I－B173 FLEXURAL BEHAVIOR OF CIRCULAR HOLLOW BRIDGE COLUMNS WITH ONE LAYER OF REINFORCEMENT UNDER CYCLIC LOADING

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Introduction

In the hollow circular section for bridge columns, some layers of longitudinal and transverse steel are often placed near both outside and inside faces and they are tied through the wall thickness by cross ties. However, the transverse steel placed near inside face and the cross ties may not significantly contribute to the confinement of concrete wall in the circular hollow section. It is also suggested that such steel arrangement causes the difficulty of construction. This paper reports the results of experimental study conducted to establish the parameters controlling the available flexural ductility of the hollow circular columns with one layer of longitudinal and transverse steel placed only near the outside face of the section.

Cyclic Loading Tests

The overall test setup is illustrated in Fig. 1. Column section up to 3480mm height from the base was constructed by reinforced concrete with hollow section, and a loading steel tube was connected to the top of the column for the extension of the column height. Two columns (called herein HF1 and HF2) with different longitudinal reinforcement ratios were constructed and tested in this program. The test columns have 34 bundles of 2 #4 bars (HF1) or #6 bars (HF2) in one layer distributed evenly with a constant cover. The longitudinal reinforcement ratios to the net area of the concrete are 1.4% (HF1) and 3.3% (HF2), respectively. The transverse reinforcement is a W5 wire (6.35mm diameter) spiral with 35mm pitch in the range of plastic end region. A vertical load was applied to the units through the use of four dywidag high strength bars and two rocker beam assemblies. A total vertical load of 2913kN (HF1) or 2997kN (HF2), corresponding to an axial load ratio ($P / f_c' A_g$) of nearly 0.13, was applied and maintained throughout the test.

Structural Response and Test Observations

The lateral force-displacement hysteretic responses of the test unit are shown in Fig. 2. It is interesting that both columns exhibited the crush of the inside face concrete at the maximum useful ductility of 3.5 (HF1) or 1.8 (HF2), which caused the significant degradation of the lateral force. At the ductility 4.0 in the HF1 unit, even though no longitudinal reinforcement buckled and the core concrete seems to be still confined, the inside face concrete significantly spalled-off. Fig. 3 shows longitudinal strain profiles in the plane section of 146mm height form the column base where the significant plastic curvature developed. It is noted that the strains of near inside face concrete at the maximum useful ductility of 3.5 (HF1) and 1.8 (HF2) seem to be nearly 5000 microstrains, indicating that the ultimate compression strain of the inside face concrete may be at most 5000 micorstrains.

Fig. 4 shows the confinement-induced strain hysteresis response measured at 280mm height of the HF1 unit. The spiral strain has reached about 1380 microstrains at the interesting ductility 3.5 and the spiral steel has yielded immediately after crushing of the inside face concrete. Similar strain behaviors were observed at other sections within the plastic hinge. It should be remarked that the confinement-induced strains at the maximum useful ductility seems to be nearly 1000 microstrains averaged over the anticipated plastic hinge region and therefore still do not reach their yield strains in a moment of crushing of the inside face concrete. Based on the test results from the units of HF1 and HF2, the strain of 0.001 would represent the effective confinement-induced strain in the circular hollow section.

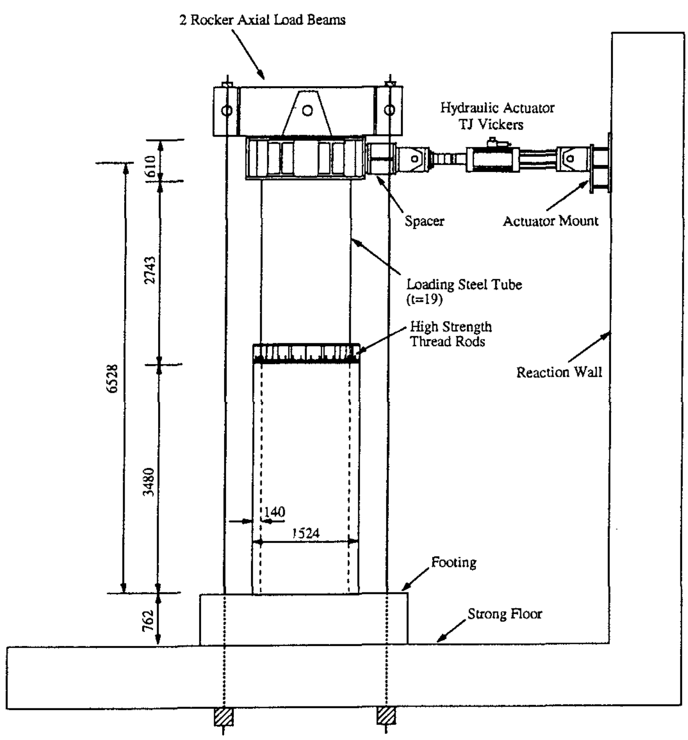

Fig. 1 Test Setup

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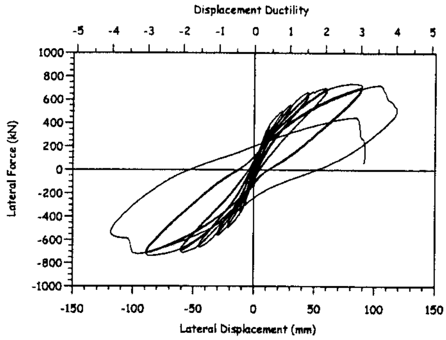

