Implementing Innovative Ideas in Structural Engineering and Project Management
Edited by Saha, S., Zhang, Y., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-1-7

MODULE SEGMENT CONNECTION FOR COMPOSITE HOLLOW RC SUBMERGED FLOATING TUNNELS

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A submerged floating tunnel (SFT) has been considered as an interesting structure to connect the banks separated by a narrow and deep sea. Governing load of a SFT is bending moment, a structure with enhanced stiffness and ductility will be useful for a SFT. Therefore, new-type structures which have superior stiffness and ductility were proposed for the SFT using composite Hollow RC structure. The cast-in-place concrete can't apply for construction, because SFT will be constructed underwater. For this reason, SFT is constructed onsite after making module segment on coastal factory. In this paper, connection method of module segment for SFT is proposed using PC tendon. It is verified by experimental study. Bending test of module segment specimens are evaluated, and the proposed connection method has good performance.

Keywords: SFT, Bending test, Underwater.

1 INTRODUCTION

The method of crossing the channel or river can be classified four types as shown in Figure 1. They are bridge, submerged floating tunnel, immersed tunnel, and submarine tunnel. The submerged floating tunnels (SFT) of those were researched by countries had many island as Norway, Italy, China, and Japan. Several sites were examined in China and Norway. Most of them investigated about seismic, dynamic, and collision performance. However, present research has poor application in the construction field, therefore, additional research is needed.

The SFT suggest that vehicles or trains are operated as shown Figure 2. Main tube of the SFT is very important to drive safely. It must have structural performance. Figures 3~6 show four types of many SFT prototypes. Figure 3 is SFT prototype of China Qinadao Lake; it is consisting of concrete, aluminum and steel tube. Aluminum extrusion is protecting corrosion of concrete against Salt-attack. Figure 4 shows Funka bay SFT in Japan, its material properties is reinforced concrete structure. It is reinforced prestressing method for preventing tensile crack. Figure 5 shows that proposed SFT for crossing of strait of Messina. Main tube is consisting reinforced concrete. This SFT has steel tube at outside of concrete to protect salt-attack and leak of water. Figure 6 is the SFT prototype in Uchiura bay Japan. Outside of section is located steel sheet; inside of section is consisting sandwich shell.

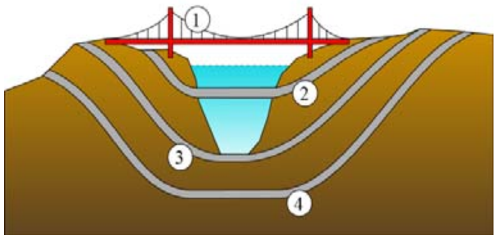

Figure 1. Crossing method on the river or channel ((1) bridge, (2) submerged floating tunnel, (3) immersed tunnel, and (4) submarine tunnel) Østlid H (2010).

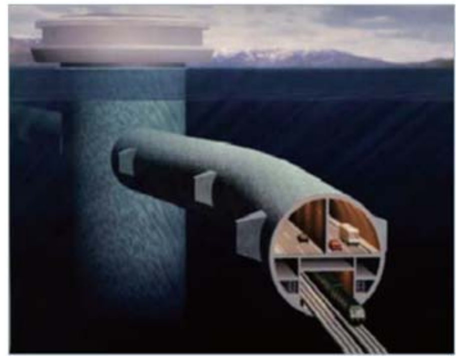

Figure 2. Concept of submerged floating tunnel for the Funka Bay (Kanie S., 2010).

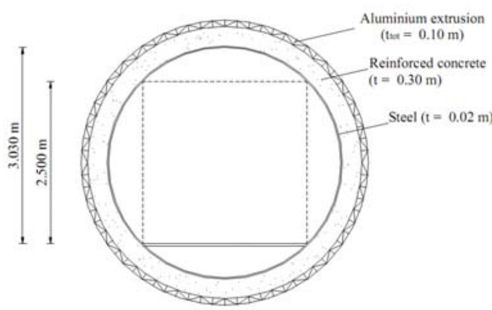

Figure 3. SFT prototype in the Qiandao Lake(China) (Mazzolani et al.(2010)).

