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Precast segment method for Immersed tunnel in Singapore

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Introduction

The immersed tunnel was constructed at Tuas, Singapore from 1996 to 1998 using tunnel elements which were fabricated by precast segment method. This method has not been used for the immersed tunnel in Japan. As this method provides some advantages in terms of the yard area, construction period and cost, and with quality of the tunnel structure in comparison with the prevalent method in Japan. As such, this precast segment method is considered to be one of the better methods to construct the immersed tunnel.

Outlines of Project

The length of this undersea tunnel in Singapore is approximately 2.1km with 11.79m wide and 4.425m high. Its size is a slightly smaller than an ordinary railway tunnel. This 1.9km immersed tunnel of 21 nos. of tunnel elements, comprising of 16 nos. of 100m long straight elements and 5 nos. of curved elements of length ranges from 52.2m to 85.1m. The design consideration on the proposed route for the immersed tunnel involved two(2) nos. of curved portion in the horizontal alignment as well as the steep slope of gradient 1 in 12 in the vertical alignment at the approach areas towards the terminal buildings which are located near the shore. Please refer to Fig.1 of the immersed tunnel route and Fig.2 showing the sequence of construction of this immersed tunnel.

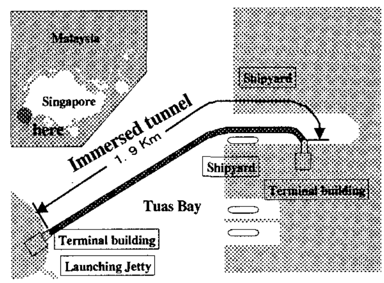

Fig. 1 Location of Project

Pre-cast segment method

Based on the Flow Chart shown in Fig.3, the tunnel elements were produced accordingly.

(1) Pre-cast segment construction

23 nos. standard segments with 2 nos. end segments were required to produce one(1) no. of 100m long straight tunnel element. The length of each standard segment is 4m with its weight of 230 tons. These segments were cast vertically in rigidly-held steel mold which consists of an outer form and two(2) collapsible inner forms.

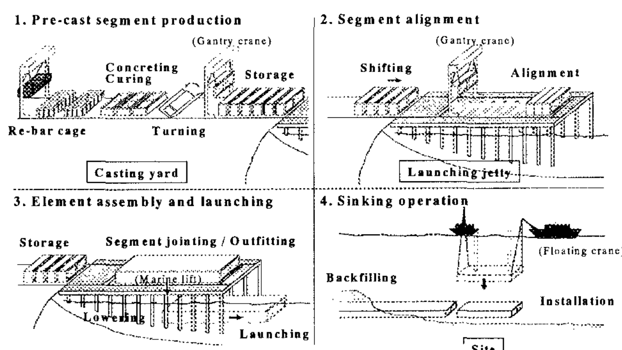

Fig. 2 Construction sequence

Before each casting, the reinforcement cage was vertically installed into the steel mold together with required number of ducts for prestressing cable. Then, concrete will be poured and the segment in one operation.

Under normal conditions, the casting yard produced 2.5 nos. segments per day. The forms were removed after a minimum of 12 hours and the curing of the segments was carried out for four days. Thereafter, the segments were rotated by 90° using the turning frame and the gantry crane. The turned segments were then transported to the storage area in the horizontal position. At the storage area both ends of the segments were grit-blasted to expose the aggregates in order a good key for the non-shrinkage mortar in between the segments to be formed.

(2) Element assembly and launching

The launching jetty was constructed on the extension end toward the sea. This will enable the 240 ton capacity gantry crane to move to and from the casting yard and jetty on the rail track. The jetty was 150m long with its width of 50m. There are two(2) rows of 18 nos. jacks with each capacity of 350 tons supporting the marine lift. These jacks are synchronized and are used to lower or raise the element on the marine lift.

