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Applicability and structural response for bearing system replacement in suspension bridge rehabilitation

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ABSTRACT

Suitable maintenance, rehabilitation, and repair methods for long-span bridges should be decided based on their purposes as evaluated by carrying out close inspection and observation. This study deals with a rehabilitation method, its applicability to a long-span bridge with a fatigue crack in the stinger-bearing connection plate. Replacing line type contact bearing systems with pot bearings was proposed as the rehabilitation method to stop fatigue cracking, reduce local stress of the fatigue-cracked connection plates, and improve the structural behaviors of the main suspension bridge members. Thus, a stringer-bearing connection specimen was fabricated; then, gouging and bracket installation were simulated for replacing a deteriorated bearing system with a new bearing system. From the results of the gouging and bracket-installation test, the applicability of the rehabilitation method for change works was verified. In addition, the structural responses of the loading tests were compared with those of a finite element analysis in terms of changes in bearing conditions. The deformations of the stringer and the end-beam improved, and local stress and displacement in the fatigue-cracked connection plate were reduced owing to the bearing system replacement. Therefore, replacement of the bearing system can improve the stress level and stop further fatigue cracking in fatigue-cracked connection plates of suspension bridges. In addition, these results can provide basic information about the rehabilitation method involving replacing the bearing systems of bridges with line type contact bearings.

1. Introduction

Bridge maintenance, rehabilitation, and repair are garnering significant levels of attention owing to the effects of inherent structural deteriorations and environmental stressors based on bridge service periods. Generally, bridge replacements can raise financial, technical, and political problems [1–6]. Therefore, various maintenance and rehabilitation methods have been suggested and applied to deteriorated bridges. Bridge maintenance, rehabilitation, and repair methods can be classified as strengthening methods and replacement methods [9–12]. Strengthening methods can be used for improving bridge load carrying capacity for supporting increased traffic volumes and loads through prestressing and installation of structural members [7,8]. Replacement can be used for refining bridge structural behavior as well as for improving its load carrying capacity by changing damaged and deteriorated members with new members following recently proposed methods that use new materials such as FRP and high-strength materials [3,7]. However, it is not simple to use these maintenance, rehabilitation, and repair methods for real bridges because multiple factors including location, service condition, state of deterioration, and cause of deterioration should be taken into account. Hence, a suitable method is decided based on the purpose of repair and after suitable observation and evaluation of a bridge. Especially, in the case of long-span bridges such as suspension bridges, doing so is more important because of constraints such as difficulty of application, environmental factors, and financial outlay.

Deterioration in the structural performance of a long-span bridge may lead to other structural problems through stress concentration and change in the stress flow direction such as fatigue problems. Furthermore, significant degradation of main structural members can occur due to minor structural problems. Recently, a fatigue crack was found in the stringer-bearing connections of Japan's oldest suspension bridge, which has a service life of 40 years under a 30,000/day traffic volume, as shown in Fig. 1. The crack appeared only in the connection plates of the outermost stringer and bearing, whose structural details are different from those of the inner connections. The crack could have been formed owing to stress level problems resulting from corrosion-related bearing deterioration of the sole plates and line type contact bearings [12]. Thus, suitable rehabilitation and repair are required for stopping the fatigue crack from propagating to the main structural members. Changing the deteriorated structural line type contact bearing system for reducing the stress level in the connection plate and for improving the structural behaviors of bridge members is also considered. Therefore, in this study, the applicability of the proposed rehabilitation method and its

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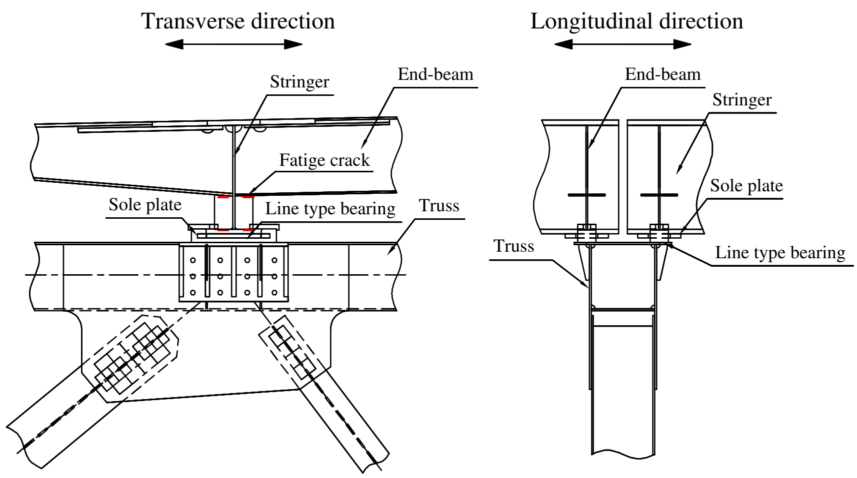
(a) Suspension bridges with 40 years' service periods



(b) Fatigue crack locations

(c) Fatigue crack

Fig. 1. Suspension bridge under rehabilitation and fatigue cracks. (a) Suspension bridges with 40 years' service periods. (b) Fatigue crack locations. (c) Fatigue crack.

effects on the behaviors of structural members were evaluated through bearing change and a loading test on test specimens having the same dimensions. For this purpose, a stringer-bearing connection specimen was fabricated, and a loading test was carried out assuming similar loading conditions, including gouging, by removing the sole plate and the line-contacted bearing and incorporating additional structural members for aiding the installation of the new bearing system. The test results were compared with the results of a nonlinear finite element (FE) analysis that considered the contact behaviors of bearing systems.

2. Rehabilitation concept and test method

2.1. Rehabilitation concept

Bearing system replacement is proposed for reducing the stress on the connection plate and improving the structural behaviors of the fatigue-cracked connection plate that was subjected to the rehabilitation and repair methods, as shown in Fig. 2. It was designed and constructed as a line type contact bearing type with R1500 about 40 years