Resilient Structures and Sustainable Construction
Edited by Pellicer, E., Adam, J. M., Yepes, V., Singh, A., and Yazdani, S.

ISBN: 978-0-9960437-4-8

EVALUATIONS OF FLEXURAL CAPACITY IMPROVEMENT METHOD FOR RC PIERS AND CISS FOUNDATION CONNECTIONS IN BRIDGES

JUNG-KYUN KIM and HAK-EUN LEE

Dept of Civil, Society and Environmental Engineering, Korea University, Seoul, South Korea

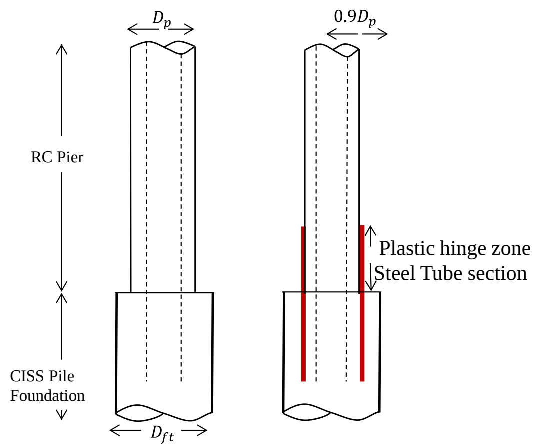
Recently, cast-in-steel shell (CISS) pile has been used as the foundation of bridges and a pier is directly connected to the pile. In this case, plastic hinge is generally formed at the connection between the CISS pile and reinforced concrete pier. To increase the flexural capacity of such structure, a proper improvement method is necessary for the connection. In this study, a steel tube, a steel pipe that has 270mm diameter with 4.5mm thickness, has been used to enhance flexural capacity of the connection and the effect by the such method was evaluated through cyclic compression-bending test. From the test results, it can be found that the flexure capacity is considerably increased by applying the steel tube at the connection when it was compared to a general reinforced concrete (RC) pier with 10% larger diameter cross-section.

Keywords: Case-in-steel shell pile, Footing-column connection, Composite structure, Compression-bending test.

1 INTRODUCTION

Cast-in-steel shell pile refers to a pile that is constructed by drilling through steel pipes in the field and pouring concrete or reinforced concrete into the pile. Steel pipes used in special situations such as soft ground are not drawn separately but are buried as sacrificial steel pipes. These piles are widely used mainly in places where reduction of construction pollution is required, such as downtown area, because noise and vibration are reduced by boring instead of hitting. Recently, such drilled piles are used directly as the basis of bridges, and reinforced concrete piers are directly connected to the top of piles (Moon *et al.* 2016). In case of extreme lateral loads such as earthquakes, the substructure of the bridge should have sufficient bending resistance. Otherwise, the plastic hinge of a typical CISS pile - RC pier will occur at the connection between the pile and the pier.

The connection of the typical CISS pile-RC pier is shown in Figure 1(a). The CISS pile section is a RC column surrounded by a sacrificial steel pipe, which can serve as a foundation and is connected directly to the RC column pier. In this case, the connection becomes weak portion which the plastic hinge can be generated. The bending strength capacity can be improved through the reinforced structure system at the connecting region. In this study, an improved structural system was developed to improve the bending strength capacity of CISS pile and RC column piers. As shown in Figure 1(b), the steel tube is installed at the height of the plastic hinge zone. For the proposed structure system, the test specimens were fabricated and the effect of flexural strength was evaluated by cyclic compression-bending test.

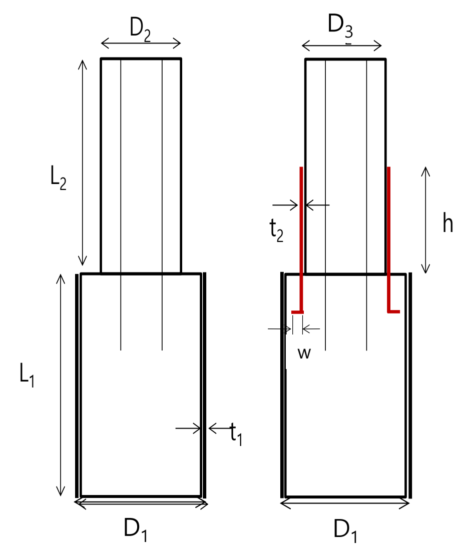


(a) specimen1 (b) specimen2

Figure 1. CISS foundation - RC pier connection and steel tube.

2 DESIGN TEST SPECIMENS

The Experimental study was conducted to evaluate the effect of the actual behavior of Steel Tube at CISS pile foundation - RC column pier connection. In this case, two test specimens were fabricated. Specimen 1, 2 is shown in Figure 2. Specimen 1 is a general CISS-RC (diameter = 300 mm) connection model.



