# The TISB and the TMF Concepts: Application on a Proposal for a Roadway Tunnel Crossing the Tagus River in Lisbon

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## Summary

The paper presents two innovative and cost-effective concepts for the construction of tunnels using the tunnel boring machine (TBM) technique: the TISB concept for tunnels executed in soft soils (e.g., alluviums), in seismic areas; and the TMF concept, which allows for the use of a single tunnel that provides the capabilities usually obtained with two parallel roadway tunnels. The paper also presents a proposal for a roadway tunnel (now under study), crossing the Tagus river, in Lisbon, in which these concepts are applied.

**Keywords:** Tunnels, Roadways, TBM, Soft soils, Earthquakes, TISB, Crossings, TMF, Lisbon

## 1. Introduction

When executing a tunnel with a TBM, the machine excavates the soil and places precast segments, which are linked together, in order to form its circular wall, reducing costs and time.

In the case of soft soils (mud, etc), the execution of tunnels with a TBM is unreliable because, in the tunnel thus formed, the connections between the precast elements are weak, hence the strength of the tunnel is low, so there is the risk of sinking, or of collapsing, particularly during an earthquake.

On the other hand, in the case of long roadway tunnels (typically, tunnels spanning more than 500 meters), it is necessary to build two separated tunnels, one for each sense of traffic, so that, for ventilation and smoke removal purposes, the air will circulate in one sense only, the sense of the traffic. In addition, it will be necessary to build evacuation routes and access galleries along the tunnel to allow for access to the interior of the tunnel and the evacuation of persons in case of accident or fire inside the tunnel.

## 2. The TISB concept

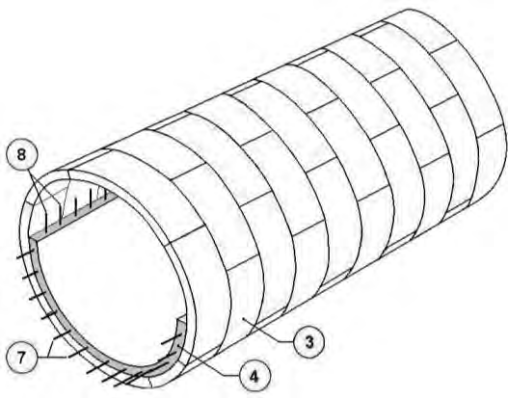


*Fig 1: The TISB concept: Detailed perspective of the tunnel*

The TISB ("Tunnel of Improved Seismic Behaviour") concept constitutes an innovative solution for the construction of tunnels of the roadway and the railway types, executed with TBM technique, when the referred tunnels are executed in weak soil (e.g., mud), allowing for the tunnel be provided with the necessary strength and ductility. The TISB concept is illustrated in Figure 1.

The tunnel is constituted by two tubes in concrete; an exterior tube (3), which is built by the TBM in the weak soil, and an interior tube (4), which is executed later on, inside the exterior tube. The exterior tube (3) is formed by precast elements, which are mounted by the TBM. The interior tube (4) is cast inside the exterior tube (3), with the help of a supplementary interior formwork. Inside the thickness of the interior tube (4) longitudinal and

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transversal reinforcements (7) (8) are placed in order to provide the tunnel with the necessary strength and ductility to resist the vertical and the horizontal actions that may act on the tunnel.

## 3. The TMF concept

The TMF ("Tunnel Multi Floor") concept constitutes an innovative solution for the construction of roadway tunnels made with the TBM technique, allowing for the creation of two identical road galleries, isolated and independent, and a service gallery for the installation of emergency vehicles, for easy access and evacuation of persons in case of accident or fire inside the tunnel [6]. The TMF concept is illustrated in Figure 2.

