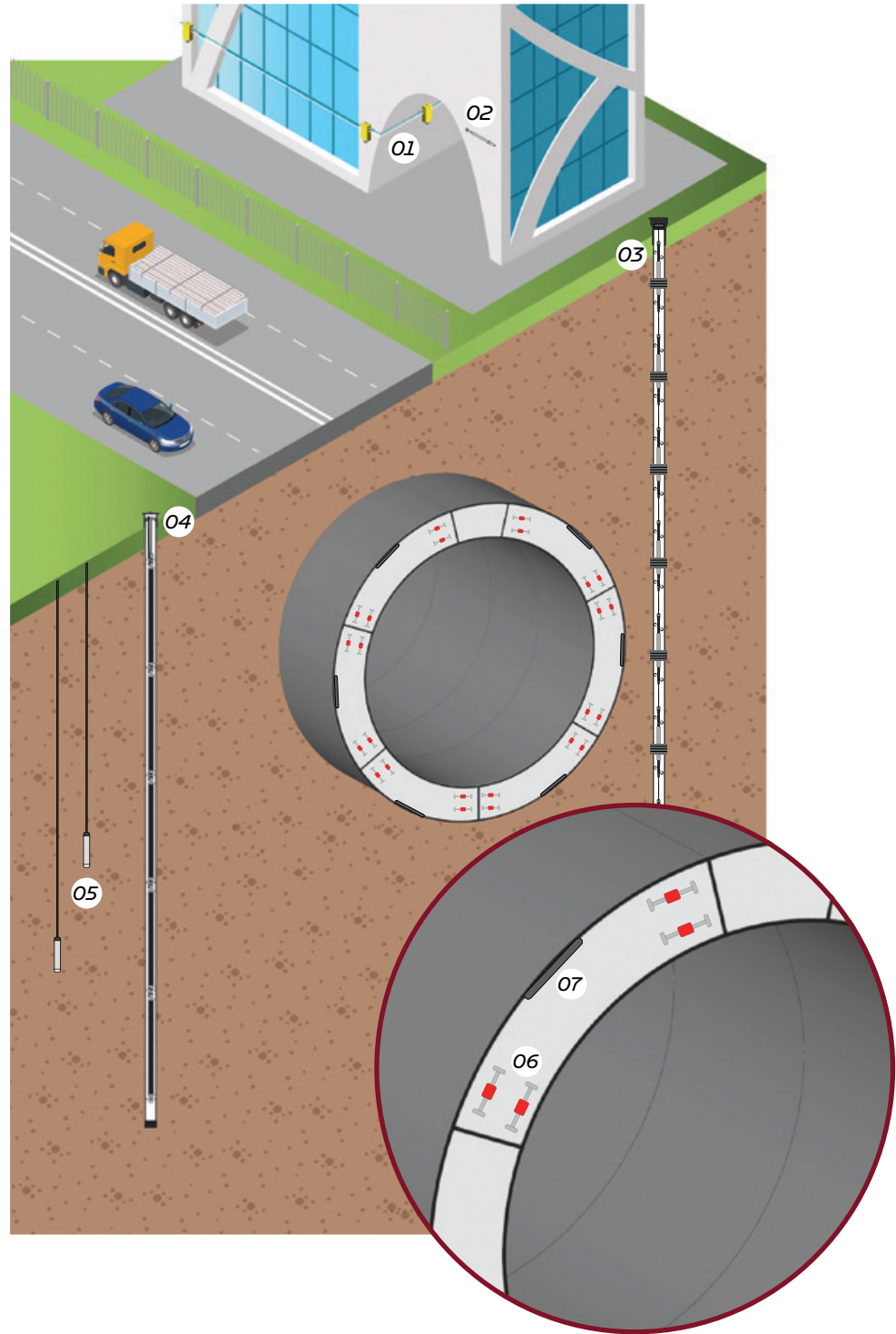
