Research on CFRP sheet reinforcement of shear steel girders

せん断鋼桁の CFRP シート補強に関する研究

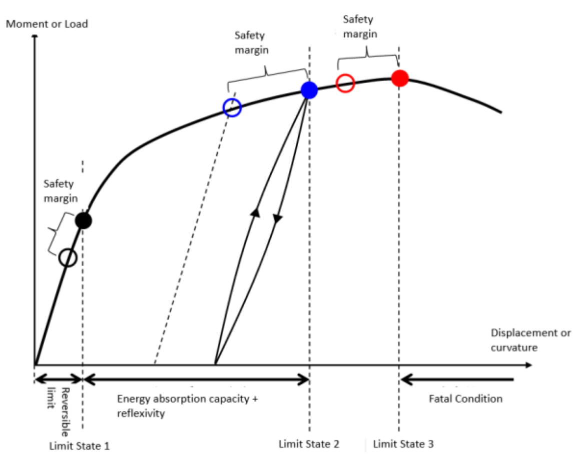
環境社会基盤工学課程　4 年　鋼構造研究室　　　　20328586 Maldonado Gutierrez Carlos Eligio

1. Research Background

On the year Heisei 29 the Road Bridge Specification was revised. As part of this revision, the traditionally used Allowable Stress Methos was changed for the Limit State Design Method, which is based in statistical data for design parameters. However, there currently does not exist a concrete procedure for delimiting the states and carrying out investigations for every type of structure and structure member.

Limit States are limits within the structural member's capacity to bear loads and deform. Traditionally, we try to keep structures within the first limit, or in other words, its elastic limit, but the limit state design method allows structures to go beyond this elastic limit and accept a certain degree of plastic deformation.

Figure 1 Limit States Graph for Members



2. Research Objectives

The objectives for this research are as follows. With regards to shear steel girders:

❖ Carry out an examination for setting the limit states of newly constructed members
  - Organize the data (events) for the states of each member section through structural experiments.

❖ Collect base data for setting the limit states for reinforcement and repair
  - Verify the repair effectiveness of CFRP through the testing of CFRP reinforced members.
  - Organize the data (events) for the states of each member section.

3. Experiment Outline

For this study 3 specimens were used: an unreinforced one, one reinforced with CFRP sheets, and one reinforced with CFRP sheets and steel plates. These specimens are labeled S-1, S-2, and S-3 respectively.

❖ Web（1 Panel）
  - 740×6，1110mm，α=1.5，SM490Y
  - 0.2% Proof Stress （Material Testing）
  - σy=402MPa→（E=200GPa）εy=2010μ

❖ Flanges（Upper & Lower），Vertical Stiffeners
  - 236×16，95×16，SM490Y
  - 0.2% Proof Stress（Material Testing）
  - σy=377MPa→（E=200GPa）εy=1885μ

❖ CFRP（Medium Elasticity Type）
  - Yield Strain: εu＝8891μ

A total of 421 sensors were installed in the specimens for collecting data from the tests, including: uniaxial strain gages, triaxial strain gages, and deflectometers.

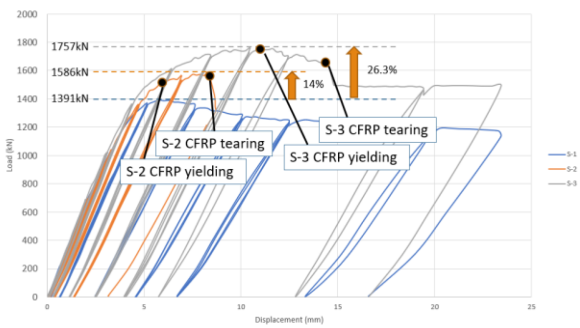
The Von Mises yield criterion (equation 1) was used for calculating the equivalent strain on the web from the triaxial strain gages.

$$\varepsilon = \sqrt{\frac{1}{2}\{(\varepsilon_1 - \varepsilon_2)^2 + \varepsilon_1^2 + \varepsilon_2^2\}} \qquad (1)$$

Here, ε_1 : Maximum Strain, ε_2 : Minimum Strain

4. Data Analysis

Figure 2 Displacement of all 3 specimens



There was a 12% and 26.3% increase in the load-bearing performance of the specimens over the unreinforced specimen for the S-2 and S-3 specimens respectively. The maximum load for the S-2 specimen represents the moment its CFRP reinforcement tears, causing a drastic reduction in its load-bearing capabilities. This behavior is controlled in the S-3 specimen with the addition of the steel plates.

Figure 3 S-1 Event Organization

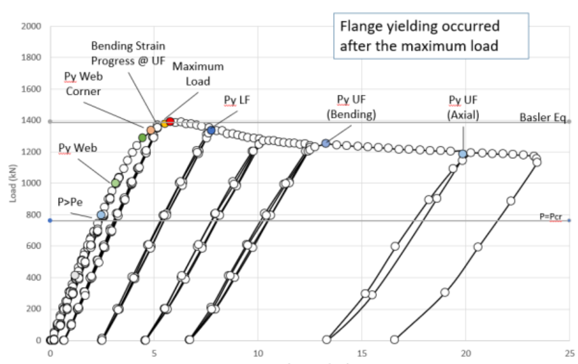


Figure 4 S-2Event Organization

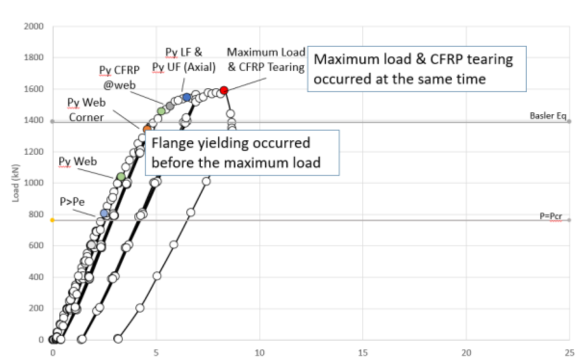
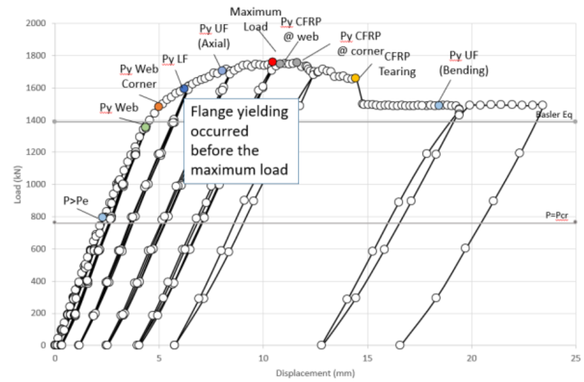


Figure 5 S-3 Event Organization



The yielding pattern of the member's sections changed as reinforcement was added. The central sections of the web were the quickest to yield, adding CFRP reinforcement did not improved yield-loads, but greatly limited post-buckling deformation. This also improved the rigidity of the specimens. Due to the reduced web deformation, bending strain was reduced on the flanges, changing their yielding behavior. The vertical stiffeners were virtually undamaged.

The displacement at the time of the maximum load for each specimen became larger as the load carrying capabilities of the girder improved. However, the residual displacement after each loading cycle became smaller.

5. Conclusions

- The event organization for each specimen was compiled, and visual and numerical representations of the results were presented.
- Base data for the elaboration of the limit states was collected.

Findings

- The usage of CFRP as a reinforcement method allows for the improvement of the load-bearing capacity and the buckling load for an I-shaped girder.

- CFRP does not provide an improvement of the general displacement of the girder under similar loading patterns, however, the out-of-place deformation of the web after buckling is vastly reduced.