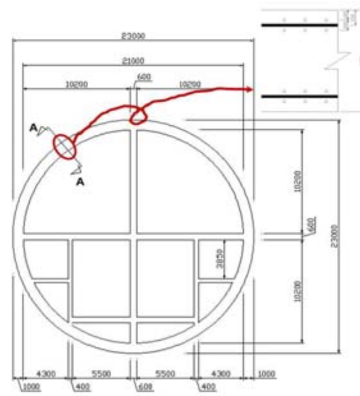

Figure 4. SFT prototype in Funka Bay Japan(Kanie S., (2010)).

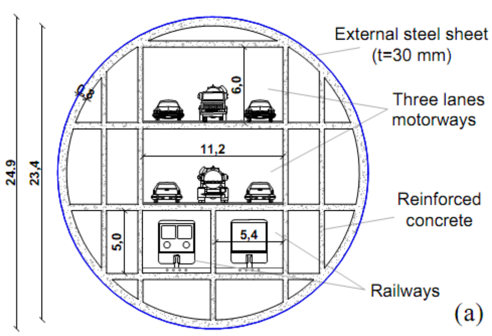

Figure 5. Proposed SFT for Strait of Messina (G. Martire *et al.* 2010).

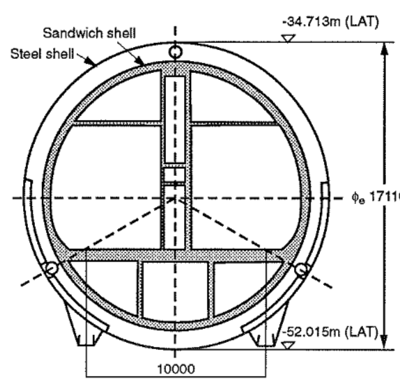

Figure 6. SFT prototype in Uchiura Bay(Maeda *et al.* 1994).

Thus, SFT suggested that it has various type of sections. New type SFT was proposed using steel composite hollow RC member as shown Figure 7. A module segment connection of composite hollow RC SFT was suggested, and its performance was evaluated in the experimental study. The cast-in-place concrete can't apply for construction, because SFT will be constructed underwater. In this reason, SFT is constructed onsite after making a module segment on coastal factory. In this paper, connection method of module segment for SFT is proposed using PC tendon. It is verified by experimental study. Bending test of module segment specimens are evaluated, and proposed connection method has good performance.

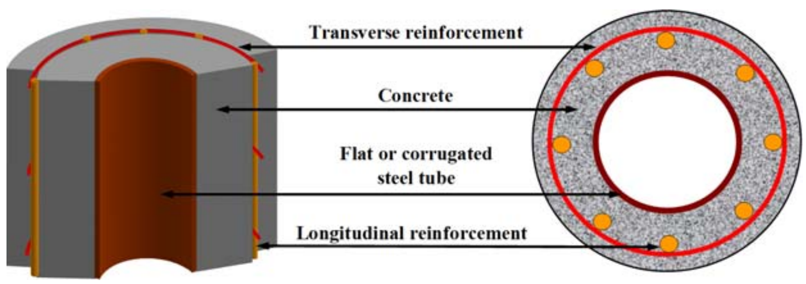

Figure 7. Steel composite hollow RC structure (Han *et al.* 2010).

