

Session 2.1 EOLE Underground Mega-Station in the Heart of La Défense Business Hub

by Michel Pré

Tunnel expert at Setec TPI, French building & civil engineering consultancy
Past President of Technical Committee of AFTES, French Association of Tunnelling & Underground Space
... and formerly Head of the Underground Works Design Team for La Défense District (2012 – 2019)

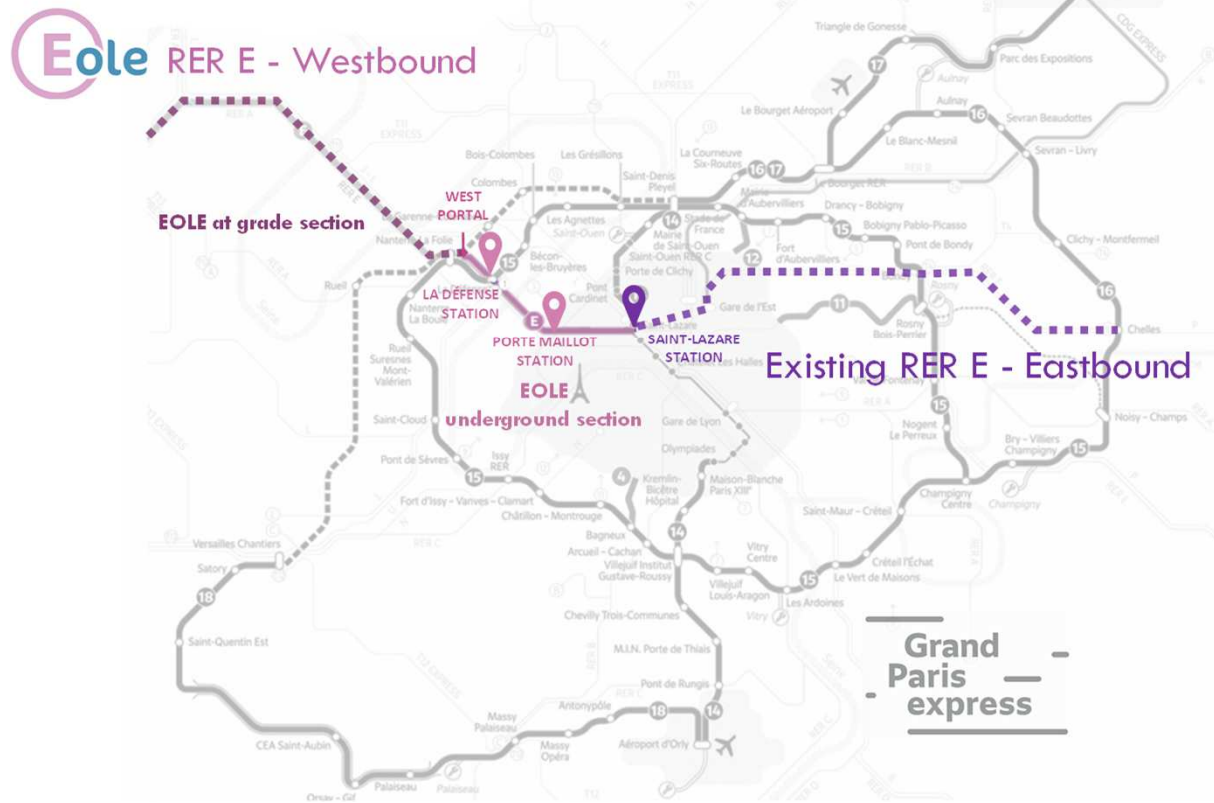


PARIS EAST-WEST EXPRESS RAIL LINK IN THE HEART OF LA DEFENSE BUSINESS HUB



1. Overview of the PARIS East-West Express Railway Link Project
2. Overview of EOLE works in the La Défense district
3. Focus on the La Défense mega-station