(a) specimen1 (b) specimen2

Figure 2. Geometry of specimen 1 and 2.

The specimen 2 is made through the design process shown in Figure 3. The maximum bending moment of the connecting section of specimen 1 is M_{p1} and that of specimen 2 is M_{p2} when the diameter of the RC bridge is reduced into 270 mm. In this state, both specimens are subjected to plastic hinge at the CISS-RC connection and the specimen with reduced cross-section is destroyed by the smaller bending moment ($M_{p1} > M_{p2}$).

The steel tube was installed up to the height “h” in the connection of the specimen 2, so that the bending moment of specimen 2 was designed to be equal to that of specimen 1. As a result, the specimen 2 can exhibit the same bending strength with a smaller cross-section diameter than the specimen 1 by the theoretical calculation ($M_{p1} = M_{p2}$). Also, if the plastic hinge occurs at the steel tube section, ductile behavior of the bridge can be induced after steel tube yielding.

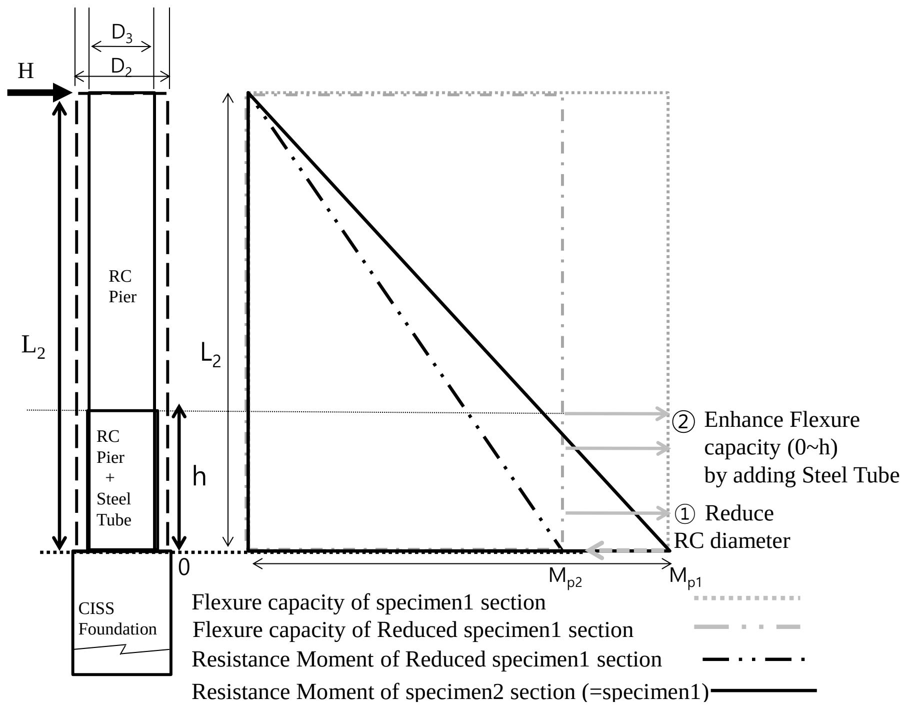


Figure 3. Bending moment diagram of specimens.

The two specimens have the same height and the diameter of the CISS pile foundation. The casing pipe of CISS pile and the steel tube are made of SS400 steel, yield strength 250 Mpa. The yield strength of steel reinforcement bar is 300 Mpa (SD300). The detailed dimensions and specifications of the specimen 1, 2 are shown in Table 1.

Table 1. Dimension of specimen 1, 2.

Specimen No.	**Diameter of RC Pier (mm)**	**Diameter of CISS (mm)**	**L_1 (mm)**	**L_2 (mm)**	**t_1 (mm)**	**t_2 (mm)**	**h (mm)**	**w (mm)**
specimen 1	300	420	550	780	4.5	-	-	-
specimen 2	270	420	550	780	4.5	4.5	270	50

3 LOADING CONDITIONS

Since the piers are being compressed by the upper structure, the loading frame is constructed as shown in Figure 4.