2 MODULE SEGMENT CONNECTION OF SUBMERGED FLOATING TUNNEL

The SFT cannot apply cast-in-place construction method because it is constructed underwater. Reasonable construction method for the SFT is fabrication method after production of module segment in coastal casting bed. It is important that fabrication method must be proposed for composite hollow RC SFT. The SFT hasn't actually been applied yet. However, Japan and Norway have design experience. Similar types of structures with the SFT have submerged tunnels. Also, it has module connection as SFT module. Connection method for module of immerged tunnel is applied prestressing method. Prestressing method is a overcoming concrete's natural weakness in tension. It can be used to produce beam, floors, precast structure, or bridges. Prestressing tendons (generally of high tensile steel cable or rods) are used to provide a clamping load which produces a compressive stress that balances the tensile stress that the concrete compression member would otherwise experience due to a bending load. Traditional reinforced concrete is based on the use of steel reinforcement bars, rebars, inside poured concrete. Prestressing can be accomplished in three ways: pre-tensioned concrete, and bonded or unbonded post-tensioned concrete. In this paper apply boned post-tensioned method for module segment connection of composite hollow RC SFT. Because boned post-tensioned concrete is the descriptive term for a method of applying compression after pouring concrete and during the curing process. The SFT can't be post-tensioning method on external side of it because external side is underwater. Therefore, post-tensioning of PC tendon must be performed inside SFT. Thus, arch type PC tendon is applied as Figure 9.

Increase of concrete section in connection part need for arch type PC tendon. Inner tube is connected by reinforced steel plate and bolting (or welding) as Figure 9.

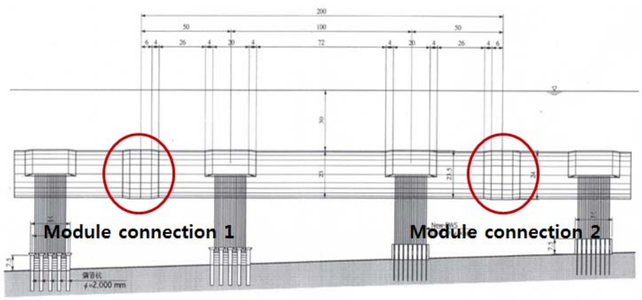

Figure 8. Constitution of SFT.

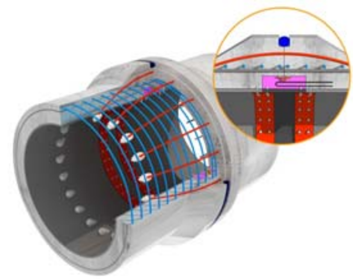

Figure 9. Module segment connection of SFT.

3 EXPERIMENTAL STUDY METHOD AND SPECIMENS

To evaluate performance of connection for SFT, bending test is performed. Length of specimen is 7m, mid span is 4.2m, and 2 point load is applied as Figure 10. Low half cyclic loading is increased 0.5%~2% of mid span length and 1step is constituted 10 time half cyclic loading. LVDT is installed to investigate the deformation of specimen as shown Figure 10.

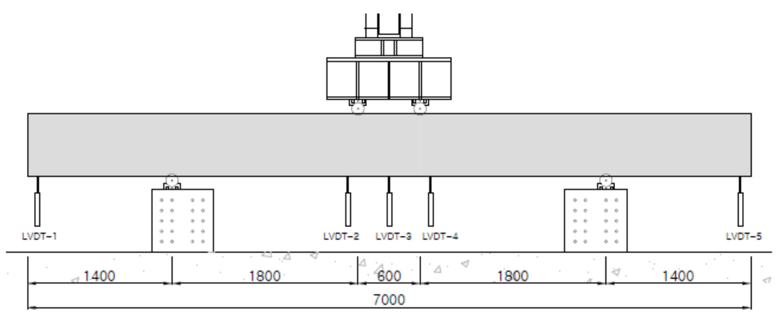

Figure 10. Bending experiment method.

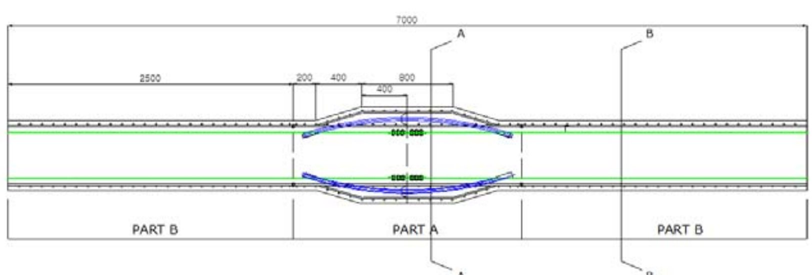

Figure 11. Constitution of SFT.

