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Study of Behaviour of Concrete Beams Strengthened by Steel Plates against Shearing Force

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Summary

The paper presents an experimental and analytical study of concrete beams strengthened by vertically encased steel plates to increase the capacity against the shearing force. It was found that if such plates were properly arranged, the shearing capacity could be effectively increased and be applied to actual bridges, where the beam depth is severely restricted. The authors also developed a new FEM method of nonlinear two-dimensional rigid body-spring system, which proved to be useful to examine the behavior of such composite beams analytically in detail.

1. Introduction

The depth of beams in a concrete bridge is often severely restricted because of the clearance under the bridge or the depth of end parts of beams is curtailed by almost half to provide hinge-supports in a cantilever-type bridge. Occasionally, the shearing resistance in these parts is not large enough to prevent local damages in a long service period or under increased loading condition. The authors have developed a method for strengthening against the shearing force in which steel plates are vertically encased in the case of newly constructed bridges and they are attached on outer faces by studs and adhesive in the case of existing bridges.

The authors conducted a series of experiment, using various test specimens and also examined their elasto-plastic behavior by a new analytical method of two-dimensional rigid body-spring system, which was developed by the authors.

2. Experiment

The test setup and an example of the specimens (Model A-1) is shown in **Fig. 1**. Steel plates with studs are encased, which are separated at the center to prevent them from resisting the bending moment. A sufficiently thick steel plate with studs is attached also on the lower side. The amount of reinforcing bars was minimized, so as to investigate mainly the effect of steel plates. Several specimens were made for the test, in which the thickness of encased steel plates and the pattern of arrangement of the studs were varied. In addition to uni-axial strain gauges, tri-axial ones were installed to measure the distribution of shearing stresses in the plates.

In result cracks occurred in all the specimens at the central portion due to bending moment, and also large cracks occurred diagonally between the end supports and the loading points. **Fig. 2** shows an example of cracks of concrete and the distribution of maximum and minimum principal stresses in the encased web plate at the maximum load. **Fig. 3** shows an example of distribution of the shearing stress in the web plate. The stress appeared higher at the mid-depth. Comparing the results of fracture of the specimens, it seems that the studs located near the upper and lower edges act more effectively than those located in the mid-depth region.

3. Analytical Investigation

The concrete and steel portions are respectively divided into triangular elements. Adjoining elements and studs are connected with each other by springs in the two directions, parallel and perpendicular to each side of elements. The springs are provided with peculiar nonlinear characteristics, in order to examine the plastic behavior of the beam. **Fig. 4** indicates an example to show how fracture or yield develops in the beam.

4. Conclusions

As the result of experiment and analysis the following conclusions are drawn:
1) The steel plates with studs encased at the end portions of concrete beams are effective for strengthening against shearing force and the studs arranged near the edges are more effective.
2) The analytical method of FEM of two-dimensional rigid body-spring system, which was developed by the authors, are useful to accurately account for the mechanism of fracture of such composite structures, which can not be detected in details by experiments.

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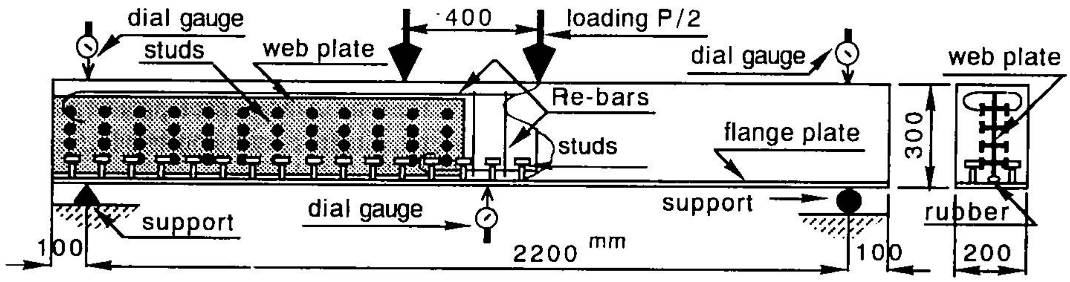

Fig. 1 Setup for test and a specimen (Model A-1)

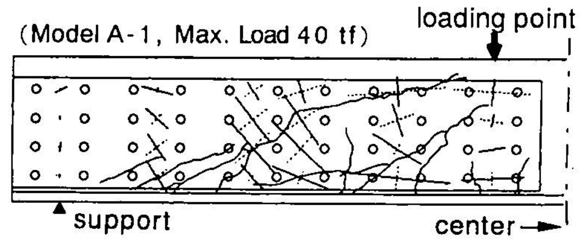

Fig. 2 Cracks of concrete and strains of web plate

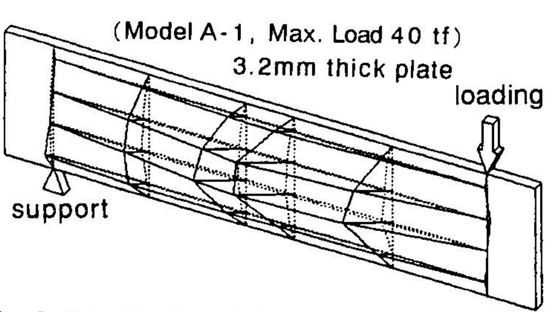

Fig. 3 Distribution of shearing stress in web plate

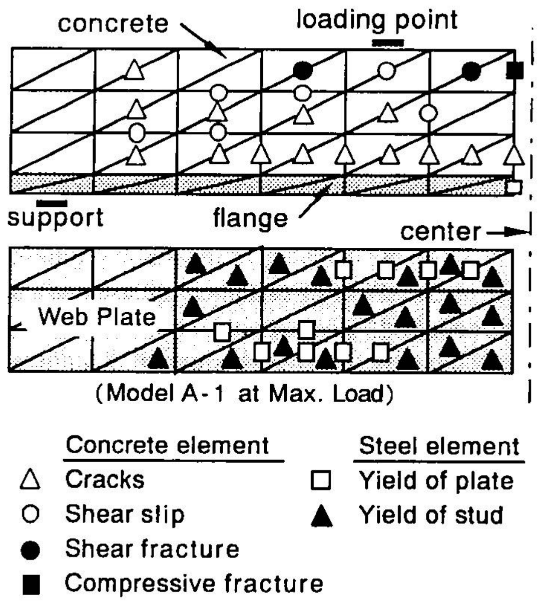

Fig. 4 Development of fracture or yielding of concrete and web plate