1. OVERVIEW OF THE PARIS EAST-WEST EXPRESS RAILWAY LINK PROJECT



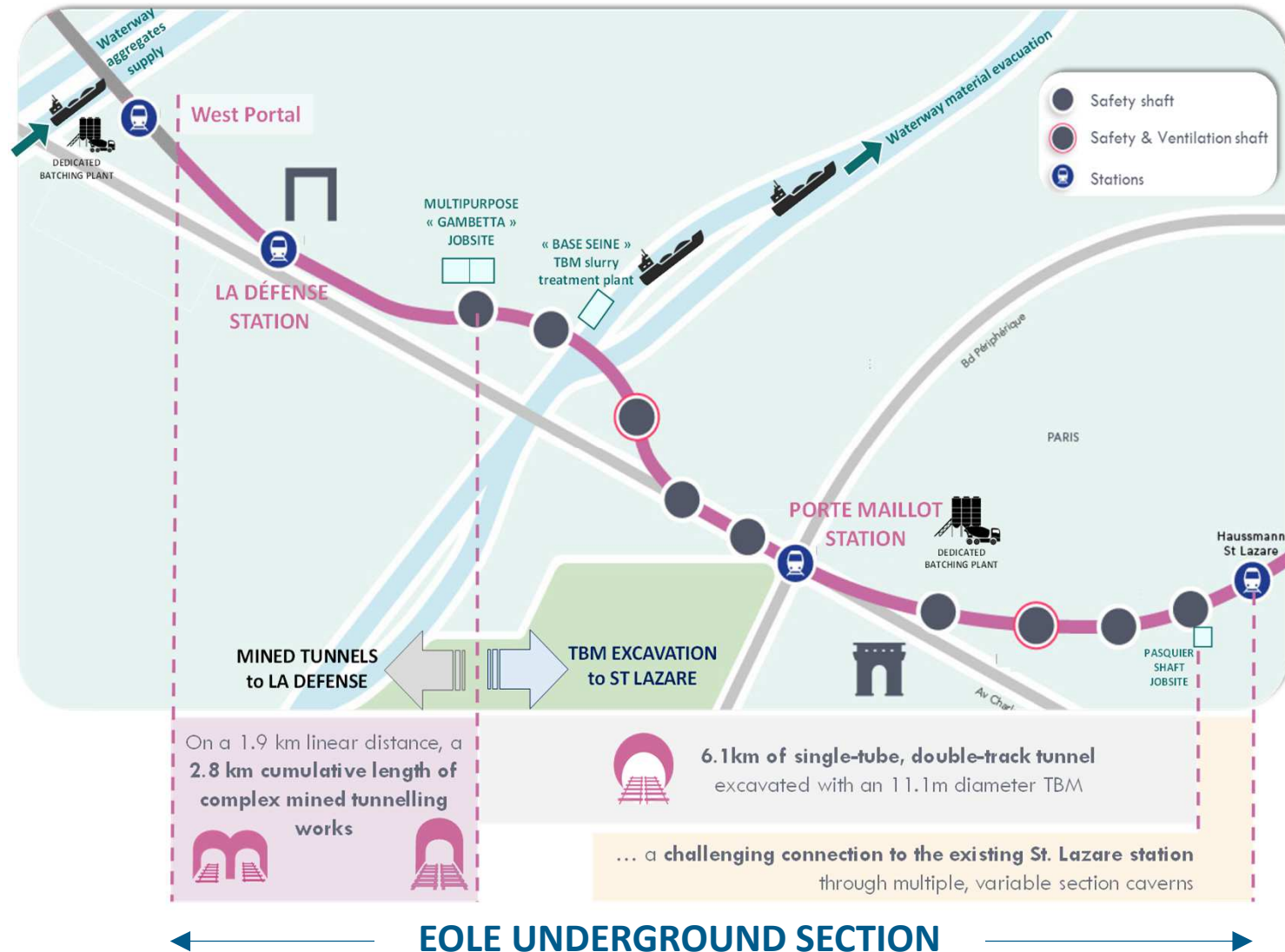
EOLE – *Est-Ouest Liaison Express* project (or East-West Express Railway Link) – in Paris will expand the existing E line of the Regional Express Network (RER – *Réseau Express Régional*) by 55 kilometers, connecting Saint-Lazare station, in the heart of Paris, to the western metropolitan region of the city.

Operation began **may-2024**.

Exceptionally inserted in an **hyperdense urban fabric and congested underground space**, EOLE is an integral part of a wider urban and public transport transformation currently happening in Paris, and **a major integrated component to the new global metro system of Grand Paris Express** interconnecting to the regional railway network.

EOLE going underground in the heart of Paris

The overall 55 km of EOLE railway express link consists of 47 km renovated section and **a new, 8 km-long section entirely underground, comprising 2 underground mega-stations.**



2. OVERVIEW ON EOLE WORKS AT LA DÉFENSE DISTRICT



- **Underground works using conventional methods** with continuous changes in **tunnel configurations and sections** to cope with the densely built underground space and with high-rise buildings foundations
- A **mega-stations fully underpinned** beneath an historical building, the CNIT
- **Multiple caverns** to connect the station to the tunnels and to different offset accesses
- A staged and complex construction sequence requiring **creative and innovative site logistic**

EOLE LA DEFENSE DISTRICT

PROJECT STAKEHOLDERS' ORGANISATION



THE OWNER



The Owner's main assistants

- ❖ General : Systra
- ❖ Buildings specialists: Veritas / Segat
- ❖ Ambiental

CONTRACTOR JOINT VENTURE



GRANDS PROJETS



FRANCE



Kind of contract : design & build

DESIGNER / ENGINEER

La Défense

Porte Maillot+TBM

The Architect



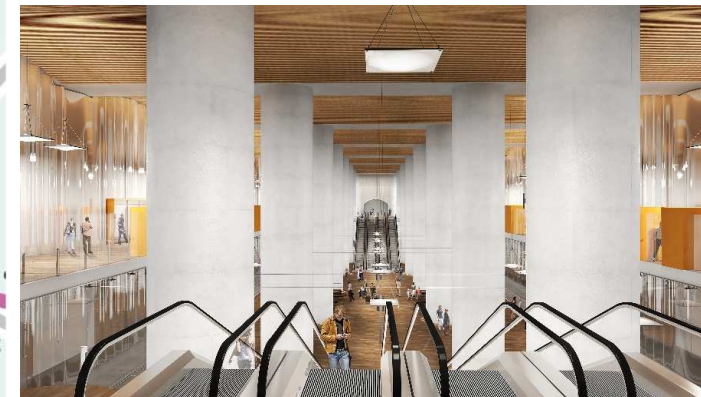


Nanterre to Gambetta shaft Section

Just beneath the historical
CNIT building (1958) ...



