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Design and construction of the GK immersed tunnel of Busan-Geoje Fixed Link Project

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국내 최장 GK 침매터널의 설계 및 시공

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Abstract The GK immersed tunnel as a part of Busan-Geoje Fixed Link Project, is the first attempt in Korea. In spite of existing of many difficulties in construction like the absent of construction cases in Korea, the connection work under approximately 50 m below sea level and weak ground condition, etc., now eight caissons were installed successfully on the accurate position and we are going to install upto the twelfth caisson in this year. The purpose of this paper is to introduce design and construction conditions of the GK immersed tunnel to advise the tunnel designers who will handle the similar project.

Key words GK immersed tunnel, longest caisson, fast track

초 록 GK침매터널은 침매터널공법으로는 국내 최초이다. 국내 시공사례의 부재, 최대 수심 약 50m에서 이루어지는 침매함체 연결 및 연약지반 등 시공상 많은 어려움에도 불구하고 현재 여덟 개의 침매함체가 성공적으로 시공되었으며 올해 안에 열 두번째 함체까지 시공될 예정이다. 본 논문의 목적은 GK 침매터널에 대한 설계 및 시공 조건을 유사 프로젝트를 수행하는 터널공학자들에게 소개하여 용이하게 프로젝트를 수행할 수 있게 하기 위함이다.

핵심어 GK, 거가대교, 침매터널, 최장함체

1. INTRODUCTION

Busan-Geoje Fixed Link Project (Fig. 1), has applied the Fast Track system whereby design and construction are carried out at the same time.

The site locates in an exposed offshore, which is affected to strong winds and strong tidal currents. The ground condition is consisting of a very soft, normally to slightly over-consolidated marine clay that will make the differential settlement along the immersed tunnel. Moreover, the deepest point at a bottom of the tunnel is approximately 50 m under the sea level (Fig. 2). And the caisson as a unit of the tunnel consisting of 8 segments with each 22.5 m long has the longest length in the world. The total length of the caisson is 180 m. On this account, the GK immersed tunnel becomes one of the most challenging immersed tunnels ever built in the world and attracts worldwide attention.

Fig. 1. The layout of GK immersed tunnel

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2. DESIGN

2.1 Geological Condition

The ground of the site consists of very soft marine clay, marine sand (alluvial deposit) and bed rock from the top layer (Fig. 2).

The marine clay is definitely classified by marine clay with $\omega_n > 65\%$ and intermediate marine clay with $\omega_n \leq 65\%$ (here, ω_n is natural water content) and well distributed through the job site. The thickness of marine clay layer along the immersed tunnel alignment is approximately over 20 m. The material properties of the marine clay are shown in Table 1.

The alluvial layer between clay and rock is consisted of gravel and sand. And their mechanical properties are so good that the influence of this layer to immersed tunnel could be ignored.

The bed rock (Andesite) has physically 22.0~147 MPa unconfined compressive strength.

2.2 Prereinforcement for ground improvement

Ground improvement was planed to minimize the ground settlement because that the thick clay layer along the tunnel alignment. Ecpecially, in the case of immersed tunnel settlement control is very important work because of the connection two caissons using an immersion joint under sea water which needs very strict accuracy and a leakage risk of the tunnel.

SCP (sand compaction pile) and CDM (cement deep mixing) were adopted as the ground improvement method. The plane and specification of each methods are shown in Fig. 3 and Table 2.

2.3 Caisson

The caisson as a unit of immersed tunnel was designed as RC (reinforced concrete) structure. The compressive strength of the concrete is 35 MPa and the steel bar is SD40. The geometry of typical cross section of a caisson is shown in Fig. 4.