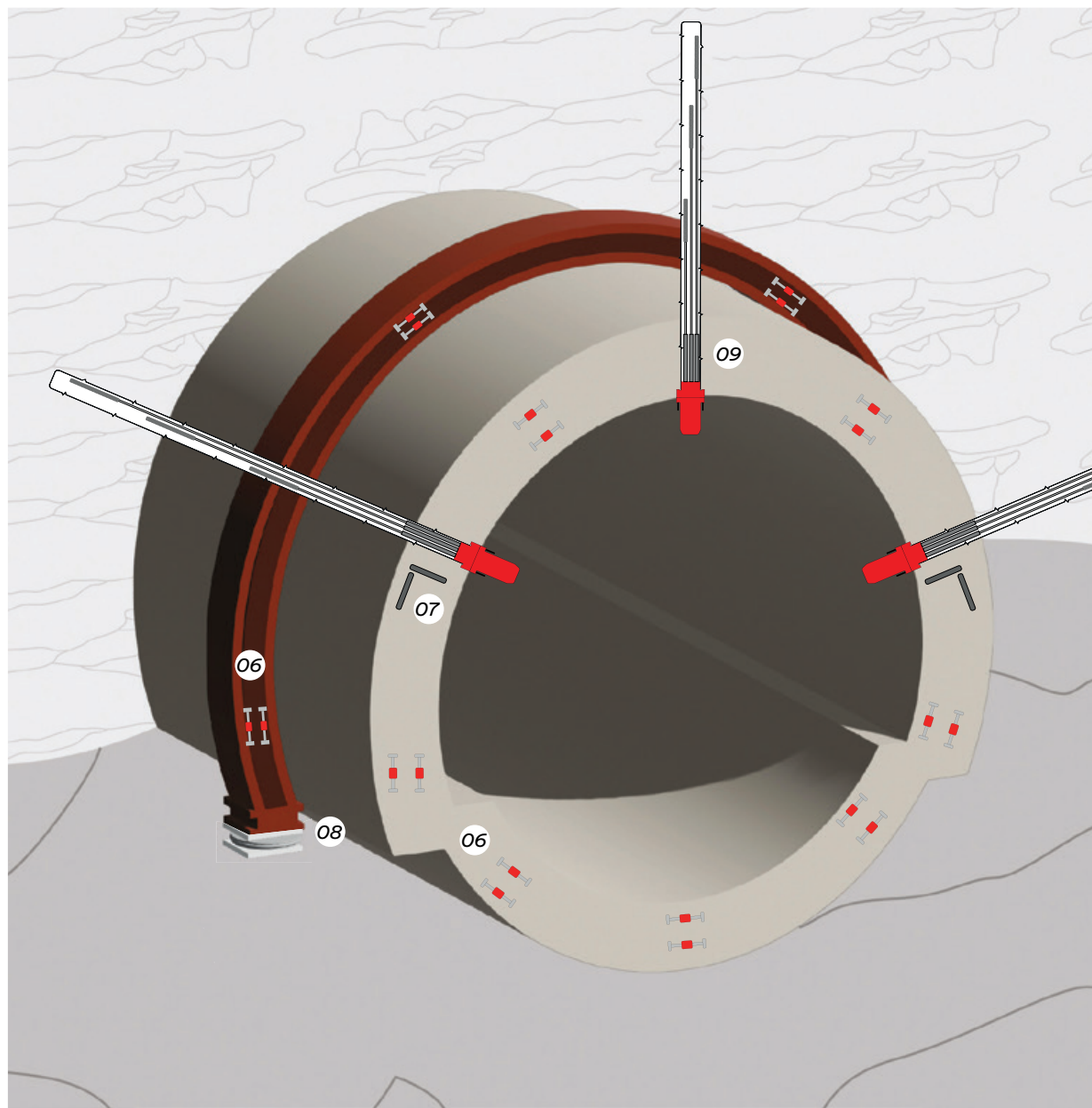