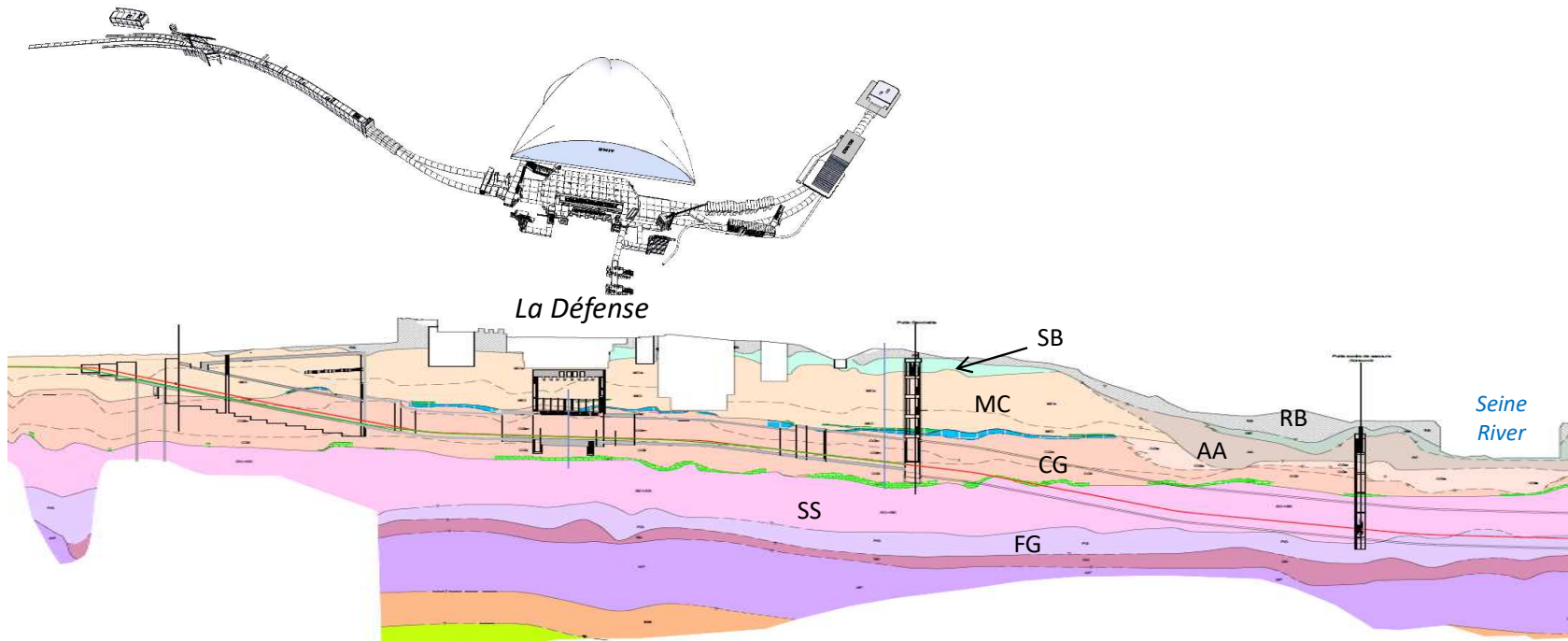
... the new EOLE underground
mega-station: La Défense



Over a linear length of 1.9 km, almost **2,8 km cumulated length of complex conventional tunnelling works** with double-track single-tubes, single-track twin tunnels, enlargements, crossover caverns and a cut-and-cover trench towards Nanterre Station (at grade).

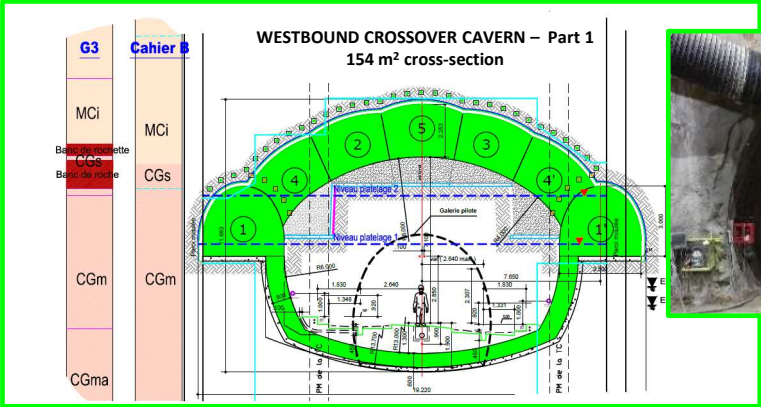
A sensitive environment and challenging ground conditions

- Extremely **dense urban environment**, characterised by **high-rise buildings**, deep foundations, **congested underground space** (parking lots, roads, metros, stations, connection tunnels, underpasses)
- **Challenging geology** through **heterogeneous limestones** and **mixed face** conditions, entirely **below groundwater table**