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The 25 precast segments were aligned longitudinal along the marine lift of the jetty. The next step was to grout the 24 nos. of 20mm wide gaps in between the segments with non-shrinkage grout. Prior to grouting, the temporary prestressing tendons at the four(4) corners were stressed to resist grout pressure. In order to prevent ingress of grout into the empty cable ducts, mortar spacer blocks were set around the prestressing ducts at the segment joints prior to grouting. Once all preparation work was ready, the segment joints were grouted. Thereafter, a 500mm wide waterproofing membrane was applied at each segment joint on the exterior surface. Once the segment grout achieved the necessary strength, the remainder 45 nos. tendon ducts were then stressed in accordance to the stressing procedure. After the stressing was completed, the ducts were flushed with water and grouted with low viscosity grout mix.

Gina gasket was fitted on one end of the tunnel element. The bulkheads with access door were then installed at both ends of the element.

Finally the buoyancy tanks and the vertical jacks were outfitted, which completed the assembly of the tunnel element process. Thereafter, the tunnel element on the marine lift was lowered into the water for duration of 12 hours for watertightness test or known as leakage test.

After the confirmation on the leakage test, the tunnel element was floated by buoyancy tanks at both sides of the element and towed to the area along the side of the jetty for mooring. Ballast concrete was then placed on the top of the element in order to achieve the required weight ratio shown in specification. Then, the survey towers and other temporary ancillary outfits for the sinking operation were installed on the top of the tunnel element.

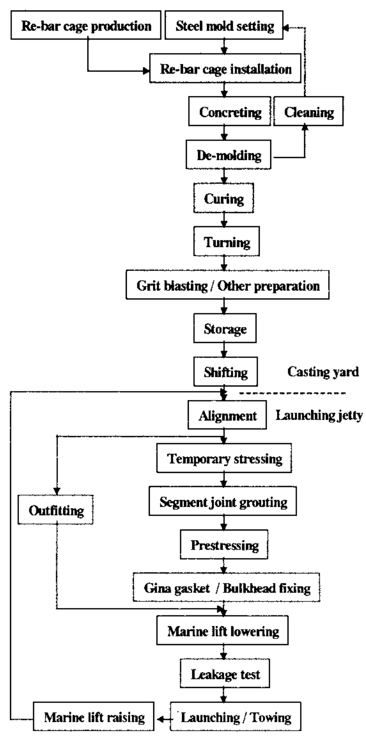

Fig 3. Flow chart of Tunnel element production

Now, the tunnel element is ready for the sinking operation.

Characteristic of Pre-cast segment method

The comparison between this immersed tunnel and the prevalent method where the tunnel elements are built in a dry dock is shown in Table 1.

Table 1. Comparison between the two methods

	The pre-cast segment method	The prevalent method (using a dry dock)
Merit	-The construction period and cost could be reduced. -The working area doesn't need to be so large. -The watertightness of the tunnel element can be ensured without any outer waterproofing.	-Any size of tunnel can be planned. -Any type of structure can be designed. (ex. Steel type, Hybrid type etc.)
Demerit	-It could be not appropriate for a large size tunnel owing to the capacity of cranes and marine lifts.	-A dry dock for shipyard could be limited for wideness, depth and so on. -A temporary dry dock could be limited for area and soil condition. -The measures for the hydration crack should be a consideration.

The working space in this method does not require an area as large as a dry dock. The precast yard, the storage yard and the launching jetty are the necessary items required for the immersed tunnel described above. There is a reduction on the construction period in this method as the sinking operation of the tunnel elements can be carried out concurrently with the production of the tunnel elements. The earliest cycle time is 12 days with 24-hour working and as such, one(1) no. of 100m length element can be produced in every two(2) weeks. In addition, the quality of concrete can be achieved, as there is no cold joint or any possible hydration cracks using the segment construction method. In undersea tunnel construction, the watertightness and the durability of the tunnel which are important factors, must be ensured without any outer waterproofing.

Conclusion

This method is a better than the prevalent method used in Japan especially for the long and small-scaled immersed tunnel. Therefore, it can be used as one of the options in the immersed tunnel construction method and can be analyzed and used in Japan.