

# PRELIMINARY DESIGN OF THE TEL AVIV METRO LINE M2: ENGINEERING A MAJOR UNDERGROUND TRANSIT CORRIDOR

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**ABSTRACT:** The Tel Aviv Metro Line M2 is one of Israel's most significant underground infrastructure projects, forming part of a three-line metropolitan system designed to transform public transport in the Tel Aviv area. The line runs approximately 23 kilometres entirely underground and includes 21 stations, nine crossovers, and two pocket tracks. The running tunnels are planned as twin single-track tubes excavated by Earth Pressure Balance Tunnel Boring Machines (EPB-TBMs) with an internal diameter of 6.5 metres. Several launching and reception shafts are distributed along the route to optimise construction sequencing and TBM utilisation. In contrast, the stations and crossovers will be built using either cut-and-cover or mined (NATM) methods, depending on ground conditions, depth, and urban constraints. Eight stations and six crossovers are designed as mined caverns up to 20 metres wide and 15 metres high, typically excavated from access shafts using sequential excavation with pipe roofs, spiles, and targeted ground treatment. The geology along the alignment comprises variable Kurkar sandstones, Hamra sands, and clayey layers, with groundwater lying above much of the tunnel horizon. These conditions require robust design measures for face stability, water control, and settlement mitigation, including jet grouting, permeation grouting, and dewatering. The paper presents the preliminary design of the M2 line, focusing on tunnelling concepts, sequencing, and interface management within one of the most complex urban environments in Israel.

## 1. INTRODUCTION

Metro M2 is part of the Tel Aviv Metro Programme (Table 1) that includes three lines (M1, M2, M3) with a total length of 150 km and 109 stations.

Table 1. Tel Aviv Metro Programme (All Stages)

	<i>Network (3 Lines)</i>	<i>M1</i>	<i>M2</i>	<i>M3</i>
<i>Km of twin tracks</i>	<i>150</i>	<i>85</i>	<i>26</i>	<i>39</i>
<i>Stations</i>	<i>109</i>	<i>62</i>	<i>22</i>	<i>25</i>
<i>Hubs</i>	<i>7</i>	<i>6</i>	<i>1</i>	<i>0</i>
<i>Depots</i>	<i>4</i>	<i>2</i>	<i>1</i>	<i>1</i>
<i>Crossings*</i>	<i>24</i>	<i>10</i>	<i>9</i>	<i>5</i>
<i>Pocket tracks*</i>	<i>16</i>	<i>4</i>	<i>6</i>	<i>6</i>
<i>* This is based on the statutory design</i>	<i>* This is based on the statutory design</i>	<i>* This is based on the statutory design</i>	<i>* This is based on the statutory design</i>	<i>* This is based on the statutory design</i>

Metro M2 will be a heavy rail line in a high-density urban area, with an underground length of 23 km, including 21 underground stations, 9 underground crossovers and 2 underground pockets tracks (Figure 1).

The preliminary design for the three metro lines has been completed and approved. Design & Build tenders for the different sections are anticipated to be released once the ongoing reference design is finalized. These tenders will cover a broad scope of civil works, including, among others, TBM tunnelling

and cross-passage excavation, cut-and-cover and mined structures, as well as dewatering and ground improvement works.