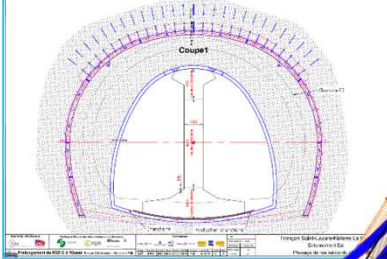
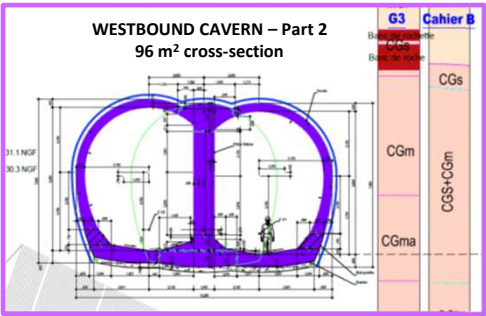
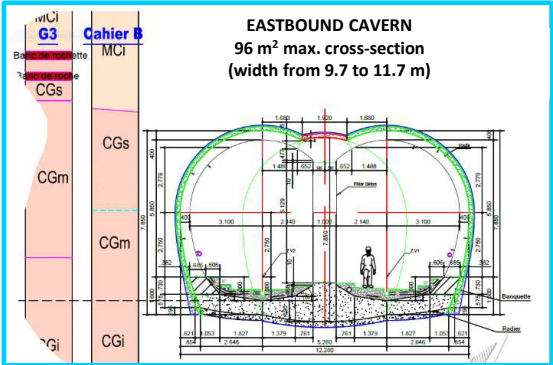
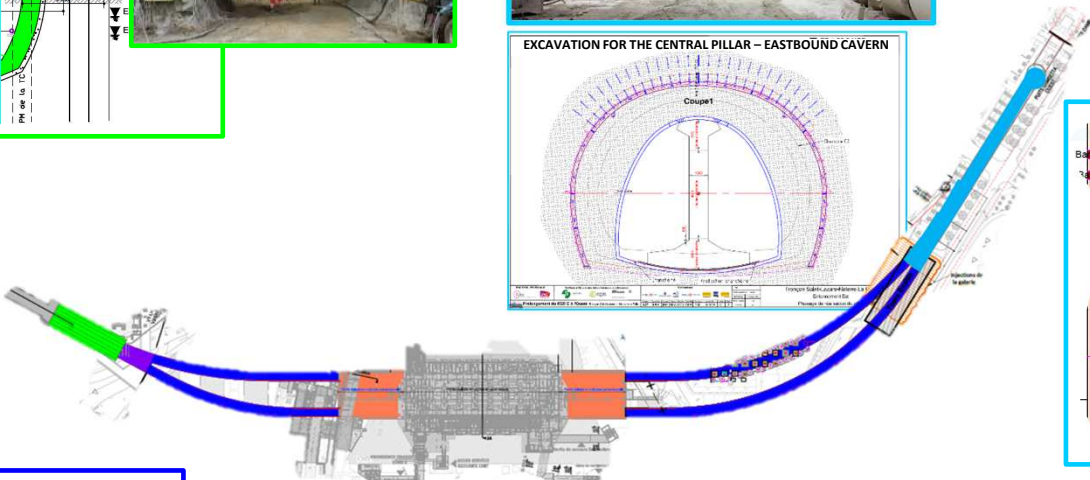
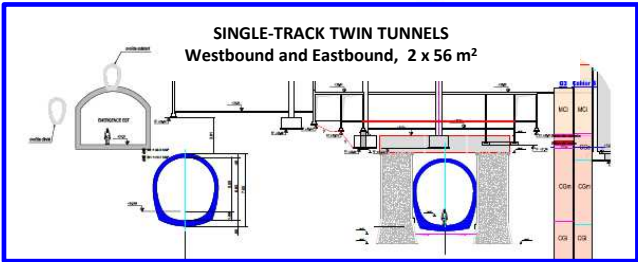
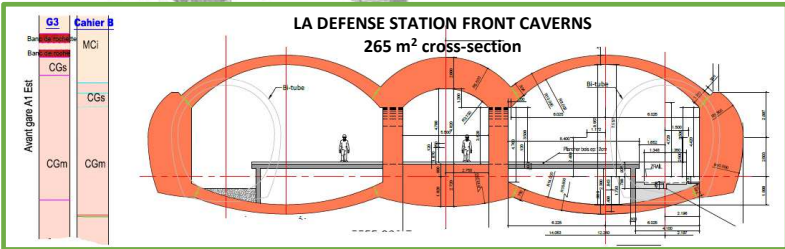


RB	backfill
AA	old alluvium
SB	clayey, fine sands, sandy clays
MC	clayey marls, marly limestone
CG	limestone
SS	coarse, siliceous/micaceous sands
FG	brown to black clay, very fine clayey sands

