HYDRODYNAMIC BEHAVIOR OF SUBMERGED FLOATING BRDIGE WITH SUSPENSION SUPPRORT AFTER CABLE FAILURE

Deokhee Won, Halla University, thekey.won@halla.ac.kr
Jihye Seo, Korea Institute of Ocean Science and Technology, jhseo@kiost.ac.kr
Seungjun Kim, Korea University, rocksmell@korea.ac.kr

INTRODUCTION

Submerged floating tunnels with suspension supports (SFTSS) resemble to suspension bridges on lands, which are installed a number of hangers on the main tower and main cables to support the girder. On the other hand, as the SFTSS installed underwater has to resist the buoyancy and the forces in an offshore environment as shown in Figure 1, the main cable was installed at the bottom of the tunnel body and connected with a hanger.

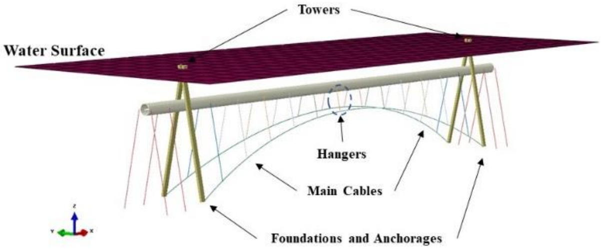


Figure 1 Submerged floating tunnel with suspension support (SFTSS)

The concept of the SFTSS was first proposed by Won et al (2019, 2022). It was found that the SFTSS was generated itself a tuned mass damper (TMD) effect due to the interaction between the body and the main cable. This can induce the vibration of the body to be attenuated according to the offshore environment conditions such as waves and currents, and had a feature that the length between the main towers can be longer than 3 km (Won et al., 2022).

The body of the SFTSS was supported by main cables and hangers as aforementioned. In case of the hanger was down by failures, the behavior characteristics of the SFTSS would be changed and be greatly reduced the structure safety. In this study, the behavioral characteristics of the SFTSS were analyzed according to five scenarios on the cable failure.

ANALYSIS MODEL

Won et al (2022) was compared the analytic technique with hydraulic experiments to analyze the behavior of a SFTSS using OrcaFlex, a specialized software for the finite element analysis of the fluid-structure interaction on offshore structures. In this study, it was performed using the analysis model verified by Won et al (2022) as shown in Figures 2 - 3.

The body of the SFTSS with a diameter of 23 m was being submerged at a depth of 28.5 m. The water depth was 250 m and the current speed was set to be 1 m/s. The body, hanger, and main cable were all modeled as the line element. The added mass coefficient and drag coefficient were applied 1.0 according to DNVGL C205 as shown in Table 1.

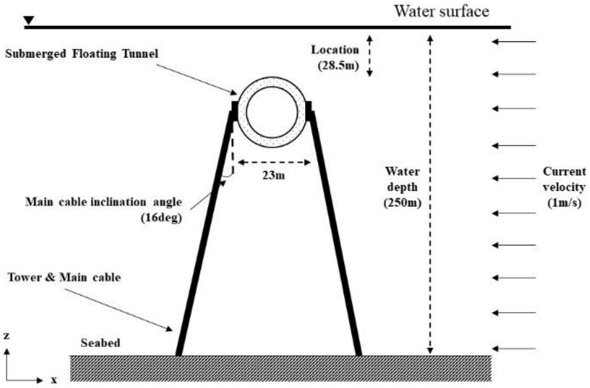


Figure 2 Cross section of SFTSS in x-z plane (Won et. al., 2022)

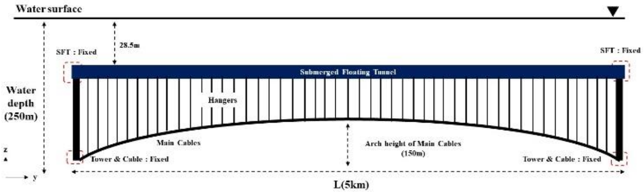


Figure 3. Cross section of SFTSS in y-z plane (Won et. al., 2022)

Table 1. Dimension of analysis model (Won et. al., 2022)

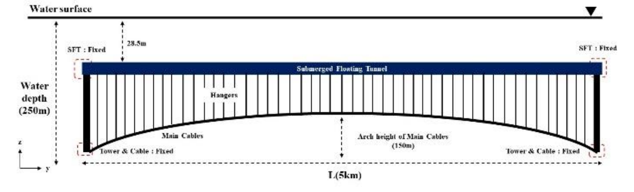
Articles	values	note
Tunnel Body		
Diameter	23.0 m	
Thickness	1.5 m	
Material	concrete	
Elastic modulus	30 GPa	
Added mass coefficient	1.0	DNV C205
Drag coefficient	1.0	DNV C205
Main cables		
Diameter	3.5 m	
Thickness	0.2 m	
Material	Steel tube	
Elastic Modulus	210 GPa	

