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Simplified analysis for estimation of the behavior of a submerged floating tunnel in waves and experimental verification

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A B S T R A C T

To achieve rational design in waves for a submerged floating tunnel which has emerged as a new offshore transportation infrastructure, it's necessary to understand its hydrodynamic behavior. For simple but accurate estimation of hydrodynamic forces, a theoretical method is proposed and the tests with physical models in a wave flume were carried out for verification. Morison's equation was used to estimate wave loads composed of inertia force and drag force. Forces calculated by applying the linear wave theory to Morison's equation coincided well with those measured by the tests. The test results showed that mooring systems played a significant role in the movement of the submerged floating tunnel in waves. A pendulum model could be used to describe the motion of the submerged floating tunnel with a single vertical mooring. Based on the verified relations, a simple slack condition which causes the submerged floating tunnel to be unstable was also proposed. The simplified approach proposed by

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this study proved to be useful in designing the submerged floating tunnel in the initial stage.

1. Introduction

A submerged floating tunnel (SFT hereinafter) shown in Fig. 1 is an underwater offshore transportation infrastructure shaped in the form of a tube which maintains a buoyancy exceeding the weight balanced by the tension of mooring lines. Though the concept of SFT was introduced some time ago, it has yet to be realized due to a lack of safety assurance [1]. An SFT can be manufactured on land before fabricating it on water, which can significantly shorten the installation schedule, as well as mitigate the risk of a long-distance undersea excavation and reduce the cost. Subsea tunnel connecting a big island to the main land has been proposed for high speed railway service in Korea, but economic feasibility study revealed less benefit than cost [2,3]. As such, a submerged floating tunnel can potentially serve as a means of long-distance marine transport, and would offer such benefits as the reduction of potential risk. A long-distance SFT is a particularly optimal alternative for railway infrastructure shown in Fig. 2 in terms of safety and efficiency. Various studies have been underway to realize SFT [4,5], but for construction and operation in practical manner, it's absolutely necessary to identify the environmental factors related to SFT and establish the appropriate measures to address them.

SFT maintains stability through a balance between buoyancy and tension, but it is continuously exposed to wave effects on the body from the free surface. The waves in the sea tend to have particle velocity, which decays exponentially when sea-bed is deep, but the motion of particles on the free surface tends to have some effect on the body to a considerable depth when the sea-bed is not deep [6]. For an SFT to be safe during its whole life, designing it in preparation for potential wave loads is a must.

The concept design of a prototype SFT was carried out for the extreme environment conditions of South Sea of Korea as shown in Figs. 3 and 4. The sea level is 60 m below the free surface, while the tunnel structure is floating 40 m below the surface. Its inner diameter along the long axis is 15 m and along the short axis 13 m. It is designed to restrain the tunnel structure which goes up by buoyancy with tension force of mooring system. For complete water-tightness, outer and inner shells are made of steel materials and to maintain the buoyancy at certain level the space between shells is filled with concrete. Inner shell also contributes to achieving the dual watertight system. A module is fabricated at intervals of 100 m and outer shell is fastened with bolts on free surface and preassembled before assembling completely in the water. Fixed-type structure for evacuation and ventilation is prepared at certain interval [3]. Mooring system is linked to piles in the sea-bed so as to convey the tension force to

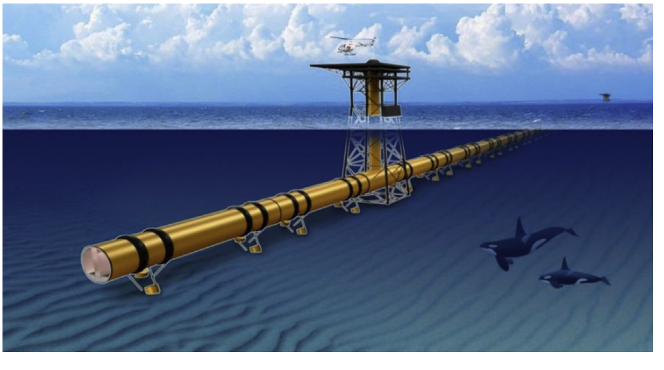

Fig. 1. SFT.