The articulation of EOLE mined works in La Défense District

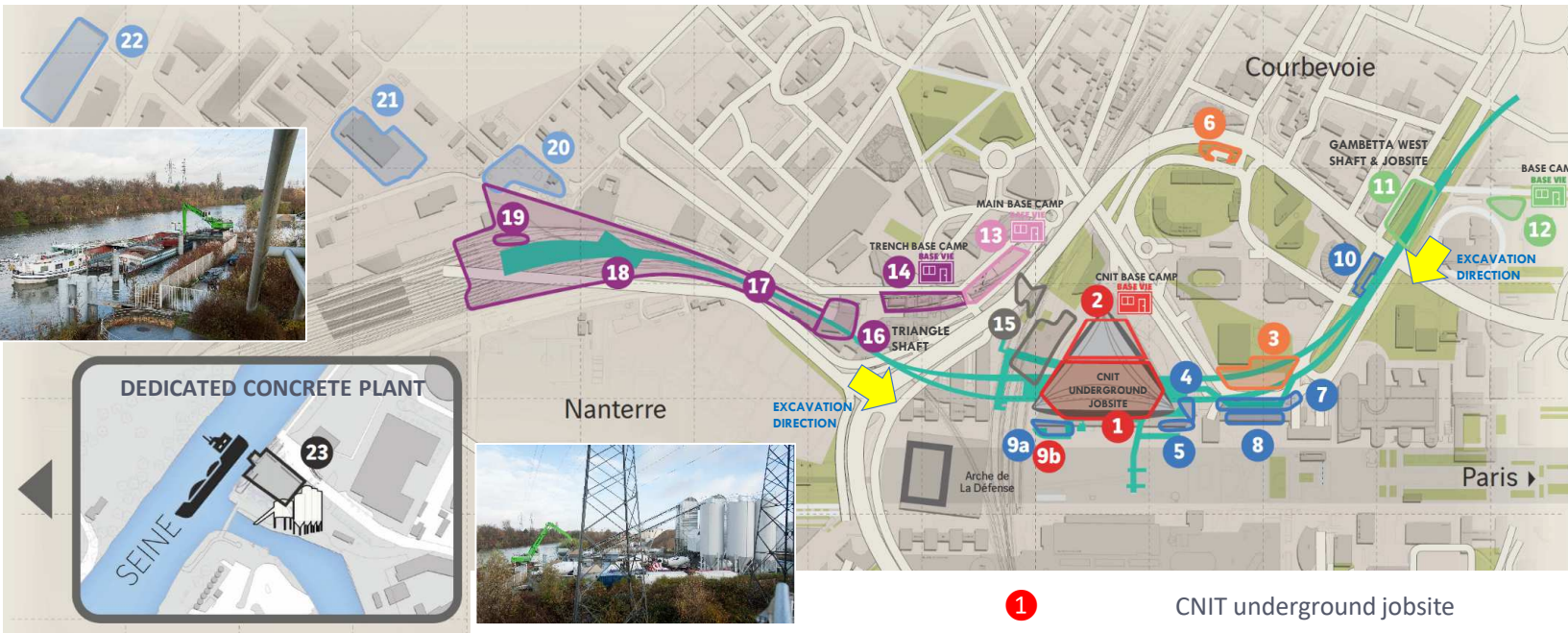


EXCAVATION FOR THE CENTRAL PILLAR – EASTBOUND CAVERN



Multiple small jobsites at the surface and articulated logistic

- **19 micro jobsites** allowing up to 7 tunnel faces open at the same time
- A **dedicated concrete plant** located nearby, on the Seine River benches, to facilitate the supply and reduce the transportation time and associated logistic
- Supply of concrete aggregates **80% by barges on waterway**
- **Evacuation of the excavated material** by trucks, 100% towards a very close final **revalorisation depot area, just 15 km apart**



1

CNIT underground jobsite

3 4 5 7 8 9 10 11 15 16 ventilation / access shafts
(intermediate accesses and jobsites during construction)

2 12 13 14

construction site base camps

17 18 19

cut-and-cover trench jobsites

20 21 22

construction site logistic areas

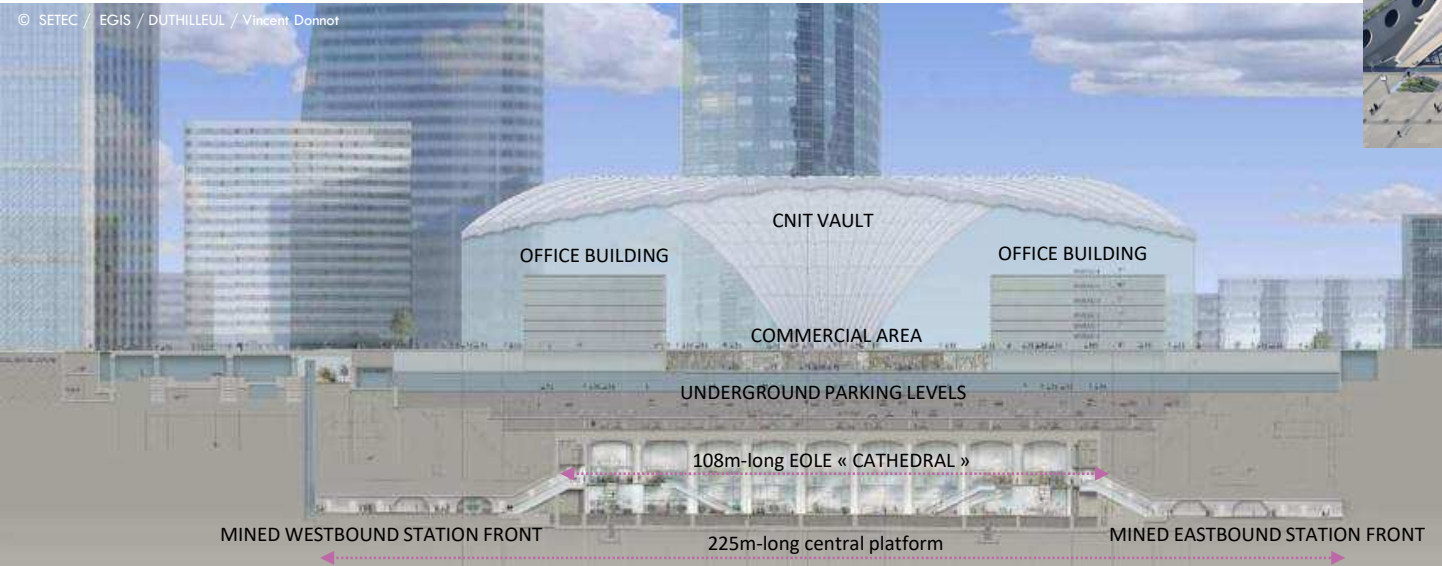


Heavy acoustic protections in the basement of CNIT allowing the normal operation of its business and commercial activities during EOLE mega-station works

3. Focus on the La Défense mega-station under the iconic and historical CNIT building

La Défense mega-station conceived as an immense underground « cathedral » extended by 2 articulated and large mined sections

- 25m large, 225m long central platform
- 30 m deep, 33 m large, 108 m long and 15 m ceiling height « Cathedral »
- 2x58 m mined extensions, each formed of 3 parallel fronts (total front face 265 m²)



A fully respected calendar

2016-2017	Preparation works
2018-2022	Underpinning of CNIT Building Excavation and civil works
2022-2023	Finishes and Equipment Final Testing
may-2024	Start of operation

Maintaining the CNIT in full operation, without impacting the vault and its foundations. 120 of the 250 pillars supporting the internal structures under the vault were cut and a **3m-thick concrete slab supported by 60 new pillars** were created, replacing the old foundations. Underneath this slab, the new RER E station was excavated and built.

