Shoring and construction of an underpass below a box culvert in Singapore Marina Bay using the GRUNDORAM pipe pushing technique

**Scope of work**
Construction of an Underpass below a huge box culvert and parallel to a technical tunnel (so called CST for Combine Service Tunnel)

**Size of the Underpass**
12 meters wide x 7 meters height x 12 meters long.
Depth bottom slab 14.5 meters from the existing ground level

**Surrounding existing structures**
Above the underpass to be constructed Box culvert 10 meters x 6 meters height which carry 3 to 4 meters of water permanently. This box culvert is also the support of an access road opened to traffic.

**Mains difficulties and constraint**
Soil geotechnical conditions:
The soil is reclaimed land taken from the seabed. A top layer of 8 meters backfilling sand and then marine clay as subsoil. The water table was 2 meter below the ground formation.

Combine service tunnel constructed on bore piles. The authorities allow a 15 mm maximum displacement of the CST

Box culvert constructed on bore piles
The underpass has to be built between the existing bore piles supporting the box culvert. (The lateral clear gap between the underpass structure and the bore piles supporting the box culvert is 400 mm on one side and 800 mm on the other side) The gap between the underpass top slab completed and the under side of the box culvert was only 500 mm.
A vertical shoring (like sheet pile, bore pile, soil improvement) was not conceivable due to the fact that the vertical shoring should be drive through the road and through the box culvert full of water before reaching the area to be treated. (With drastic regulation about water pollution and silt content)

Horizontal shoring was the only sound solution. Pipe jacking with a micro tunnel machine was considered to be slow and expensive.

**The solution**

Finally due to the above constraints a solution was provided by using a relatively light pipe ramming machine: a Grundoram weighing less than 1 tonne. A rammer is a big impact hammer which does not need an abutment wall or special reaction support. The rammer can push pipe or H-Beams horizontally and also vertically. Very simple to operate and require only a compressor with high pressure
and high volume of air output. The H beams 400 x 400 x 237kg/m x 12 meters were pushed one by one to create 2 lateral walls and an horizontal bottom row. The upper part was in fact the underface of the exposed box culvert acting as a protecting roof.

**The site implementation**

On site, 2 cofferdams have been constructed on both side of the box culvert to build the underpass.

One side was structurally completed and it is from the other side that the ramming was operating. As the excavation was deep more than 15 meters, several layers of strutting was necessary (5 in total) making the ramming difficult. Scarcity of space and difficulty to unload the 12 meters beams between the strutting to the launching area.

So it became obvious that the ramming sequence should be done concurrently with the excavation and strutting. Instead of completing the excavation and strut and then start the ramming.

It means that when the stage of the excavation level was reached and prior to the installation of the next layer of strut, the ramming was done in a sequence from 3 to 6 beams (according to the distance between two layers of consecutive strut)

The concrete launching platform was in fact seated on the excavated area. The sheet pile was opened to let the H beams go through and rammed to the next extremity. When the H beams punched the sheet pile in the other side then the sheet pile was cut to let the beams go through.

When the sequence of ramming was completed then the strutting started again followed by excavation for the next stage of ramming.
When the ramming and strutting was completed, the existing structure was extended to embed the extremities of the H beams in the concrete and achieve a rigid support on both sides. The excavation of the underpass was then started.

First operation was to open the sheet pile and let the excess water and mud flow through the opening until the opening was big enough to allow a mini excavator to operate.

When the excavation was completed the 2 support walls and bottom beam layer showed a good connection between all the H beams.

The construction of the structure then commenced in a conventional way except for the casting of the top slab which required the team to pour and vibrate the concrete into position.

Based on past records, The Sail site is the first site that has used the Grundoram Gigant ramming technique in such a difficult restricted working environment.

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