Structural responses and deck stress distributions of an orthotropic steel deck stiffened with bulb ribs

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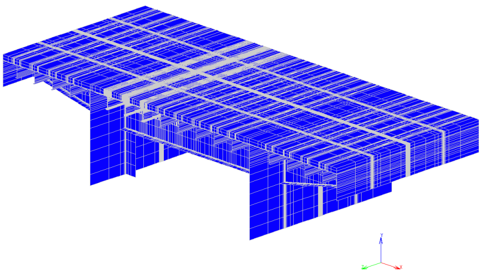
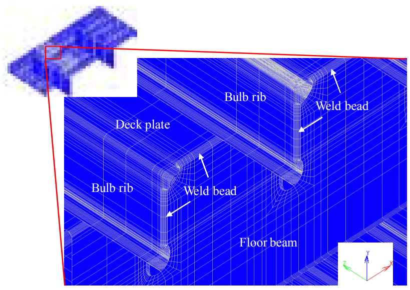
1. Introduction Recently, in an orthotropic steel bridge deck stiffened with bulb ribs, severe corrosion and fatigue cracks were found. It was corroded through approximately 25% of its deck design thickness, even though it had a waterproofing layer to prevent corrosion of the orthotropic deck[1]. In this study, three-dimensional FE analysis models were used to consider the details of the orthotropic steel deck stiffened with bulb ribs. The deck thickness condition and elastic modulus of the asphalt pavement were changed. The deformation behaviors of the orthotropic steel deck stiffened with bulb ribs were examined, including the displacement and rotation angle relationships, in relation to the corrosion damage of the deck plate and the elastic modulus of the asphalt pavement.

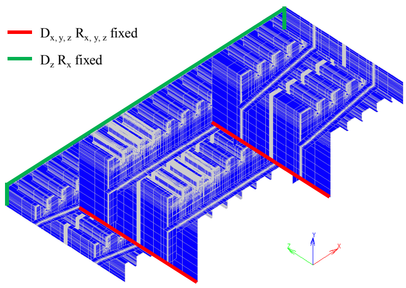
2. FE analysis model of orthotropic bridge deck stiffened with bulb ribs In order to examine the deformation behaviors and stress levels at the prominent locations and corroded surface for fatigue cracks in an orthotropic steel deck stiffened with bulb ribs, a steel box girder model was used for an orthotropic steel deck stiffened with bulb ribs. A finite element analysis model was created to examine and compare the structural behaviors and stress levels at prominent locations and the corroded surfaces of the orthotropic bridge deck with fatigue cracks using the FE analysis program MarcMentat 2012. Figure 1 shows the details of the FE analysis model and its boundary condition. In this FE analysis model, the main deck plate, bulb ribs, and asphalt were modeled using eight-node and six-node solid elements (hex8, penta6). The other deck plate and bulb ribs were modeled using four-node shell elements (quad4) to achieve an analysis model that was closer to the real behaviors of deck plate members. An elastic modulus of 206,000MPa and a Poisson's ratio of 0.3 were used for the material properties of the steel[2].Two kinds of loading conditions were considered in center span(load case I) and connection of the floor beam and the deck plate(load case II).