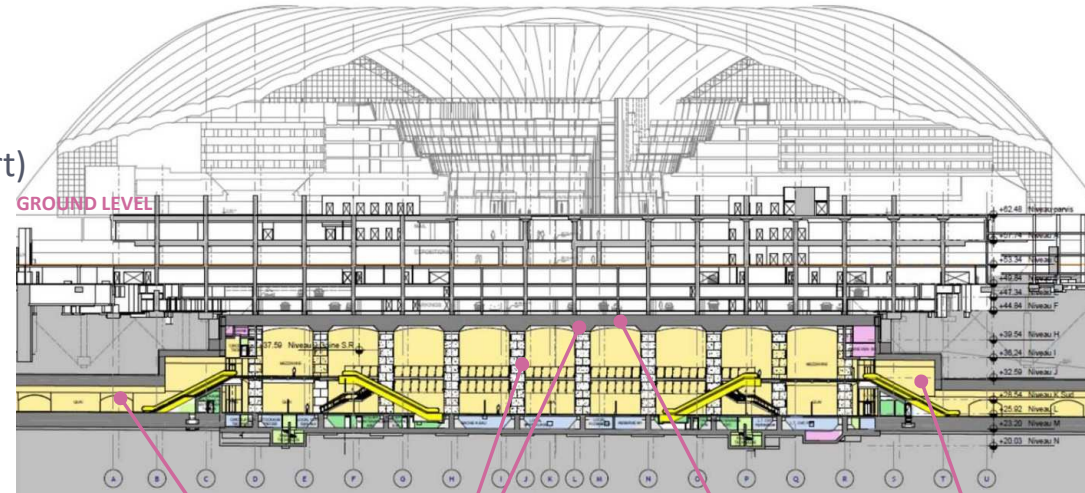
CNIT vault: an unmatched world record in numbers



A complex phasing for the construction works

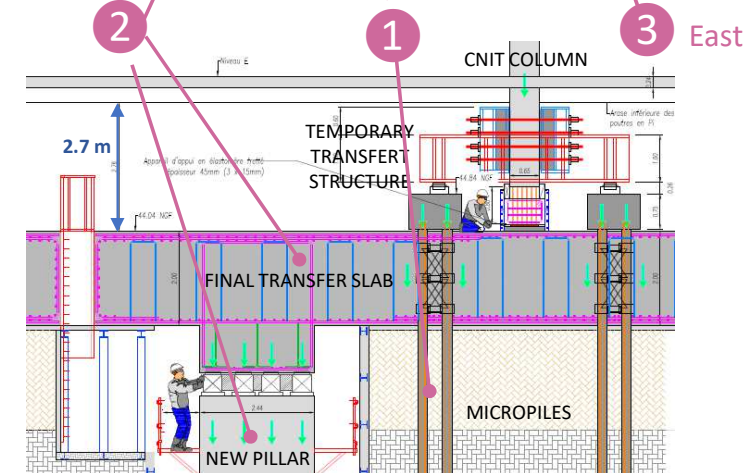
PHASE 1: enabling works and underpinning

- Underpinning of **118 existing columns**: **1st load transfer**
- **900 jacking points** on **15 km of micropiles** (temporary support)
- **60 new pillars by shafting**:
 - 5m excavation diameter, 15 to 22 m depth
 - shafts reinforced concrete base shaped in “elephant’s foot”
 - 3m diameter final reinforced concrete columns built inside
- **1 additional logistic shaft** used to evacuate the 1/3 of the excavated material down to the mined tunnels



PHASE 2: transfer slab, retaining walls, earthworks and civil works

- **7,000 m² of 2m-thick transfer slab**, area on 60 new pillars: **2nd load transfer**
- retaining walls in reinforced concrete built top-down beneath the slab edges, totalling
- **136,000 m³ of earthworks** (in marls and limestone)



PHASE 3: East and West front station caverns

① underpinning



1.A) Micropiling preparation



1.B) Execution of micropiling (15 km)



1.C) Steel bearing structure on micropiles, tightened to each existing column. **Jacking** of the existing structure and **separation** of the columns from their old footings