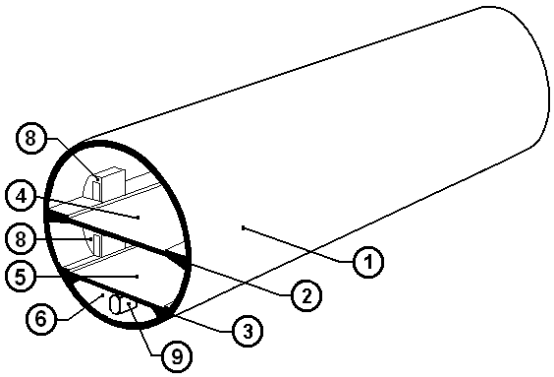


*Fig.2: The TMF concept: Perspective of the tunnel*

The TBM excavates the soil and places precast segments, which will form the wall of the tunnel (1). Inside the tunnel two slabs (2) (3) are executed, at its full width, one placed roughly at half the height of the tunnel and the other placed a bit over the bottom of the tunnel, in order to form three overlapping galleries, isolated and independent: two roadway galleries (4) (5), one for each sense of traffic, and a service gallery (6).

Placed close to the circular wall of the tunnel (1), openings (7) are created, regularly spaced, and protected with fireguard devices of box type (8). The superposed fireguard devices (8) are connected through closed vertical access galleries (10), inside of which interior stairs are installed to allow for safe passage of persons from the road galleries (4) (5) to the service gallery (6), or vice versa. Inside the service gallery (6), emergency vehicles of shuttle type are installed (9), to allow for easy access of the personnel and the evacuation of persons in case of accident or fire inside the tunnel.

## 4. Proposal for the Algés-Trafaria tunnel, in Lisbon

The Algés-Trafaria roadway tunnel will cross the Tagus river, in Lisbon, Portugal, closing the regional inner ring of the Lisbon region, formed by the CRIL (on north), the CRIPS (on south) and the Vasco da Gama bridge. The tunnel will be built in weak soil (mud, etc), and in a very prone-seismic area. It will be 5,1 km long, of which 2,25 km under the river (Figure 3).

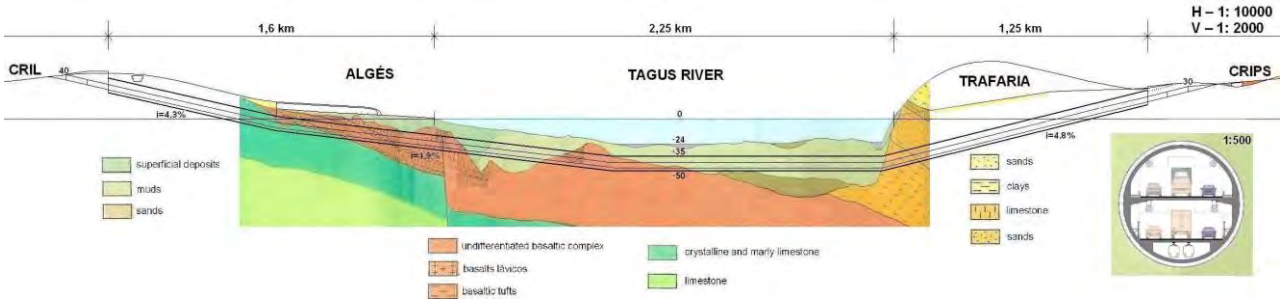


*Fig. 3: The Algés-Trafaria tunnel, in Lisbon (proposal): elevation and cross section*

Based on the TISB concept, the tunnel built with the TBM technique will be enhanced with an interior tube, cast in- situ, provided with longitudinal and transversal reinforcements (Figure 1), dully confined, in order to provide the tunnel with the adequate ductility under earthquakes.

Based on the TMF concept, the tunnel will be constituted by a single tunnel, in which two superposed roadway galleries (with two lanes in a first phase, and three lanes in a second phase, each) and a service gallery will be installed (Figures 2 and 3). This becomes possible with a tunnel with an exterior diameter of 15,2m and wall thickness of 1,0m (precast segments thickness of 0,50m, interior tube wall thickness of 0,4m and grout injections 0,10m thickness between the precast segments and the soil). The service gallery is in connection with the roadway floors through fire protected vertical access galleries and is provided with emergency vehicles of shuttle type for personnel access and evacuation of persons in case of accident or fire inside the tunnel.