FATIGUE BEHAVIOR OF WELD ROOT CRACK AND STRUCTURAL RESPONSE IN ORTHOTROPIC STEEL DECKS

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https://doi.org/10.15017/1866286

出版情報：九州大学, 2017, 博士（工学）, 課程博士
バージョン：
権利関係：

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論 文 名　：FATIGUE BEHAVIOR OF WELD ROOT CRACK AND STRUCTURAL RESPONSE IN ORTHOTROPIC STEEL DECKS
（鋼床版の溶接ルートき裂の疲労挙動と構造応答）

区　　分　：甲

論　文　内　容　の　要　旨

The orthotropic steel decks have been commonly applied to long-span bridges and expressways because of the structural properties such as low self-weight, high load-carrying capacity and high stiffness. The main components of an orthotropic steel deck including the deck plate, longitudinal stiffeners and transverse crossbeams, these members are connected by welding. In the past decades, severe fatigue cracks have been reported at several welded joints in orthotropic steel bridge decks in Europe and other countries. In Japan, many orthotropic steel bridges were extensively constructed in the 1960s-80s during the period of rapid economic growth. Until now, various types of fatigue damages to the steel decks were reported owing to long-term operation and the changed operating environment including the emergence of heavy-duty vehicles and increasing traffic volume beyond design expectations.

A fatigue crack initiation from the weld root tip is one kind of most common and adverse damage, which usually occurred from the rib-to-deck connection and rib-to-rib butt weld, etc. The rib-to-deck structure includes a large number of single-fillet weld joint, root crack is easy to occur due to the inadequate welding details in conjunction with the residual stress induced by the welding process and unfavorable weld shape. Besides, root crack cannot be observed by visual inspection, which might have severe impacts to bridge safety.

Depending on the randomness of vehicle loading in actual bridge, dispersion of fatigue life, and the indeterminacy of crack propagation. The objective of this research is to direct towards cracks at the welded joints of steel bridge with U-shape ribs. The principal aim is to investigate the fatigue behaviors and crack characteristics of welded joints. The methods used in this research is based on the dynamic experimental simulation and parametric numerical analysis. The dissertation is divided into two main parts: (I) Fatigue crack behavior analysis; (II) Structure response of artificial crack simulation.

In **Chapter 1**, the background and topic review was described, and structure of dissertation was presented.

In **Chapter 2**, the fatigue damage cases and related theoretical foundation was clarified.

The part I focused at certain location of orthotropic steel deck and conducted with crack behavior analysis which taking into account structural parameters and fabrication process. This part including three sub-objectives in Chapter 3, 4, 5.

In **Chapter 3**, the fatigue behaviors of rib-to-deck welded joints were experimentally evaluated according to the most adverse loading position. Typical crack patterns were obtained from fatigue tests by cutting and MPT inspection. The relationship between reference stress condition and crack depth of specimens could be understand, according to six types of structural parameters.

In **Chapter 4**, the cause identification of the crack initiation of this structural detail were clarified by analyze on the fatigue test results. The effect of weld residual stress on root crack initiation were clarified by using a cutting method and thermo-elastic-plastic FE analysis. The fatigue cracking patterns and their influence factors were discussed by comparing the crack sizes and crack angles in the cross section.

In **Chapter 5**, the cracking mechanism and stress responses around root tip were analyzed by establishing the matching FE models, to verify with fatigue tests results. The effect of root gap shapes, weld penetrations, and plate thicknesses on crack initiation were discussed. Besides, various root crack depths were simulated in models to clarify the stress variations occurring during the propagation stage under cyclic loading.

The part II focused on the stress responses in different locations of orthotropic steel deck which including various crack combination, and investigated the structural characteristics and mechanical properties of structure. This part was investigated in chapter 6 and chapter 7.

In **Chapter 6**, to investigate the effect of rib fractures, and the combination of rib crack and rib-to-deck cracks, the field tests results were compared with FEA by simulating the long artificial cracks. The structure responses and stress behaviors were analyzed, the effects of asphalt stiffness and various loading positions were also discussed.

In **Chapter 7**, the FEA on three-span steel deck was conducted to investigate the stress characteristics of structure with artificial crack combinations. By establishing the solid-shell hybrid models, the interaction between rib cracks and other weld details were clarified. Thus not only the local stress around crack position, but also the crossbeam response was evaluated by hot spot stress method.

In **Chapter 8**, it summarized the conclusions of the obtained results for the experimental and numerical studies.