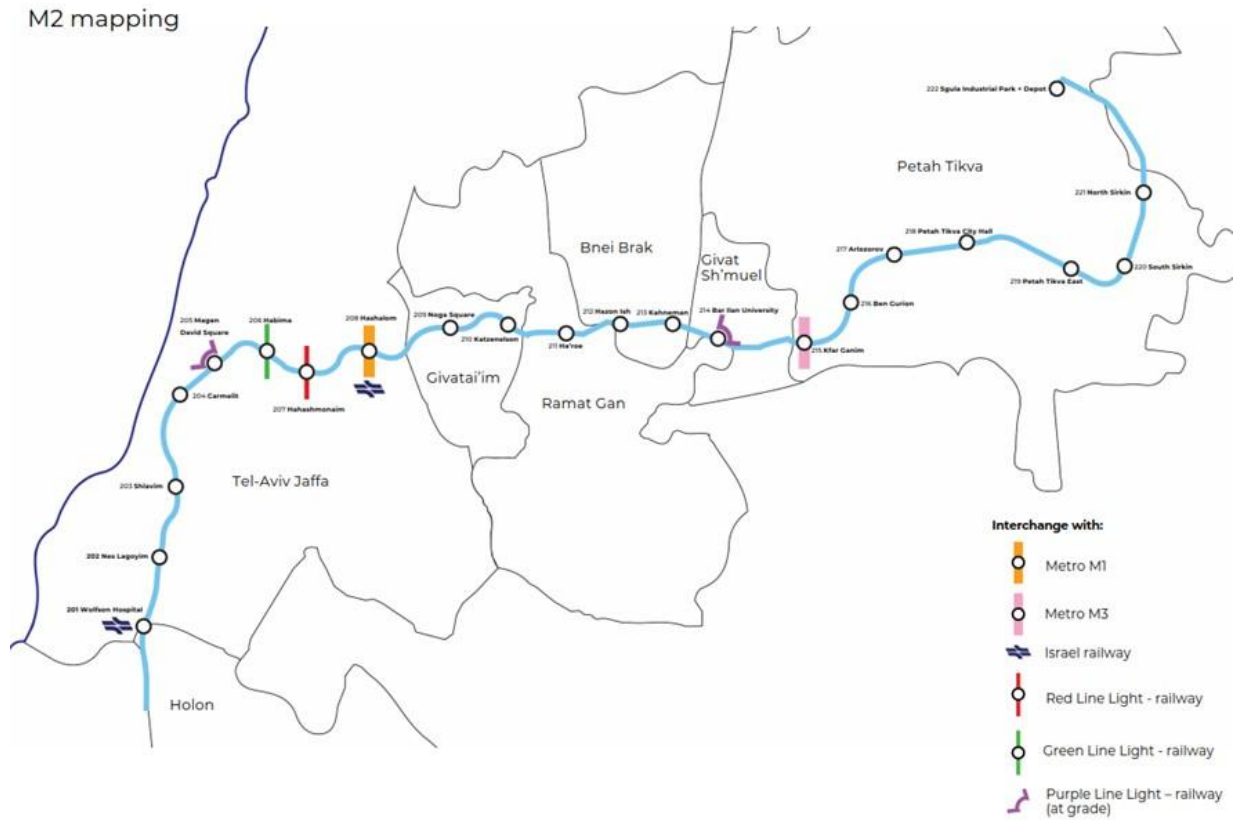


Figure 1. Metro M2 map

## 2. GROUND CONDITIONS

The stratigraphy of Israel's coastal area comprises several geological formations, dominated by sediments deposited during the Quaternary. Along the M2 alignment (Figure 2), the principal unit is Kurkar (Qk), the local term for calcareous sandstone. Kurkar lithology ranges from clean calcareous sand with about 10–20% sandstone concretions (sub-unit K1, expected in most sections) to weak sandstone with UCS of 0.5–20 MPa (K4, identified in only a few boreholes). This variability is largely attributed to differences in carbon content, which acts as the cementing binder.

The geotechnical profile also includes clayey Hamra (red) sands, formed by the weathering/corrosion of Kurkar and typically occurring above it. Dune sand deposits are expected as well, varying from loose sands near the coastline to more cemented sands; these may occur near the surface closer to the sea and at depth in other parts along the M2 corridor. Alluvial deposits are generally anticipated along the main river channels, particularly the Ayalon and Yarkon.

