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Underwater tunnel under the Dead Vistula river in Gdańsk

Underwater tunnel under the Dead Vistula river is located in Gdańsk, which is the largest city in the Northern Poland. Gdańsk is the Polish maritime capital and large economic and industrial centre, science, culture, and a popular tourist destination during vacation season. It is located on the Baltic coast and it is Poland's principal seaport and fourth the most important metropolitan in all country.

Tunnel is a linkage between 2 crucial for regions economy industrial zones - Gdansk airport and Northern seaport as well as opens a high capacity road success to the harbour. The tunnel is constructed in a way to connect two routes: one headed towards the airport and the other one headed straight to the harbour. Tunnel building was a part of a huge investment performed by main contractor OHL of Spain. The cost of investment is more than 250 million euro and it included several projects like road reconstruction, building a new parts, additional communal works etc.

When it comes to the design of the tunnel, it consist of two tubes of 12.5m and it is the largest diameter tunnel in Poland. The total length of the tunnel is 1.4km and its lowest point is at 35m. The tubes are linked with 7 emergency exists designed for pedestrians to pass. The average capacity of cars passing through tunnel is more than 1000cars/h.

Methods used to build a tunnel

The building of the tunnel required to use two basic methods: boring with Tunnel Boring Machine (TBM) and Cut-and-cover method. The majority of the tunnel including the main part that is underwater was built using machine called TBM. Due to difficult conditions it was crucial to choose the best possible method that will provide expected results. TBM method is mostly used for long tunnels because it ensures quick work progress but also precision and high quality performance.

The machine used under Dead Vistula river was named Damroka and it is the biggest boring machine ever used in Poland with its diameter 12.56m and 91m length. There are different types of TBM machines but for the sake of this project TBM Mixshield machine was specially designed by German company Herrenknecht. The basic con of this structure is an advance on conventional slurry technology. The support pressure in the excavation chamber is precisely managed using an automatically controlled air cushion. That means that the geologies and high water pressures of more than 15 bar can be controlled safely even with very large excavation diameters.

Before the boring in Gdańsk began, firstly the steel chamber using Cut-and-cover method was built. The machine was placed and the incitation of first tube was on. The head of the machine starts working and excavates the soil using disk cutters. The output is later transferred to a belt conveyor and removed outside the tunnel. After making the free space, the prefabricated segments are placed in designed sequence. The machine continues through the tunnel by hydraulic thrust cylinders that push the machine forward. The process repeats itself until the end of the tube. After finishing, machine was transported again to the chamber and the second tube was drilled.

Another method used to built the tunnel is called cut-and-cover method. It is one of the first methods introduced to hydrotechnics due to its simplicity. In a cut and cover tunnel, the structure is built inside an excavation and covered over with backfill material when construction of the structure is complete. Cut and cover construction is used when the tunnel profile is shallow and the excavation from the surface is possible, economical, and acceptable. There are two type of this method: Bottom-up and Top-down. In Bottom-up method the final structure of the tunnel is independent of the support walls.

In tunnel under the Dead Vistula river the top-down method was used. In comparison to the bottom-up method, the tunnel's roof and ceiling are the structural parts of the support of excavation walls. Excavation is carried out through the technological openings in the tunnel roof. The method was used to built the driveways and connections to the routes on both sides of Dead Vistula tunnel. The whole construction covers the building of 81 segments.

Difficulties

Building tunnel under water always comes with many difficulties. It is very important to take into consideration the impact of water pressure, ground water penetration and hard geological conditions. While boring under Delta of Dead Vistula River engineers had to deal with very difficult hydrological states such as: alternating layers, sediments, muds, soft grounds, high groundwater level and low-strength soils.

That is why the special TBM Mixshield machine was used. Its system and design provides perfect performance in hard and soft soils. Thanks to construction of the machine special materials to protect the soil can be injected while boring. In very hard soils jaw crushers are used to deal with big rocks.

Due to low-strength soils the emergency exits needed to be done using ground freezing method to reinforce the soil. Ground freezing is a construction technique used in circumstances where soil needs to be stabilized so it will not collapse next to excavations, or to prevent contamination spilled into soil from being leached away. Method involves pipes run through the soil to be frozen, and then refrigerants are run through the pipes, freezing the soil which in the end can be as hard as concrete. This method has been used for at least one hundred years. In tunnel's project engineers had to face some problems with the time of freezing, so the whole process lasted 12 weeks instead of 4 as in assumptions.

In the parts where cut-and-cover method was used the biggest difficulty was obviously unpredicted behaviour of water, so to protect the excavation there had to be used different lengths of slurry walls.

Social and logistical importance

Apart from technical and innovative importance, building of tunnel has social and logistical benefits.

First of all, tunnel has been built to relieve busy city centre from heavy traffic. It causes changes in traffic flow in all city including the restrictions for trucks over 24 tonnes to enter the city. Tunnel relieves heavy traffic in a city with almost 1 million inhabitants which leads to shorter traveling time, better time management and indirect economic benefits for society.

Secondly, inhabitants from nearby regions of Gdansk have easier and faster access from the one side to capital city Warsaw, from the other- touristic places on Baltic seaside. Shorter traveling time to Warsaw means better connection between 2 main business and industrial zones in Poland and leads to, primarily, to better time efficiency and business management in overall. Additionally, the introduction of new bus line which connects airport and harbour is simplifying tourist movement throughout the city as well as relieving traffic on the roads connected with the seaside during vacation season.

Tunnel facilitates logistics between the two economically important spots in region of Gdansk - North port in Gdansk and airport what brings certain benefits in terms of time management and cost optimisation. Supply chain and other transportation companies have a possibility to become more competitive also internationally, while providing faster delivery, therefore better customer service.

Moreover, it has roads for the bikes, which simplifies movement for growing number of cyclists in the city and indirectly affects society's quality of life.

The tunnel is considered by polish authorities as an impressive investment that has important local and regional impact in the mobility of the area. It gave polish engineers a chance to get familiar with a new modern method using special Tunnel Boring Machine that is now the future of tunneling. Despite many obstacles on the way such as difficult geological conditions and unexpected behaviour of the water, the tunnel was finished and became a huge success. It was a bold and unique challenge from an organisational and engineering point of view. Apart from technical importance, the tunnel help citizens of Gdańsk by reducing traffic in the city centre and introducing new link between the airport and the harbour. This link will bring many profits for the whole country, making it internationally important.