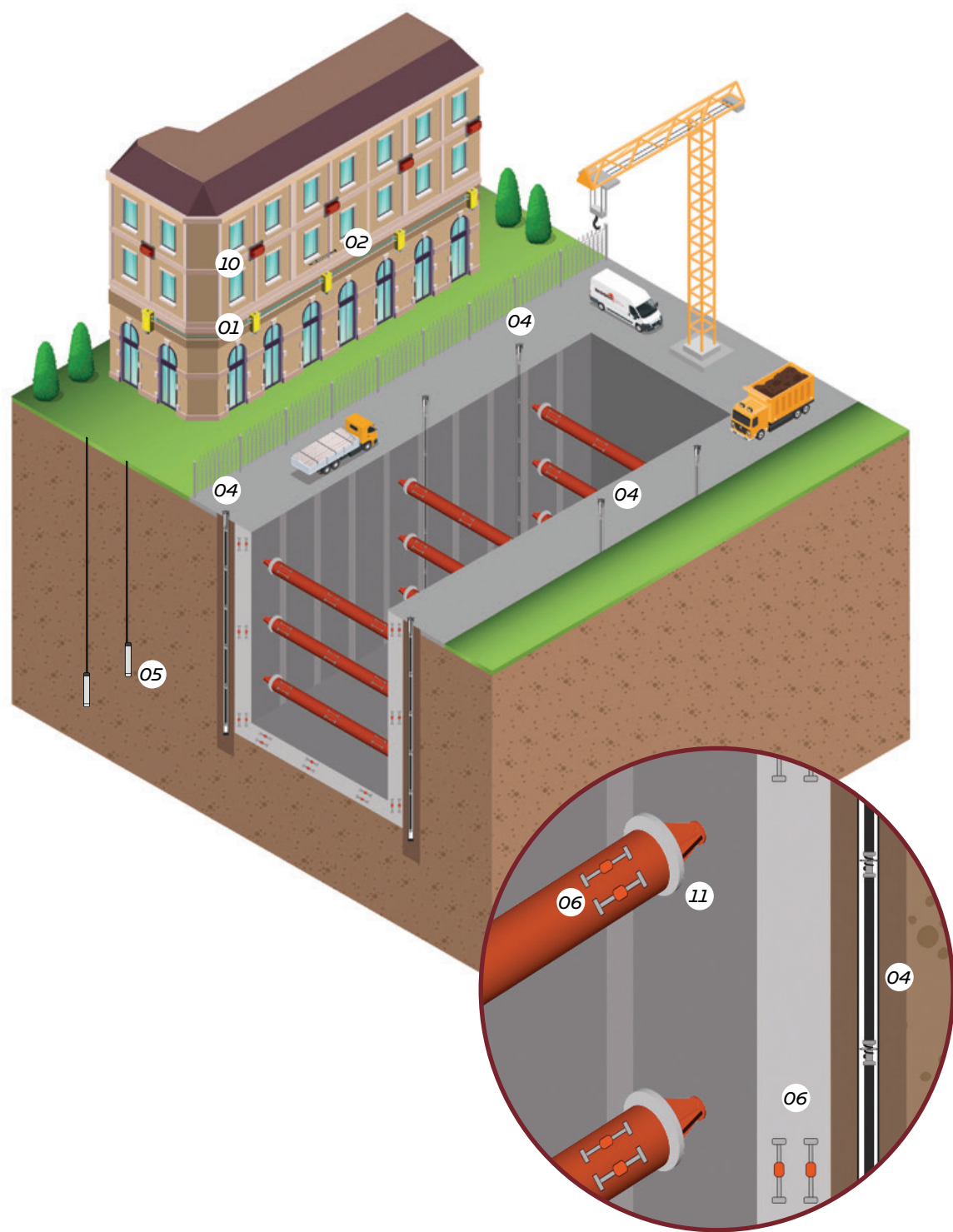
# TBM TUNNEL IN URBAN AREA



# TUNNELING WITH NATM METHOD



# DEEP EXCAVATION WITH TOP-DOWN METHOD



## INSTRUMENTS

- 01 Digital H-Level settlement system: Differential settlement monitoring of structures
- 02 Vibrating wire crackmeters: Monitoring of the cracks opening
- 03 Digital DEX-S inclino-extensometer: 3D borehole automatic profiling
- 04 MD-Profile array: High accuracy horizontal deformation monitoring in boreholes
- 05 Vibrating wire piezometer: Monitoring of the pore water pressure
- 06 Vibrating wire strain gauge: Check the stress conditions of concrete mass or steel structures

## INSTRUMENTS

- 07 Pressure cells: Monitoring the radial and tangential stresses
- 08 Electro-hydraulic load cells: Monitor the load applied to steel linings or struts
- 09 MPBX - Multipoint Borehole Extensometers: Monitoring of displacements and/or settlements at different depths
- 10 Digital tiltmeter: Tilt monitoring of the structures
- 11 Electro-hydraulic load cells for struts: Control the load on steel linings

## READOUT AND DATALOGGER

- MIND readout
- OMNIAlog multichannel datalogger
- Wireless system



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BH-Profile In Place Inclinator head  
Thessaloniki Metro - Greece



BH-Profile chain installation

## FOCUS ON Grand Paris Express project

The Grand Paris Express is the largest urban project in Europe with the construction of 200 km of automatic lines, as much as the current metro, and 68 stations. The four new lines of the Grand Paris Express (15, 16, 17 and 18), as well as the line 14 extended to the north and south, will be connected to the existing transport network. The new network, essentially underground, will cross the territories of Grand Paris to connect them to each other and to the capital. The civil works of lines 15, 16 and 17 have been in progress since 2017. The quantity of TBMs simultaneously digging could reach 21 machines and equal the Doha record (Qatar). The commissioning of all lines is scheduled for 2030 but some strategic lines will be in service for the Paris Olympic Games by 2024. Alongside this gigantic project, several existing lines are also extended such as line 11, line 12 and EOLE (RER E).