GK immersed tunnel is constructed with 18 caissons

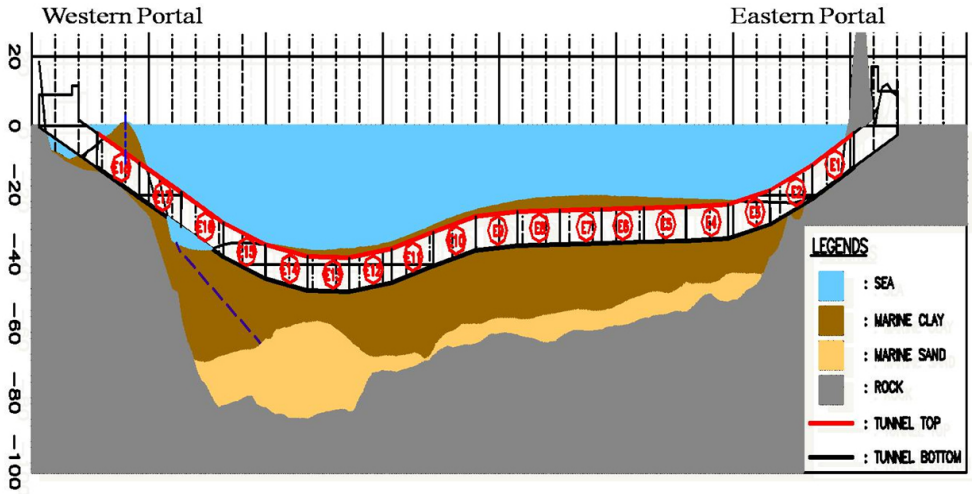


Fig. 2. The strata profile of GK immersed tunnel

Table 1. Material properties of the marine clay and intermediate marine clay

	Marine clay	Intermediate marine clay
Natural water content	> 65%	≤ 65%
Specific gravity	Avg. 2.69	Avg. 2.69
Plasticity Index	Avg. 63%	Avg. 31%
Liquid Limit	Avg. 90%	Avg. 75%
Activity	0.74 ~ 1.58	0.55 ~ 1.78

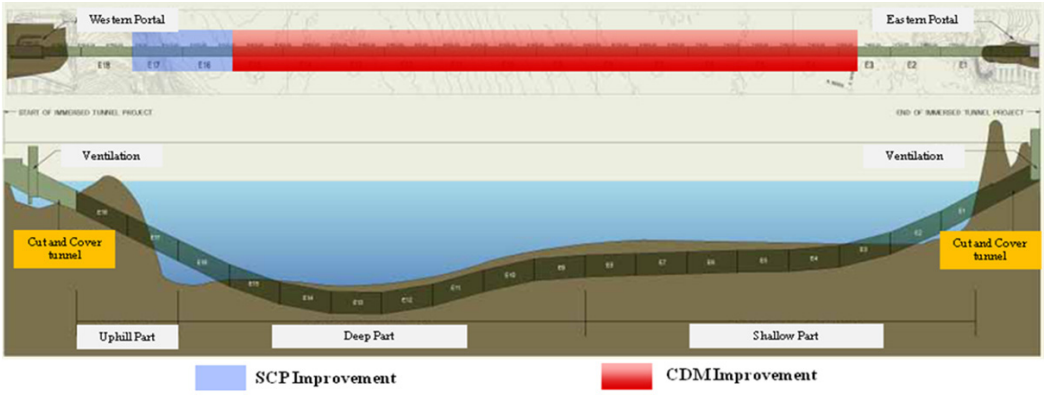
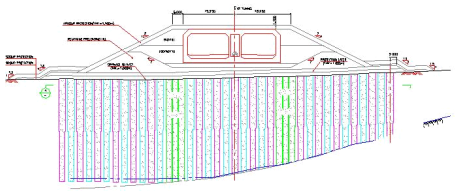
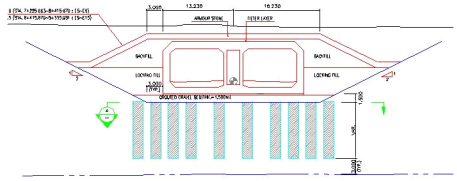


Fig. 3. The plan of ground improvement

Table 2. The Specification of SCP and CDM SCP

SCP (Sand Compaction Pile)		CDM (Cement Deep Mixing)	
Improvement Depth	Avg. 20 m	Improvement Depth	Avg. 13 m
Improvement Ratio	40~61%	Improvement Ratio	32~51%
			

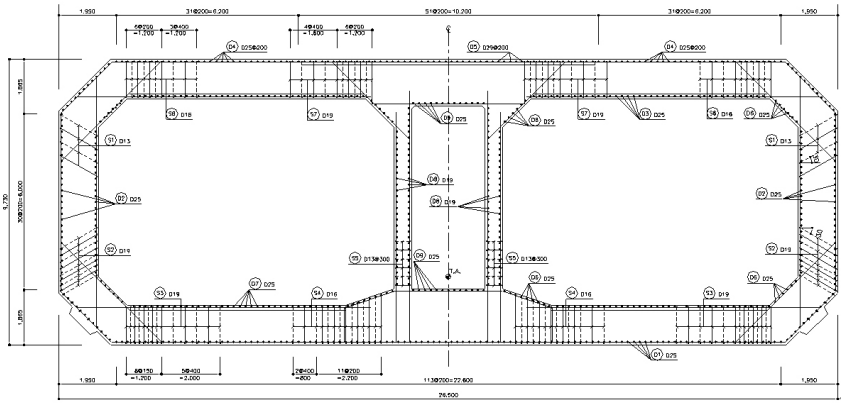


Fig. 4. A typical cross section of a caisson

from E1 to E18. Each caisson is composed of 8 segments which are 22.5 m long and it's total length is 180 m (Fig. 5).

