Analytical Studies on Load Carrying Capacities of Riveted Railway Bridges Subjected to Collision Damages

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Summary

Collision accident to an aged railway bridge girder obstructing train services occasionally occurs due to the collision by the construction vehicle exceeding the limited height passing under the railway bridge. In this study, using a multipurpose FEM code LS-DYNA, we analytically investigate the effects of the damage level and the impact deformation pattern on the load carrying capacities of the riveted steel girders.

Keywords: Railway steel bridge, collision damage, load carrying capacity, FEM analysis.

1. Introduction

At some intersections where road runs under railway bridge, there are accidents in which vehicles exceeding the overhead clearance height collide with bridge protective frames or over-bridges. This study involves investigations of the load carrying capacities of steel I-section riveted girders subjected to the deformation simulated as collision damage, focusing attention on collision damage patterns and deformation levels through quasi-static FEM analysis.

2. FEM Analysis of Steel I-Section Girders Subjected To Collision Deformation

2.1 FEM Analysis

To evaluate the load carrying capacities of steel girders subjected to the collision deformations, we carried out FEM analyses using LS-DYNA, a multipurpose impact response analysis program. The overall FEM analysis model is composed of three-dimensional solid elements forming a main deck plate girder. The successive two-step loading method comprises a preliminary loading to apply a predetermined quantity of deformation at the lower flange, and a subsequent vertical loading downward onto the upper flanges in the center panel of the I-section girder. The first step loading is as designed to reproduce collision-related deformation by pressing the deformation-applying jig vertically upward against the bottom of lower flange for local turned up deformation, and pressing in an out-of-plane horizontal direction, for out-of-plane deformation (Fig. 1). The stress-strain relationship of the steel plate was determined by a non-linear characteristic of true stress/ true strain based on the tensile test results of the aged steel plate.

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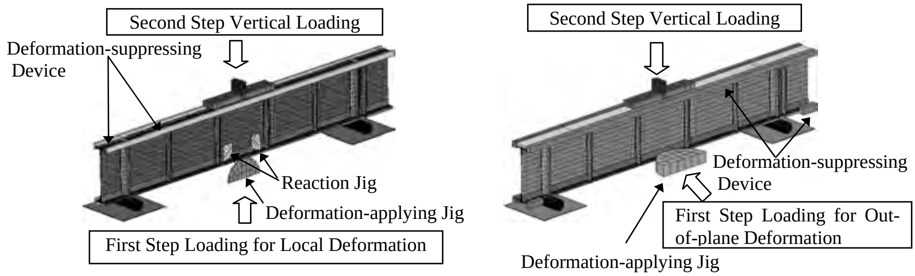
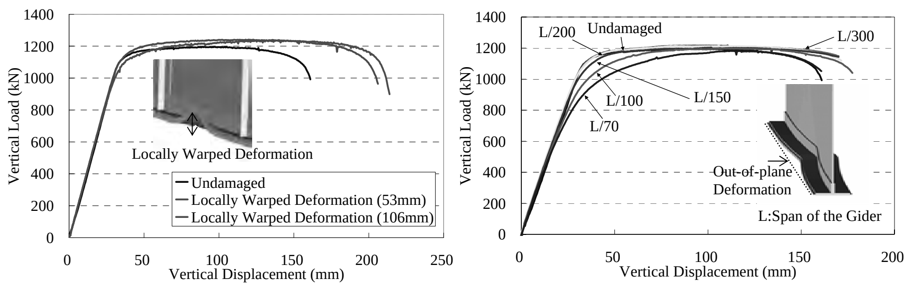


(a) Locally Warped Deformation Model *(b) Out-of-plane Deformation Model*

Fig.1 I-Section Girder Model and Two-Step Loading Method



(a) Effects of Locally Warped Deformation *(b) Effects of Out-of-plane Deformation*

Fig. 2 Load Carrying Capacities of I-Section Girders with Collision Deformations

2.2 Effects of Collision Deformation on Load Carrying Capacities

We conducted parametric analyses by changing the quantities of deformation imposed to steel I-section riveted girders, and tried to examine the effects of the deformation level on the characteristics of their load carrying capacity. Analysis results taking the collision deformation size as a parameter will be given for a single main deck plate girder with an effective span of 12 900 mm.

Figure 2 (a) shows the relationship between vertical load and vertical displacement for three cases that the warped deformations of 0 mm (undamaged state), 53 mm and 106 mm were applied preliminary. It was evident that the effect of locally warped deformation applied to lower flange on the load carrying capacity characteristics is small.

Figure 2 (b) shows the effects of out-of-plane deformation on the load carrying capacity. The quantities of out-of-plane deformation applied for five cases from 40 mm to 190 mm, represented by a ratio to span L as L/300 to L/70. In Fig. 2(b), maximum loads exhibit little change, however, when the quantity of out-of-plane deformation exceeds L/200, yield load and stiffness apparently decreases.

3. Conclusions

Throughout these analytical studies, we can conclude that in the case that the lower flange is locally warped, its load carrying capacity does not decrease unless an excessive deformation is imposed, in case that a lateral deformation is imposed, the performance slightly decreases from the one of the undamaged bridge girder when the lateral deformation is exceeding 1/200 of the span of the girder.