There are two types of specimens. One case is that inner tube is connected bolting and reinforced plate as shown Figure 12. Another case, inner tube doesn't connect. Contact surface if concrete is installed shear key to increase shear resistance force as shown Figure 14. Specimens are made as shown Figure 15.

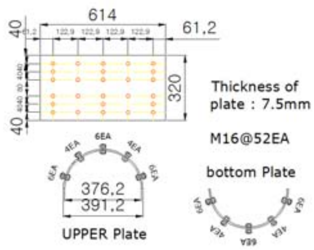

Figure 12. Connection method of inner tube.

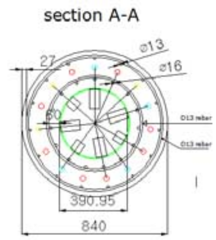

Figure 13. Installation of PC tendon.

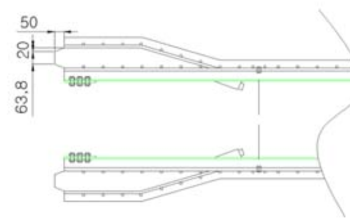

Figure 14. Shear key of connection.

Figure 15. Production of specimens.

4 BEHAVIOR OF MODULE SEGMENT CONNECTION

Result of experimental study, maximum strength of inner tube connection model is 1200kN and another model is 700kN. Due to connection of inner tube, strength of connection is increased. Also, restoration of connection is very well by PC tendon. Inside connection of concrete, omega seal will be installed. This experimental study is not consideration omega seal. It provides the unique properties to withstand high water pressure in combination with large movements in all directions.

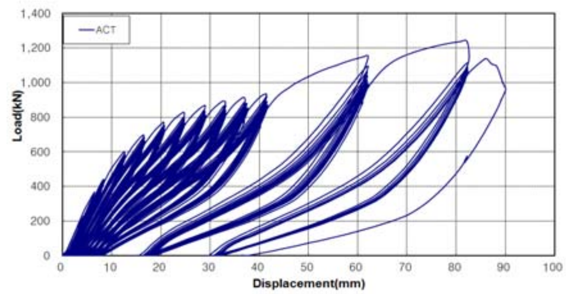

Figure 16. PC tendon + bolting of inner tube.

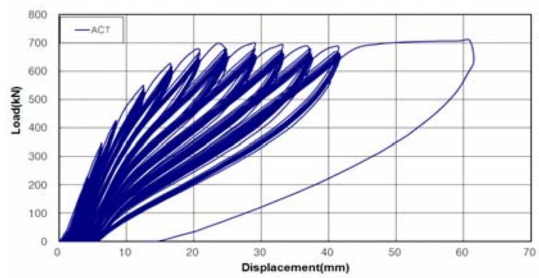

Figure 17. PC tendon.

5 CONCLUSIONS

In this paper, connection method of module segment for SFT is proposed using PC tendon. It is verified by experimental study. Bending test of module segment specimens are evaluated, maximum strength of inner tube connection model is 1200kN and another model is 700kN. Due to connection of inner tube, strength of connection is increased. Also, restoration of connection is very well by PC tendon.

Acknowledgments

This research was financially supported by Korea Institute of Ocean Science & Technology (KIOST), project no. PE99321.

References

Han TH, Yoon KY, Kang YJ. Compressive strength of circular hollow reinforced concrete confined by an internal steel tube, Construction and Building Materials 24(9) 1690-1699, 2010.

Havard ØOstlid, "When is SFT competitive", Procedia Engineering, 4 3-11, 2010.

Kanie S., Feasibility Studies on various SFT in Japan and their Technological Evaluation, *Procedia Engineering*, 4, 13-20, 2010.

Lidvard Skorpa Developing new methods to cross wide and deep Norwegian fjords, *Procedia Engineering*, 4, 81–89, 2010.

Martire G., Faggiano B., Mazzolani F.M., Compared cost evaluation among traditional versus innovative strait crossing solutions, *Procedia Engineering*, 4, 293–301, 2010.

Mazzolani F.M., Faggiano B., Martire G., Design aspects of the AB prototype in the Qiandao Lake, *Procedia Engineering*, 4, 21–33, 2010.