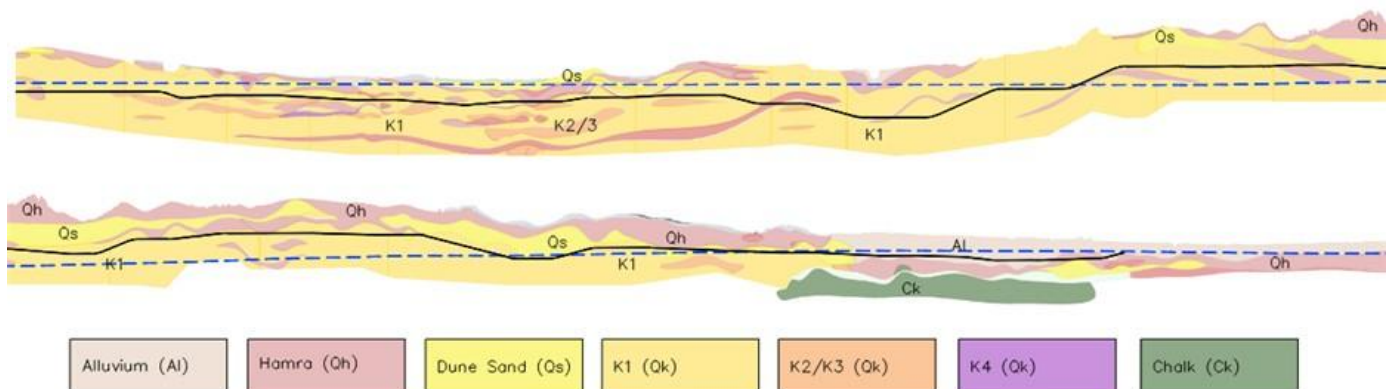


Figure 2. Indicative geotechnical section along the M2



reached via a mined tunnel and a small shaft at the western end of the alignment. At the eastern end, the tunnels terminate at a ramped portal. This scheme included five drives, varying from 2.7 km to 5.5km enabling normal routine maintenance and minimizing wear and tear of the machine. The design assessed various numbers of TBMs operating simultaneously as shown in Table 2 based on the following assumptions:

- TBM first approach: tunnels excavated before the stations.
- Average progress of 10m/day including a learning curve and routine maintenance stops.
- Normal operation without unexpected events.
- Launching shafts and structures prepared during manufacturing and delivery of new TBMs to the site - 12 months.
- 2 weeks lag between two TBMs at the same front of excavation.
- Assembly of the TBMs at site - 1 to 2 months.

Table 2. TBM alternatives assessed

Alternative	TBM N <sup>o</sup>	Time(months)
Scenario 1	4	56,7
Scenario 2	4	47,0
Scenario 3	5	47,0
Scenario 4	6	38,6
Scenario 5	7	35,6

Ground treatment solutions were assumed in the interfaces with the C&C structures to ensure safe break-in and break-out of the TBM, as well as to perform the initial/ultimate phase of excavation with reduced face, considering different ground conditions, water table and overburden. Two examples are shown in Figure 4.

