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"Technical Research and Development for Road Policy Quality Improvement" Study Summary

No.	Title	Principal Researcher
No.29 - 8	Research and Development of Design Method of Steel Girders Considering Plasticity for Partial Factor Design	Nagaoka University of Technology, Associate Professor, Takeshi Miyashita

This study aims to understand the characteristics of the load-carrying capacity of steel girders with a partially plasticized cross-section by experiment and analysis. Furthermore, we analyze the design criteria for steel bridges in various countries and develop a design method for steel girders that take into account the partial plasticization of members, which are not specifically described in the current Japanese road bridge specifications.

1. Backgrounds and Objects

In the road bridge specifications revised in July 2017 (after this referred to as the "Road Specifications"), the design method changed to the partial coefficient design. Besides, the need for large-scale renewal of aging bridges will increase rapidly. Therefore, it is expected that there will be a need to reduce costs even more than before. It is reasonable and reliable to make the best use of the bridge's load-carrying capacity to reduce the bridge's construction cost. However, the evaluation method of load-carrying capacity for a steel girder, which is the most common type of steel bridges, is based on the members' linear behavior. The Road Specifications have not been revised for more than 40 years since 1973. On the other hand, there is a lack of research on load-carrying capacity, although more rational design methods must be developed. As a result, not enough information is available to create a new design method.

2. Activities in Research Period

This research aims to propose a design method for steel girders with partial plasticity by conducting loading tests and numerical simulations and collecting data about previous research in other countries. In the fiscal year 2017, we studied the bending strength of composite girders, mainly focusing on the position of the plastic neutral axis and web width-thickness ratio. In the fiscal year 2018, this study focused on the bending and shear strengths of composite girders to understand the effects of the web width-to-thickness ratio, bending to shear ratio, and the composite effect steel girder and slab. Besides, based on the previous year's results, the effect of slab detailing on the bending strength of composite girders was also studied. In the fiscal year 2019, we investigated the behavior of the composite two girders as a bridge system and obtained information on the maintenance of existing bridges.

3. Study Results

(1) Bending strength of composite girders (FY 2017)

Three composite girder specimens were fabricated, and four-point bending tests and FEM analysis were carried out. The first specimen (MY1) is the upper limit of the web width-to-thickness ratio (R_w = 1.2). The second specimen (MY3) has a larger web width-to-thickness ratio for rationalized design (R_w = 1.3). The third specimen (MY4) has wider lower flange than MY1 to understand the effect of the plastic neutral axis position on the load-carrying characteristics. The main findings are below.

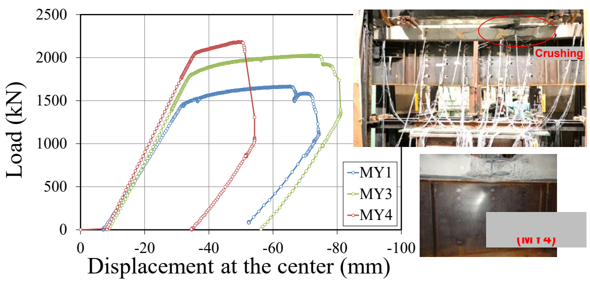

Figure 1 Load-displacement relation and failure condition (FY 2017)

- The conventional design reaches the total plasticity moment, and the strength is expected to be achieved after the yield moment. However, since the load is rapidly reduced due to the slab's crushing at the ultimate sate, it is necessary to improve the slab's toughness.

- Even if the web width-thickness ratio is relaxed, the total plastic moment is reached when the plastic-neutral axis is in the slab or upper flange.

(2) Bending and shear strength of composite girders (FY 2018)

One specimen for bending and four specimens for bending and shear were fabricated, and then we conducted loading tests and FEM analyses. Although the former's specifications are the same as those of MY1, a grid reinforcement is placed in a slab. The latter is designed by the current design (A: R_w = 1.2), a larger web width-to-thickness ratio (B: R_w = 1.4) and increased bending/shear ratio (C: R_w = 1.4). Furthermore, to investigate the composite effect between a steel girder and a concrete slab, specimen D, which is the same specifications as those of specimen B, were tested by applying a release agent to the contact surface between the steel girder and the slab. As a result, we found that the total plastic moment is reached even if the bending/shear ratio is increased or R_w is relaxed. In addition, the arrangement of reinforcing bars in the slabs makes the structure more tenacious even after the slab failure, and specimen D showed the same load-vertical displacement relationship and failure mode as the specimens without the release agent. Furthermore, there was no correlation between bending and shear capacity in each case.

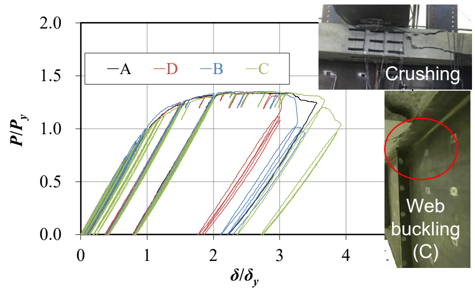

Figure 2 Load-displacement relation and failure condition (FY 2018)

(3) Bending and Shear Capacity of Composite Two Main Girders (FY 2019)

The bridge system's limit state is also mentioned in the revised Road Specifications with the expectation of redundancy as a structural system. Therefore, we conducted loading tests of two composite main girders and analyses to understand the bridge system's ultimate state. The loading method in the experiment was the same as the loading test in the previous years, a three-point bending load. Besides, to obtain knowledge on the maintenance of the existing bridges, fatigue damage was introduced to one of the RC slabs in the specimens in advance. As a result, we found that two test specimens with different degrees of damage to the RC slabs tended to be similar to the overall mechanical behavior of a single composite girder. This is not only the knowledge of the ultimate state of the bridge system but also the availability of emergency vehicles after a large-scale earthquake.

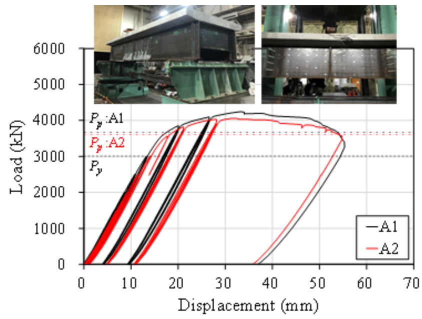

Figure 3 Load-displacement relation (FY 2019, A1:w/o damage, A2:w/ damage)

4. Papers for Presentation

- H. Sato, T. Miyashita, K. Ono, et al.: Bending Strength Tests of Composite Girders for Critical State Design Method, *33rd Japan Road Congress*, 2019.11.
- F. Chao Yue, Kiyoshi Ono, T. Miyashita, et al.: Adhesion of RC slabs and flanges on steel girders Experimental Studies on the Influence of Elasto-Plastic Behavior of Composite Girders, 13th Symposium on Composite Structures, 2019.11.

5. Study Development and Future Issues

The results of this research make possible to maximize the effect of the revision of the specifications for road bridges. In addition, it is expected to improve the international competitiveness of Japanese road bridges design. Future issues will be to examine the limit state of composite girders under negative bending and continuous girders.

6. Contribution to Road Policy Quality Improvement

Reflections in the Specifications for Road Bridges: limit state and design method.

7. References, Websites, etc.

https://whs.nagaokaut.ac.jp/struct/, http://www.ono-lab.sci.waseda.ac.jp/index.html