### THE PROJECT IN NUMBERS

4797 TOTAL  
INSTRUMENTS

12 KM OF INCLINOMETERS  
CASING

1200 BH - PROFILE

900 H - LEVEL



Settlement and supporting wall monitoring  
Doha Metro - Qatar



Madrid M30 Motorway - Spain

## REFERENCE PROJECTS

### Europe

Frejus tunnel - France  
CERN cavern - Switzerland  
Mont Blanc tunnel - France  
Brennero tunnel - Italy  
Limfjords tunnel - Denmark  
Visnove tunnel - Slovakia  
Isisberg tunnel - Switzerland  
Renaix tunnel - Belgium  
Gubristunnel - Switzerland  
San Bernardino tunnel - Switzerland  
Cantanghel hydraulic tunnel - Italy  
Capodichino tunnel - Italy  
Panagopoula tunnels - Greece  
Dolonne tunnel - Italy  
San Julian Line, Lugo - Spain  
Swinoujscie tunnel - Poland  
Trinberg tunnel - Germany  
Trojane tunnel - Slovenia  
Pajares tunnel Lot 3 - Spain  
Cantanghel hydraulic tunnel,  
access tunnel and main tunnels - Italy

### America & Africa

Riachuelo plant Lot 1&3 - Argentina  
El Toyo tunnel, Antioquia - Colombia  
Cucuta-Pamplona 4G highway - Colombia  
Rio Subterraneo tunnel, Lomas - Argentina  
Atiz-Atla tunnels - Mexico  
Microtunnel Linea Impulsadora - Ecuador  
Tizi Ouzou tunnel - Algeria  
La Linea tunnel - Colombia  
Tuy Medio Caracas-Charallave - Venezuela

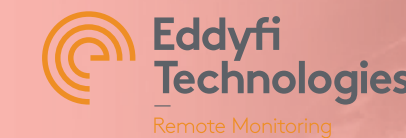
### Asia & Oceania

Pir Panjal tunnel - India  
Makkah service tunnel - Saudi Arabia  
West Gate tunnel - Australia  
Esfahan-Shiraz tunnel - Iran  
5th Waterline tunneling, Tel Aviv - Israel  
Albirkah tunnel - Saudi Arabia  
Koohrang tunnel, Esfahan - Iran

### METRO PROJECTS

Gran Paris, Lines 14, 15, 16 & 18 - France  
Rome metro, Line C - Italy  
LA subway, Purple Line - USA  
Melbourne metro - Australia  
Bogotá metro - Colombia  
Sidney metro West - Australia  
Porto metro - Portugal  
Lima metro, Line 1 - Perú  
Frankfurt U5 subway - Germany  
Doha metro - Qatar  
Milan metro, MM4 Line - Italy  
Amsterdam metro - Netherlands  
Milan metro, MM5 Line - Italy  
Rome metro, Line B - Italy  
Madrid metro, Line 5 - Spain  
Singapore MRT - Singapore  
Bangkok MRT, Blue Line - Thailand  
Thessaloniki metro - Greece  
São Paulo metro - Brazil

Riyadh metro - Saudi Arabia  
Bangkok MRT, Orange Line - Thailand  
Lisboa metro, Terreiro do Paço - Portugal  
Warsaw metro, 2nd Line - Poland  
Tel Aviv metro, Red Line - Israel  
Marmaray project - Turkey  
Algeri metro extension, lot 1 - Algeria  
Bucharest metro, Line 5 - Romania  
Panama metro, Line 1 - Panama  
Los Teques metro, Line 2 - Venezuela  
Otogar-Bagcilar light metro - Turkey  
St. Petersburg metro - Russia  
Barcelona metro, Line 9 - Spain  
Milan metro, MM2 - Italy  
Fortaleza metro - Brazil  
Paris metro, Line 11 - France  
Napoli metro, Line 1 - Italy  
Athens metro - Greece  
Genova metro - Italy



## TUNNELS SAFETY AND MONITORING



## TUNNELS SAFETY AND MONITORING

The planning and design of a monitoring programme is an essential component of a successful tunnel construction.



Riachuelo Environmental Recovery Plant, sub-fluvial tunnel - Buenos Aires, Argentina

Tunnel monitoring is recommended to determine the behavior of the surrounding soil during excavation and to ensure the stability and safety of above ground structures.

Tunnels and underground works monitoring should always take in consideration the type of excavation (TBM, NATM, drill and blast, cut and cover, etc.), their different stages and the surrounding environment:

- monitoring of tunnel entrances
- monitoring of first phase NATM excavation (steel linings)
- monitoring of the final concrete lining
- monitoring of the shafts and deep excavations for the stations
- monitoring of the precast TBM segments
- monitoring of surrounding soil/rock in case of both low and high coverage
- monitoring of buildings on the surface in case of low cover and/or heavily man-made environment

Monitoring of underground projects both during and after construction allows designers and owners to take the right decisions, manage risks, increase safety, increase productivity, optimize designs and reduce costs.

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