1.D) Excavation and hydro-demolition of the old foundation footings

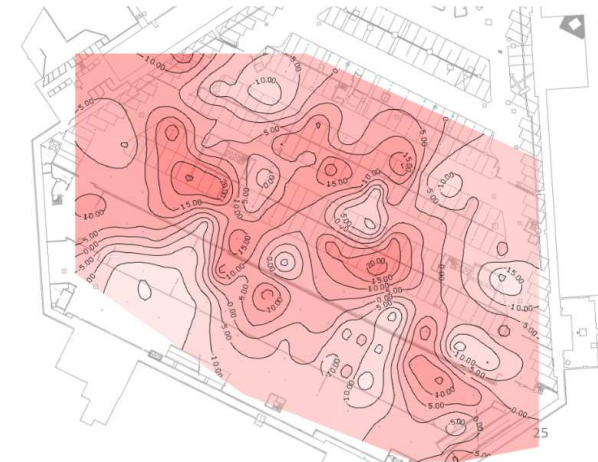
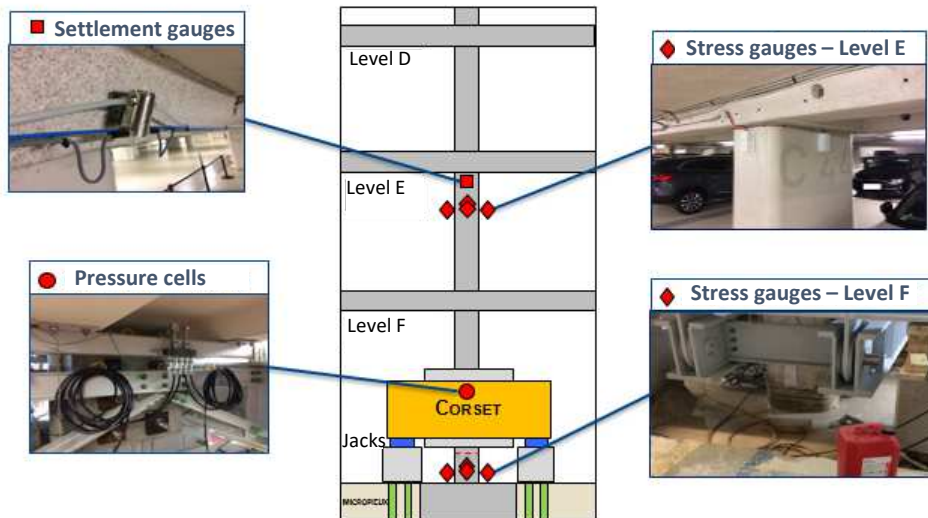
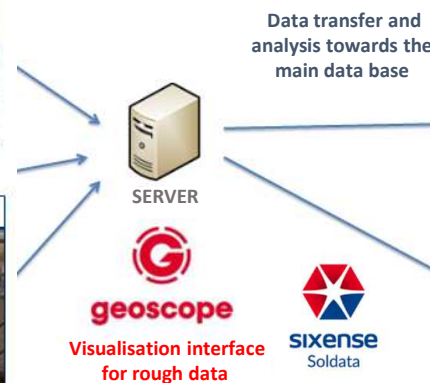


1.E) Excavation and completion of the underpinning

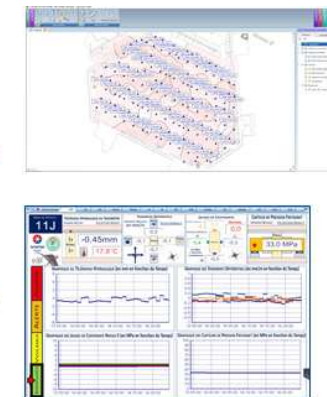
Controls on the 1st load transfer (① underpinning)



- **First load transfer** : from the old foundations to the temporary underpinning system consisting of micropiles and steel beams
- Transfer **steered by levelling** and **checked by load and deformation** on the temporary underpinning structure
- About **500 readjustment interventions** (global variation vs. forecast < 2%)



MONITORING OF DÉFORMATIONS & LOADS (62,000 tons)



① shafting



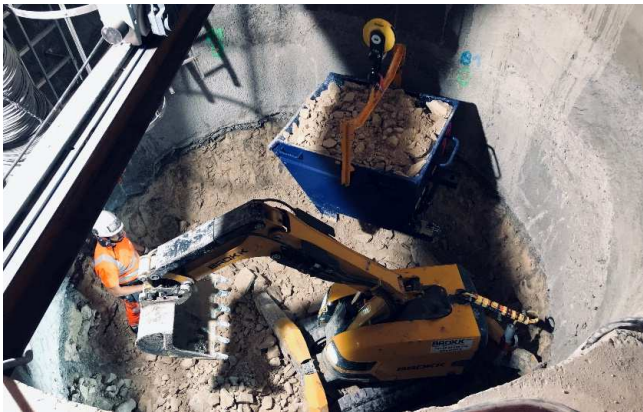
1.F) Paving and shafts' capping beams



1.G) Execution of the 60+1 shafts for the 60 pillars and the site logistic



1.H) Installation of gantries and easements within the shafts



1.I) Excavation of the 22m deep pillar shafts by steps of 1.0 m to 1.2 m, then lining top-down