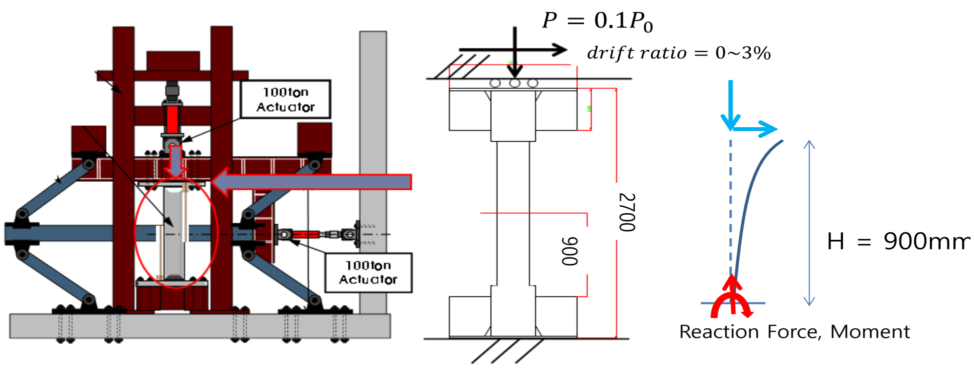


Figure 4. Diagram of axial-bending test frame and loading summary.

4 TEST RESULTS

Figure 5 shows the CISS Pile-RC pier connection of the specimens after the test. Figure 5(a) shows the damage of the connection of specimen 1 and the plastic hinge occur from the bottom line of the CISS Pile-RC pier connection part. Figure 5(b) shows the damage of the specimen 2 after the test, and it shows that the plastic hinge occur near the top of steel tube, not the bottom line of the connection part.

(a) (b)

Figure 5. (a) Deformed specimen 1 and (b) deformed specimen 2 (steel tube).

Figure 6 shows the lateral reaction force-drift relationship of the specimen. In the specimen 1, the maximum lateral reaction force was about 126 kN at 1.5% drift. As displacement increases to opposite direction, the reaction force increases to 110 kN at 1% drift, less than the maximum reaction force in forward direction. In the specimen 2, it showed steady increase to around 2% drift and maximum lateral reaction force was about 135 kN. Unlike specimen 1, the maximum lateral reaction force in negative direction was 136 kN in the specimen 2.

Comparing the absolute maximum lateral reaction force of the two specimens, maximum lateral reaction force of specimen 2 is 7.9% higher than that of specimen 1.

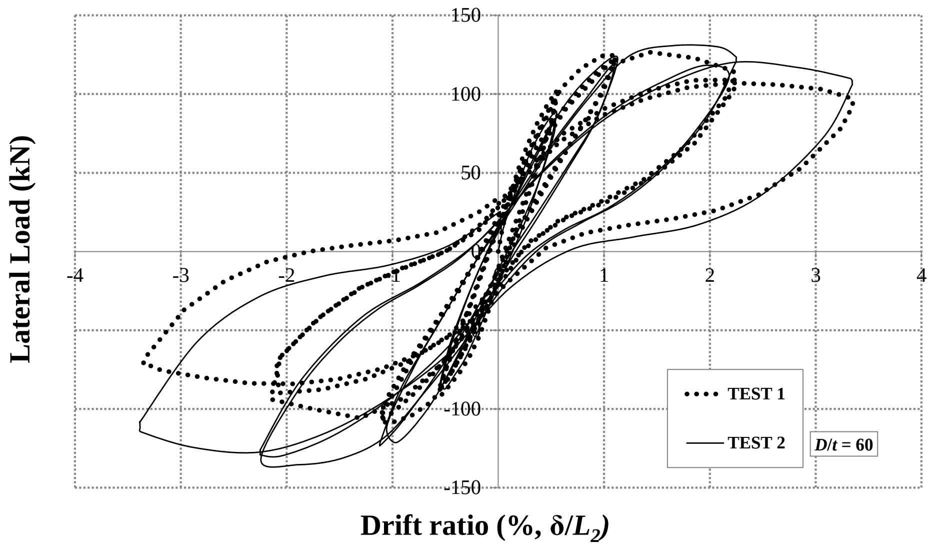


Figure 6. Later reaction force-drift curve of specimen 1 and 2.

5 CONCLUSIONS

In this study, we proposed a structural system that can improve the bending strength by installing steel tube on CISS pile-RC pier connection. Experimental results show that the maximum lateral reaction force of specimen 2 (added Steel Tube) is 7.9% higher than that of specimen 1 even though the diameter of specimen 2 is about 10% smaller than that of specimen 1. Also, the drift ratio at maximum lateral reaction force increased from 1.5% (specimen 1) to 2% (specimen 2). It shows that the steel tube of the CISS pile-RC pier connection can enhance the flexural resistance and ductile behavior of connection part.

References

Moon, J. H., C. W. Roeder, D. E. Lehman, Lee, H. E., and Lee, T. Y., Analytical Evaluation of Reinforced Concrete Pier and Cast-in-Steel-Shell Pile Connection Behavior Considering Steel-Concrete Interface, *Advances in Materials Science and Engineering*, 14, 2016.