(a) FE analysis model

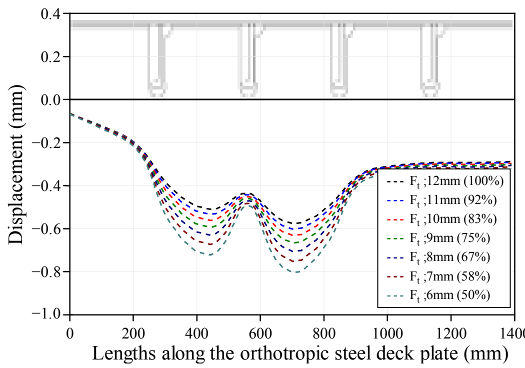


(b) Details of FE analysis model

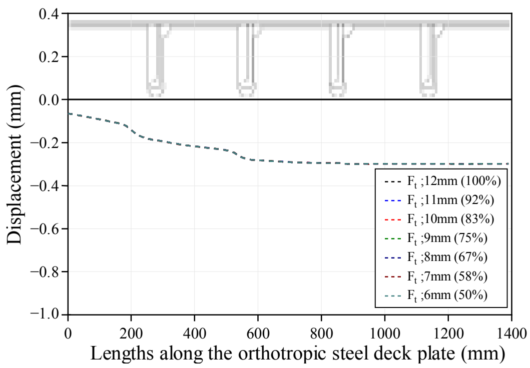


(c) Boundary conditions

Figure 1 Details and boundary conditions of FE analysis model



(a) Load case I



(b) Load case II

Figure 2 Displacement distributions on lower surface

Keywords: orthotropic steel deck, corroded deck surface, deformation behaviors, stress concentration, FE analysis
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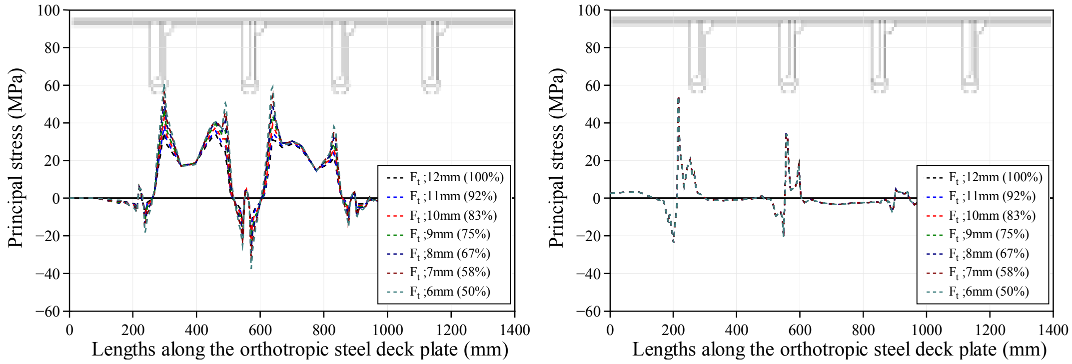

(a) Load case I (b) Load case II

Figure 3 Stress distributions on lower surface

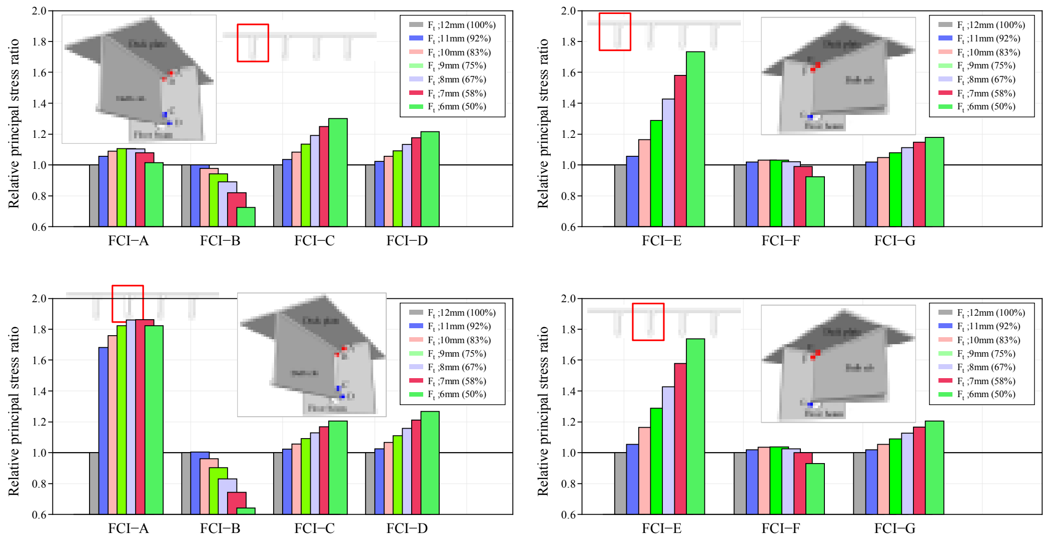

Figure 4 Relative principal stress ratios at prominent locations for fatigue cracks for load case I

3. Discussion and FE analysis results for orthotropic steel bridge deck Displacements of load case I are shown to have increased and to have slightly rotated based on the bulb rib. However, load case II showed that the corrosion damage did not have an effect on the displacement distributions because the floor beam resisted the applied loads, as shown Fig. 2. Figure 3 shows the stress distribution on the deck surface in the transverse direction according to it corrosion damage. The stress distribution is also shown to have been increased by varying the corrosion damage, and it can be confirmed that that was determined by the moment distribution of the deck plate developed by the applied loading condition. Figure 4 shows the changes in the relative principal stress ratios at the prominent locations near the connection between a bulb rib and a floor beam, which were based on the elastic modulus of the asphalt pavement during the summer season. the relative stress ratios at A, C, D, E, and G of the selected fatigue crack initiation locations were shown to be increased according to the corrosion damage of the deck plate because of its deformation behaviors under load case I. In particular, the change in the relative stress ratio at E (the rib-deck floor beam connection) was shown to be greatly increased to 1.8 times that of the deck with corrosion.

4. Summary This study numerically examined the structural responses of an orthotropic steel deck stiffened with bulb ribs. The three-dimensional FE analysis models were developed considering the change in the corrosion damage of the deck plate and the elastic modulus of the asphalt pavement. The deformation behaviors of an orthotropic steel deck stiffened with bulb ribs were shown to be increased and slightly rotated based on the bulb ribs according to the corrosion damage of the deck plate.

References

1) K. Sakiya, Y. Sugiyama, T. Yoshiyuki, Crack penetration of orthotropic steel bridge deck by corrosion in Nishinomiya Osaka line, the 42nd Hanshin Expressway technical research conference 2007: 233-240(in Japanese).

2) X. Cheng, J. Murakoshi, K, Nishikawa, H. Ohashi, Local stresses and fatigue durability of asphalt paved orthotropic steel decks, Orthotropic Bridge Conference 2004; 543-555.