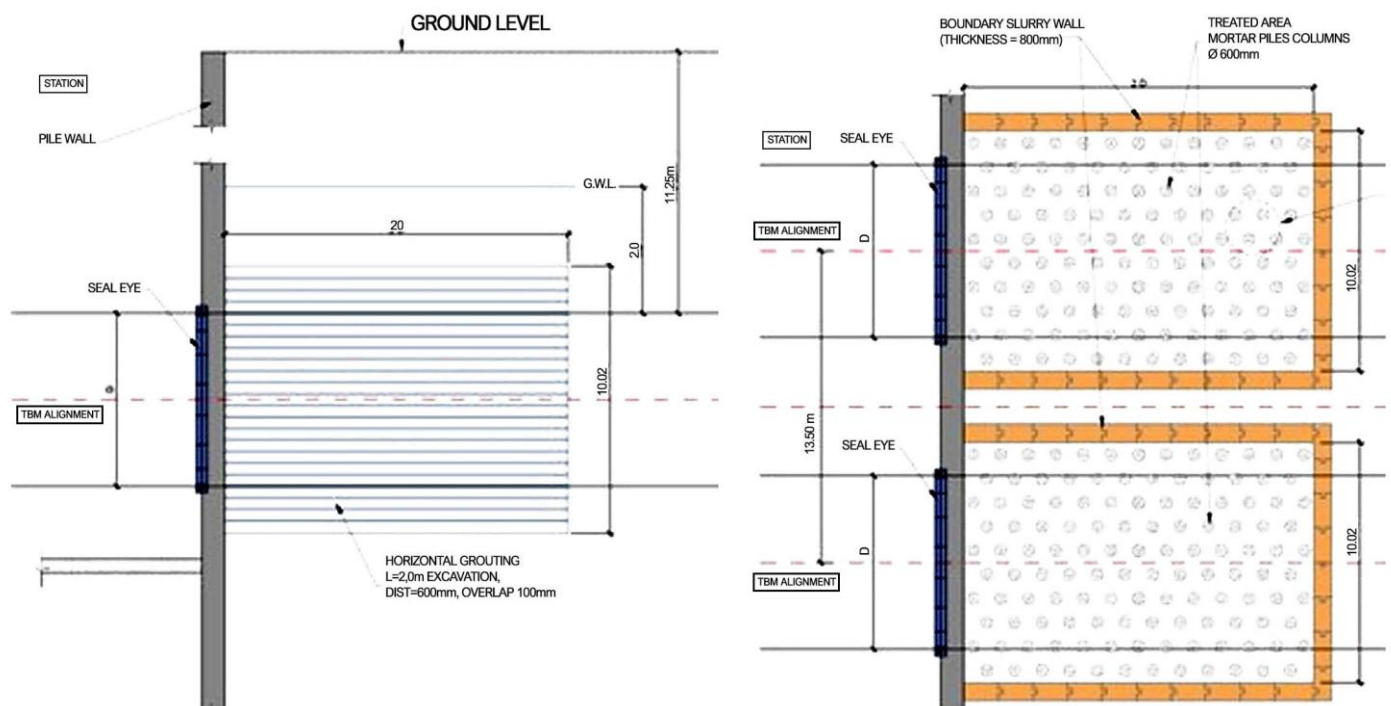


Figure 4. Boundary slurry wall with mortar piles and horizontal jet-grouting

A tapered universal ring of 6+1 precast segments was selected, with a thickness of 35 cm, in accordance with AFTES recommendations. The ring length is 1.5 m, which aligns with typical values for similar tunnels in urban environments which are usually between 1.2 m and 1.7 m. A total conicity of 41,5 mm was calculated for a minimum radius of 260 m, according to the tunnel alignment.

#### 4. MINED STRUCTURES

There are 16 mined structures along the M2 line: 8 stations, 6 crossovers, and 2 pocket tracks. Two platform-cavern layouts were considered—one with a 7.5 m-wide platform (small cavern) and another with a 9.8 m-wide platform (large cavern), as shown in Figure 8. The crossover arrangement is broadly consistent with Type B.