2.4 Immersion Joint

Two caissons are joined using an immersion joint under sea water. All immersion joints of GK immersed tunnel are equipped with Gina gasket M34 and an Omega seal OS400/100 which is installed later inside the tunnel as a secondary line of defence.

The Gina gasket is the initial seal between the tunnel elements. It is loaded with a compression force corres-

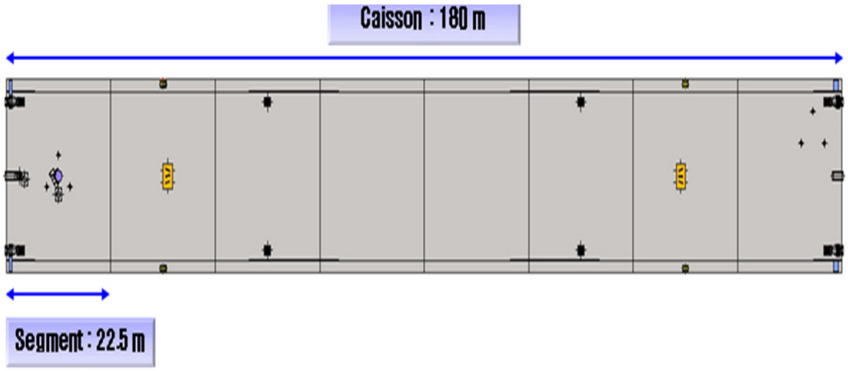


Fig. 5. The schema of a caisson

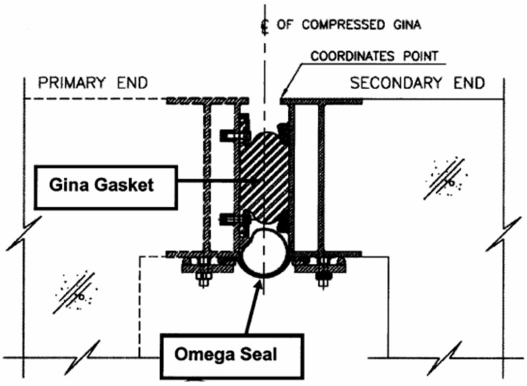


Fig. 6. Immersion joint seal configuration

ponding to the water pressure inside the Gina perimeter. Over time relaxation of the rubber will cause the force in the Gina to decrease. Two effects are taken into account in the design.

The Omega seal is installed inside the Gina gasket as shown on Figure 6 and which is clamped to the inner part of the steel frame by means of clamping strips. The clamping force was calculated taking the following factors into account: Tension in the curved part of the Omega seal, Water tightness, Relaxation of clamping force.

The principal layout of an immersion joint is illustrated in Fig. 6.

3. CONSTRUCTION

The construction procedure of GK immersed tunnel is broadly divided into four steps as follows: manufacturing of a caisson, floating and transportation, mooring, immersion and connection.

3.1 Manufacturing of a caisson

All caissons of the immersed tunnel are manufactured at a dock located near the construction site to guarantee a good quality.

3.2 Floating and transportation

After manufacturing the caissons, the space of dock is filled with sea water until the inner water level becomes identically equal to the outsider water level. Then the caissons will be floated by their buoyancy and towed by tugboats to the mooring place.