Added mass coefficient	1.0	DNV C205
Drag coefficient	1.0	DNV C205
Hanger		
Diameter	0.32 m	
Material	Steel Wire	
Axial stiffness	6.464e6 kN	
Added mass coefficient	1.0	DNV C205
Drag coefficient	1.0	DNV C205
Tower		
Diameter	10.0 m	
Material	Concrete	
Elastic modulus	30 GPa	
Added mass coefficient	1.0	DNV C205
Drag coefficient	1.0	DNV C205

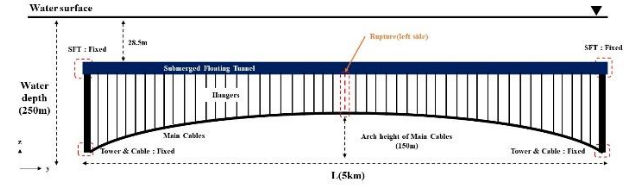
CABLE FAILURE CASES

Table 2 shows five cases of cable failure scenarios of the SFTSS. Table 2 shows five cases of cable failure scenarios of the SFTSS. Case 1 was a general condition without the cable failure as a comparison group. Case 2 was assumed that one hanger is fractured at the center of the body span, and Case 3 was set to be broken five hangers at the center of the span. And, Case 4 had five fracturing hangers where close to the tower. Finally, Case 5 was assumed that the anchor of the left side main cable was damaged. Here, the JONSWAP irregular wave with an effective wave height of 8.9 m and a wave period of 12.6 s was applied to these failure scenarios as shown in Figure 4.

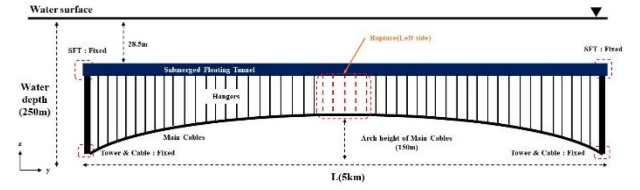
Table 2. Cable failure cases



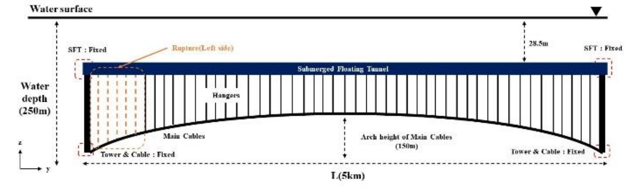
Case 1



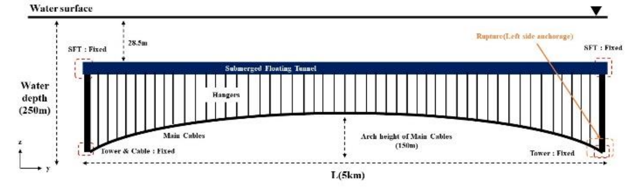
Case 2



Case 3



Case 4



Case 5

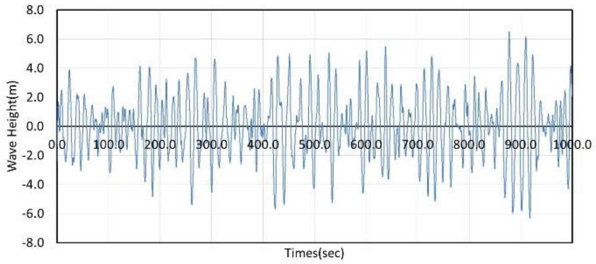


Figure 4. Wave propagation

Figure 5 plots the sway and heave motions of the body in the center of span under irregular waves. It can be seen that the Case 5, where the anchor part of the main cable was broken, had the greatest deformation. It can be judged that the body had lost its bearing capacity due to the anchor damage by the structural characteristics of the SFTSS in which the body is supported by the main cable and the hanger. Accordingly, the maximum acceleration of the body at center of the span was also the largest in Case 5 as shown in Figure 6.