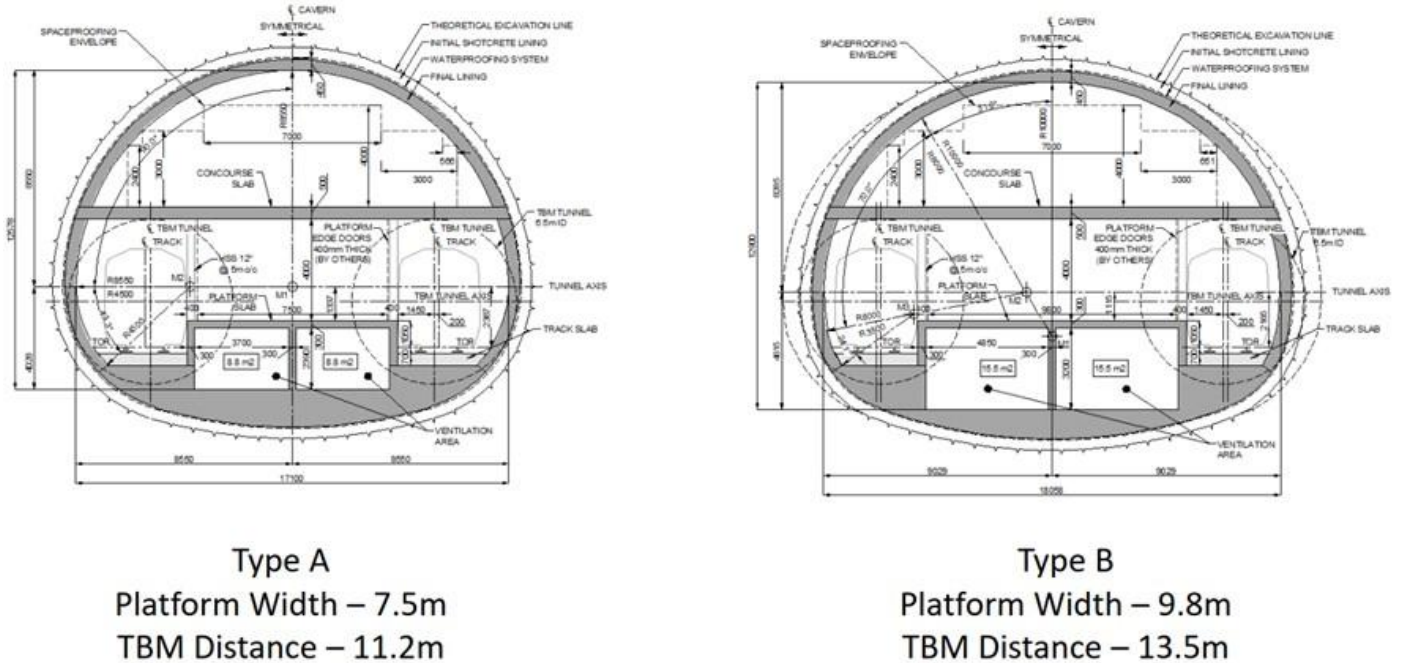


Figure 5. Mined stations cavern cross sections

The caverns, with lengths typically in the range of 130–200 m, were designed to be excavated mainly from off-line shafts via a cross-cut tunnel. Excavation would generally follow a double side-drift approach, with pre-support provided by pipe-roof umbrellas and/or spiles, and with ground treatment implemented as required (e.g., dewatering and grouting). Each drift is further subdivided into a top heading and an invert, as illustrated in Figure 6.

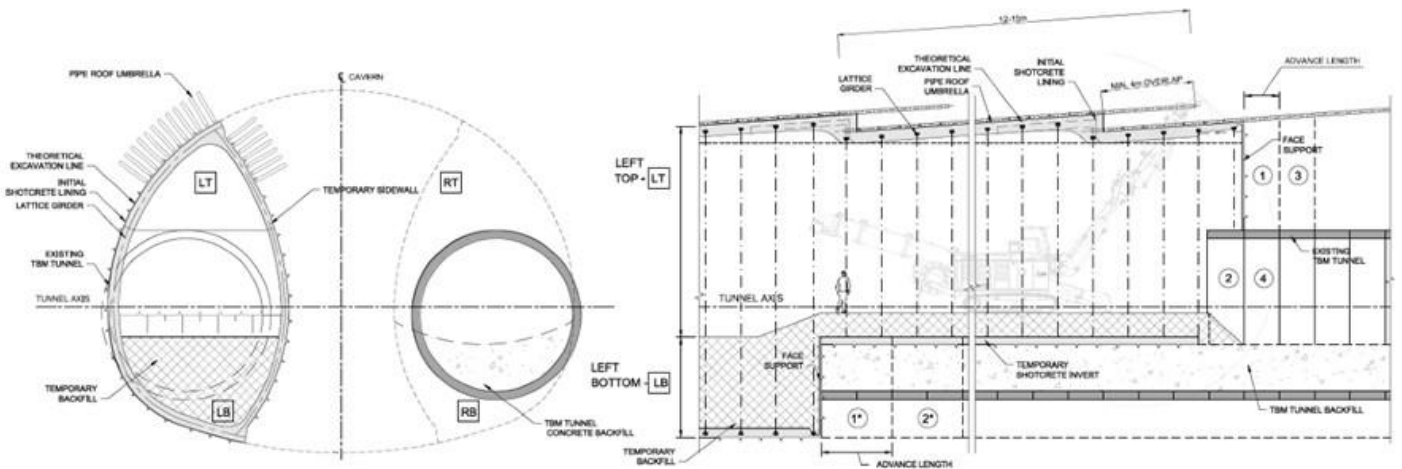


Figure 6. Excavation sequence of the cavern

An example of mined station showing the platform cavern, cross-cut, adits and the C&C box is shown in Figure 7.

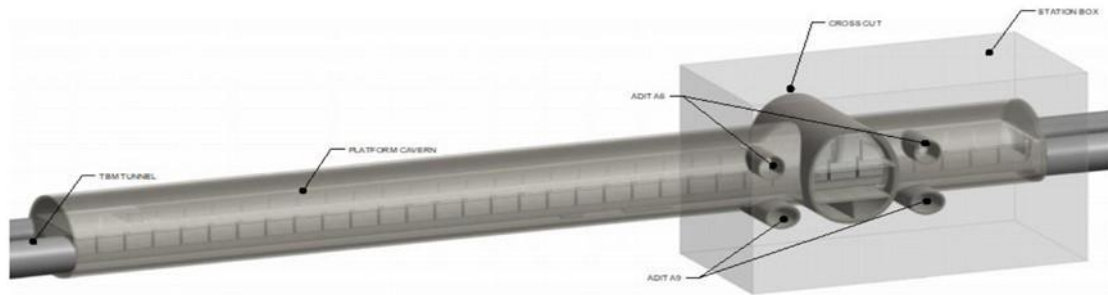


Figure 7. Mined station 3D model

Additionally, two complex mined structures, the terminus and the security tunnel, were designed as shown in Figure 8 and Figure 9 respectively. Turnout caverns were foreseen to provide the required space for the alignment.