Fig. 2 (a) Lateral Force-displacement Response (HF1)

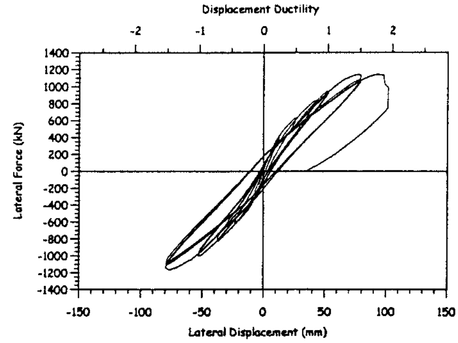

Fig. 2 (b) Lateral Force-displacement Response (HF2)

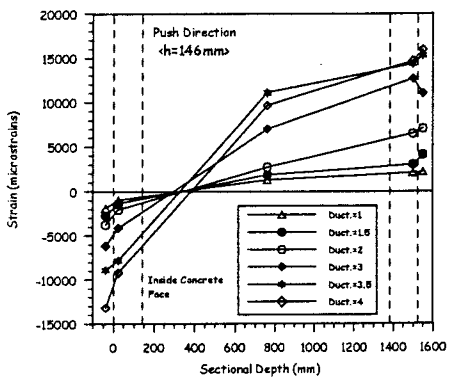

Fig. 3 (a) Longitudinal Strain Profiles (HF1)

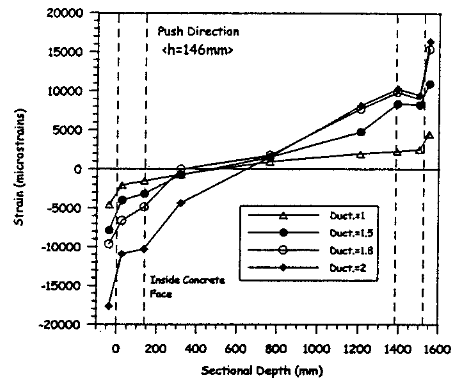

Fig. 3 (b) Longitudinal Strain Profiles (HF2)

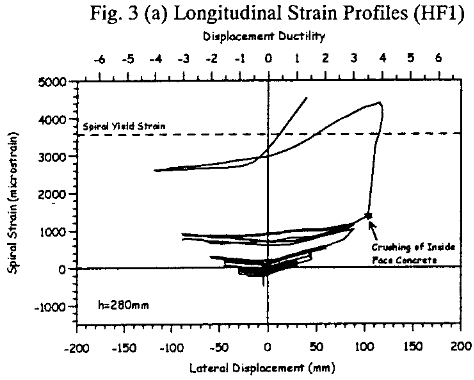

Fig. 4 Confinement-induced Strain Response

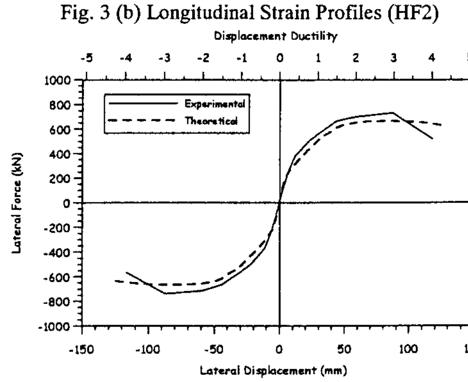

Fig. 5 Comparison of Analytical and Experimental Envelops (HF1)

Analytical Approach for Prediction of Flexural Response

Based on above discussion, the conventional moment-curvature analyses were carried out with the following considerations: effective maximum transverse steel strain induced by the confinement may be 0.001 in the hollow section; and the ultimate compression strain of the inside face concrete is assumed to be 0.005 for the circular hollow columns. Analytical lateral force-displacement response was compared with the experimental envelops in Fig. 5, where the plastic hinge length was calculated from $0.08L+0.022\,f_y\,d_{bl}$. Effect of deformation developed in the loading steel tube on the lateral displacement at the loading point was taken into account in the analysis. Although the measured lateral force is slightly higher than the theoretical value, the analytical results show a good agreement with the experimental responses.

Conclusions

The flexural ductility capacity of the circular hollow columns with one layer of longitudinal and transverse steel was evaluated based on the conventional moment-curvature analyses taking account of two key factors, that is, the confinement loss and failure of the inside face concrete. The experimental results show that the confinement-induced strain on the transverse steel and the compression strain of the inside face concrete at crushing may be at most 0.001 and 0.005, respectively.

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