method succeeded in describing the propagation of cracked elements for fixed pulsating and moving load. The numerical results are compared with the experimental results to examine the applicability of this method for plain and reinforced concrete beams.

In the second part, three RC slabs reinforced with plain bars are conducted using the proposed numerical method. Moreover, one RC slab reinforced with deformed bars is analyzed to compare with

that reinforced with plain bars. The numerical model is verified using previous experimental data. This model is also able to capture the cracking pattern, change in displacement and rebar strain. The numerical results provide a good agreement with the experimental ones. In this part, a successful explanation of fatigue failure mechanism is existed. The effect of plain reinforcing bars on the fatigue behaviors is described.

In the last, three full scale RC slabs reinforced with plain bars under moving load are analyzed using a proposed numerical method to simulate their fatigue behaviors. two of them were strengthened with externally bonded FRP sheets in longitudinal and transverse directions on slab bottom surface. The interfacial bond behavior between FRP sheet and concrete surface with its degradation due to fatigue loading are integrated to obtain appropriate numerical results. The propagation of cracked elements, center displacement evolution, cracking pattern and FRP strain are presented in this study. According to the results, FRP sheets play an important role to restrict the major crack opening. This leads to a slow degradation, longer fatigue life and smaller deformations for the strengthened RC slab. These numerical results are compared with the experimental results, and this comparison provides a good agreement.