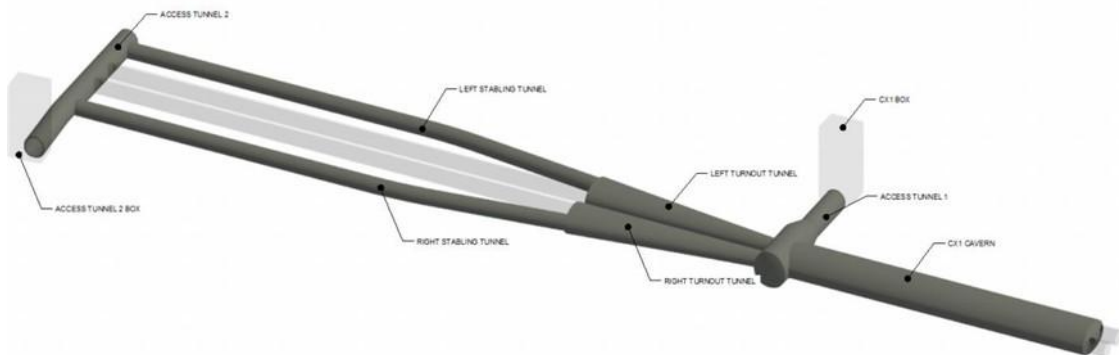


Figure 8. Terminus 3D model

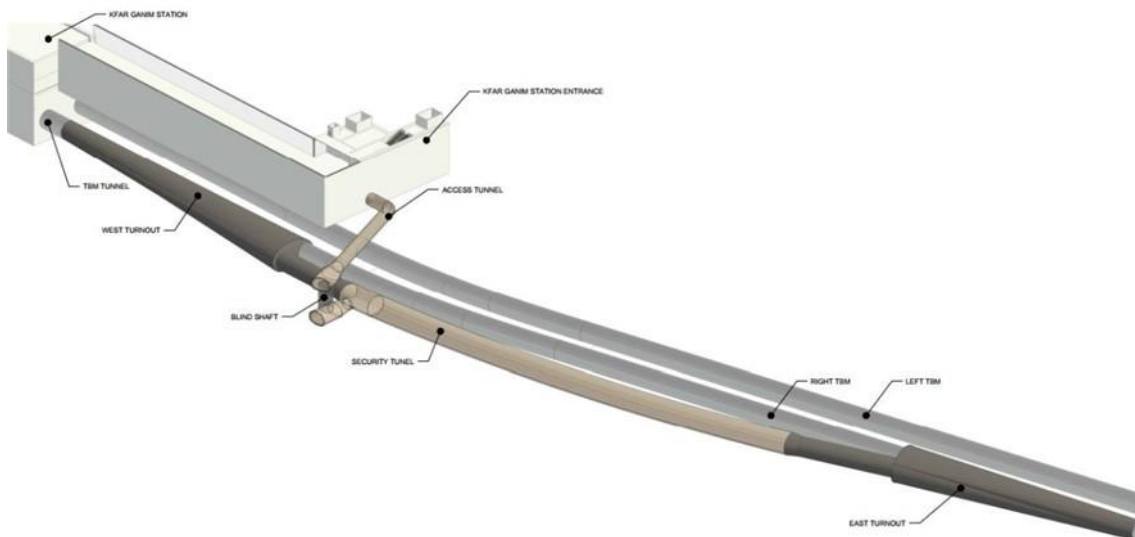


Figure 9. Security tunnel

## 5. GROUND TREATMENT

Given the high geotechnical risks associated with large mined excavations in predominantly sandy, soft ground under a high groundwater table, a range of ground-treatment measures may be required. The purpose of ground treatment is to control groundwater inflows, stabilise the excavation face in loose sands, limit settlements, facilitate cross-passage construction, and manage interfaces between the TBM tunnels and the stations.

During the preliminary design stage, several ground-improvement options were reviewed, including dewatering from both the surface and from within the TBM tunnels, permeation grouting carried out from the TBM tunnels, vertical and horizontal jet grouting, and ground freezing.

## **6. CONCLUSIONS**

This paper describes the Tel Aviv Metro M2 line, which forms part of a three-line metro programme intended to improve urban transport. The scheme comprises two running tunnels, each approximately 23 km long, together with a series of mined and cut-and-cover structures constructed in challenging ground conditions. In the coming years, the Metro programme is expected to increase demand for experienced contractors and specialist manufacturers.

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