Fig. 7. The features of floating and transportation of caissons

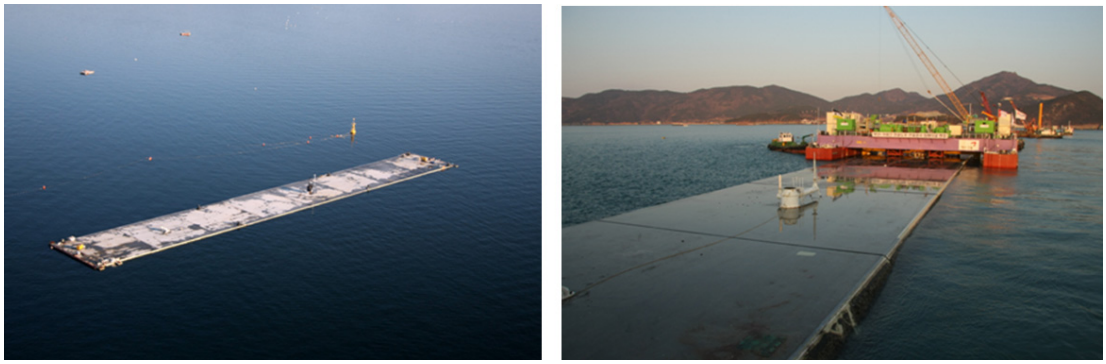
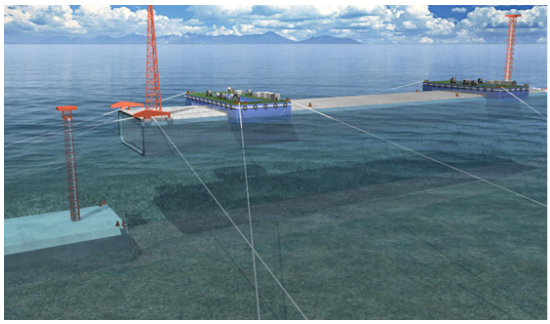
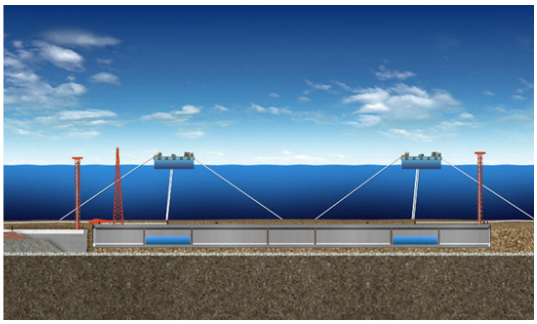


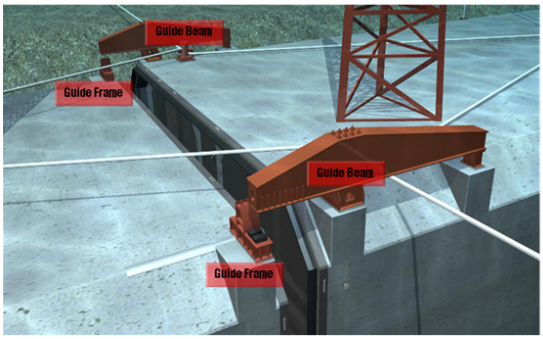
Fig. 8. The features of mooring



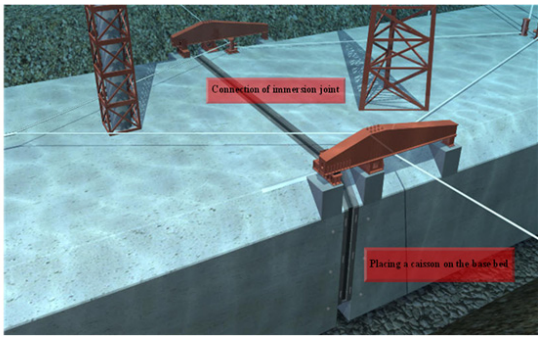
1) Connecting wire to pontoon and caisson



2) Filling the water tank



3) Immersing the caisson through adjusting wire



4) Connection the caisson to primary one

Fig. 9. The detailed procedure of immersion

3.3 Mooring

While mooring the caissons, some accessories should be installed for immersion and joining work of caissons.

3.4 Immersion and Connection

After finishing the trench dredging, gravel filling and protection works of the base ground, the caissons are towed to the immersion point by tugboats. Since this activity is very crucial, weather condition should be checked prior to start it. Then the caissons are immersed at the accurate install point using by pontoons. The detailed procedure of this work is shown in Fig. 9.

4. CONCLUSIONS

The GK immersed tunnel is the first time in Korea. And it is constructed under very high water pressure and weak ground condition. On this account, the prevention

of ground settlement is very important because it could cause many problems in the following works. SCP and CDM were adopted as a ground improvement method.

Immersion joint is one of the salient characteristics of the immersed tunnel because the breaking of the joint necessarily leads to serious problems such as an inflow of sea water. So, it needs to check the factors carefully which might have influence on the behavior of the caisson joints.

The immersed tunnel construction work can be performed into following four steps.: manufacturing of a caisson, floating and transportation, mooring, immersion and connection.

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