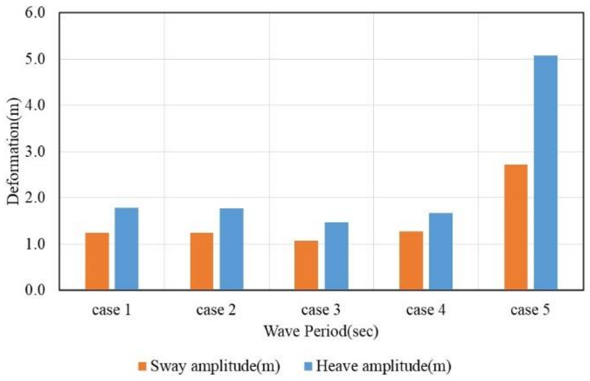


Figure 5. Motion of tunnel body at center of span

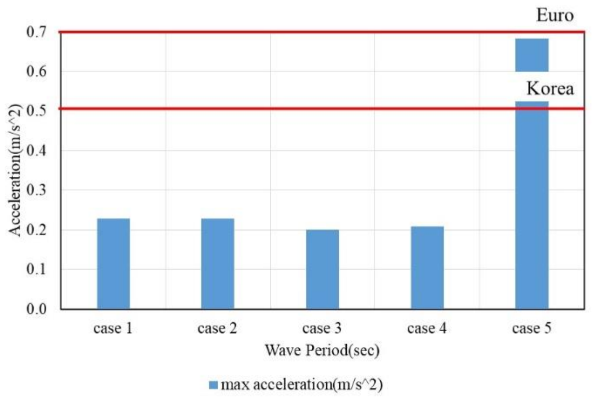


Figure 6. Maximum acceleration of tunnel body at center of span

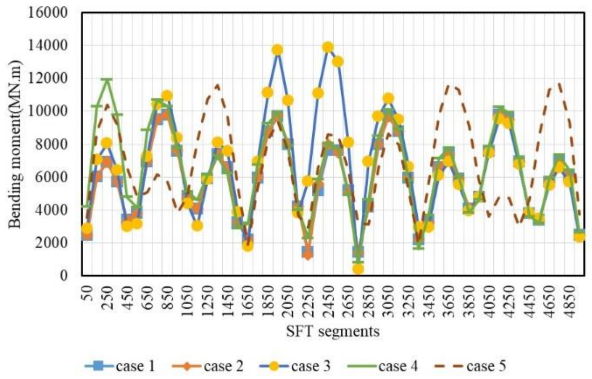


Figure 7. Bending moment diagram on tunnel body

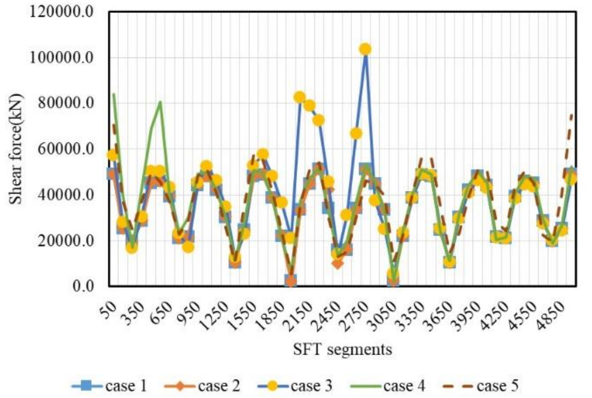


Figure 8. Shear force diagram on tunnel body

Table 3 Maximum tension increase ratio of hangers

Failure cases	Maximum tension increase ratio of hangers
Case 1	1.0
Case 2	1.74
Case 3	4.51
Case 4	4.38
Case 5	1.83

Figures 7 and 8 show the bending moment and the shear force on the tunnel body, respectively. For Case 3, as there were damaged five hangers at the center of the span, it can be seen that the bending moment and the shear force were greatly increased. In addtion, Table 3 lists the maximum tension increase ratio of hangers compared to that of Case 1. The hanger closest to where the cable broken in Case 3 was increased by 4.51 times compared to Case 1, and Case 4 also increased by 4.38 times, it was analyzed to exceed the fracturing tension of the hanger.

SUMMARY

In this study, the behavior characteristics of the submerged floating tunnels with suspension supports (SFTSS) were analyzed considering the cable failure. In the fracturing case of the one hanger, the tension of the nearby hanger was increased by a maximum of 1.74 times, but there was no significant deformation in its behavior. However, in the cases fractured as a cluster, it was analyzed that the internal force of the tunnel body was increased and have influenced. In addition, it can be seen that the failure of the main cable rather than the that of hangers had the greatest influence on the overall behavior for the SFTSS.

REFERENCES

Deokhee Won, Woo-Sun Park, Seungjun Kim (2022) Vibration characteristics of submerged floating tunnels with suspension cables according to wave periods, Ocean engineering, 254, 11343

Deokhee Won, Jihye Seo, Seungjun Kim, Woo-Sun Park (2019), Hydrodynamic behavior of submerged floating tunnels with suspension cables and towers under irregular waves, Applied science, 9(24), 5494

Funding: This study was funded by the Korea National Research Foundation (grant number NRF-2018R1D1A1B07050335 and 2017R1A5A1014883)