1.J) Construction of the “elephant foot” shaped base of the pillar

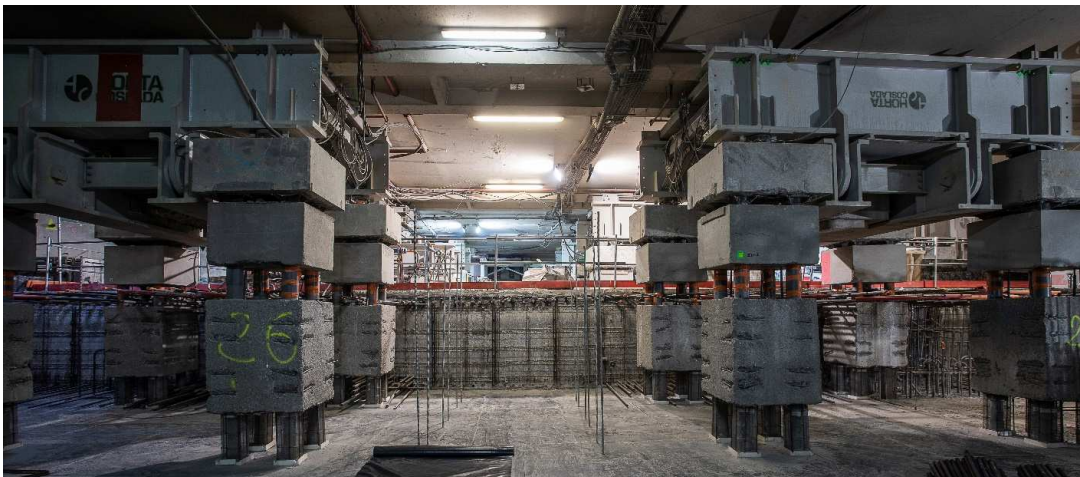
① shafting & ② slab



1.K) Climbing **formwork in 3m lifts** for the realisation of the reinforced concrete final pillars

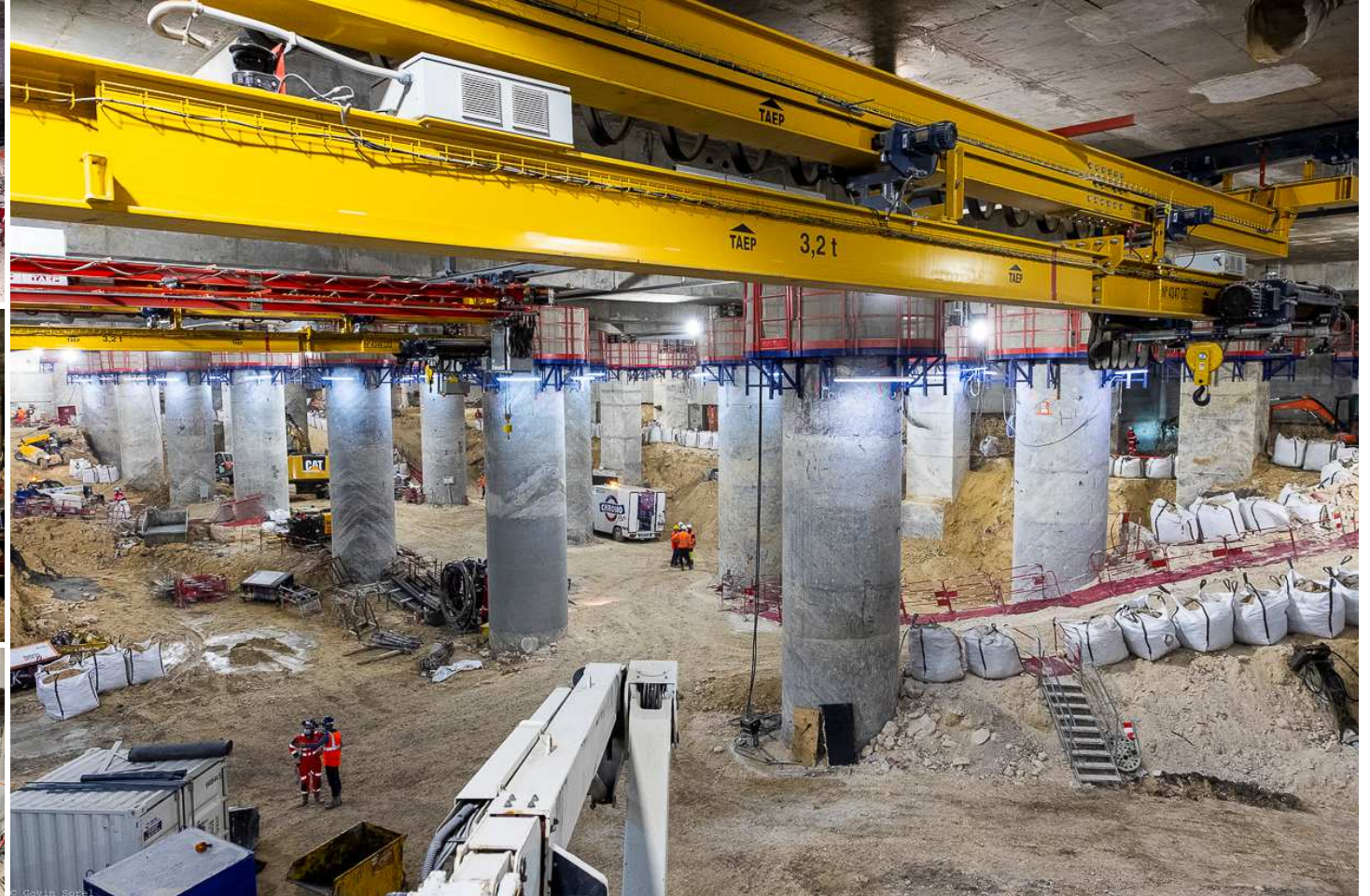


1.L) Installation of jacks on the head of each pillar: 6 to 8 jacks per pillar, **total transfer capacity 100 000 ton**



- 2.A) Refitting of pillars' heads with interposition of neoprene sheet between the pillars and the transfer slab
- 2.B) Execution of the **transfer slab**
- 2.C) **2nd and final load transfer from the temporary micropiles to the slab on final pillars**: the loading system is steered by loads and checked by levelling until completion of the overall construction and general settlement stabilization

② excavation



2.D) Excavation of the “cathedral” part of the mega-station under the transfer slab

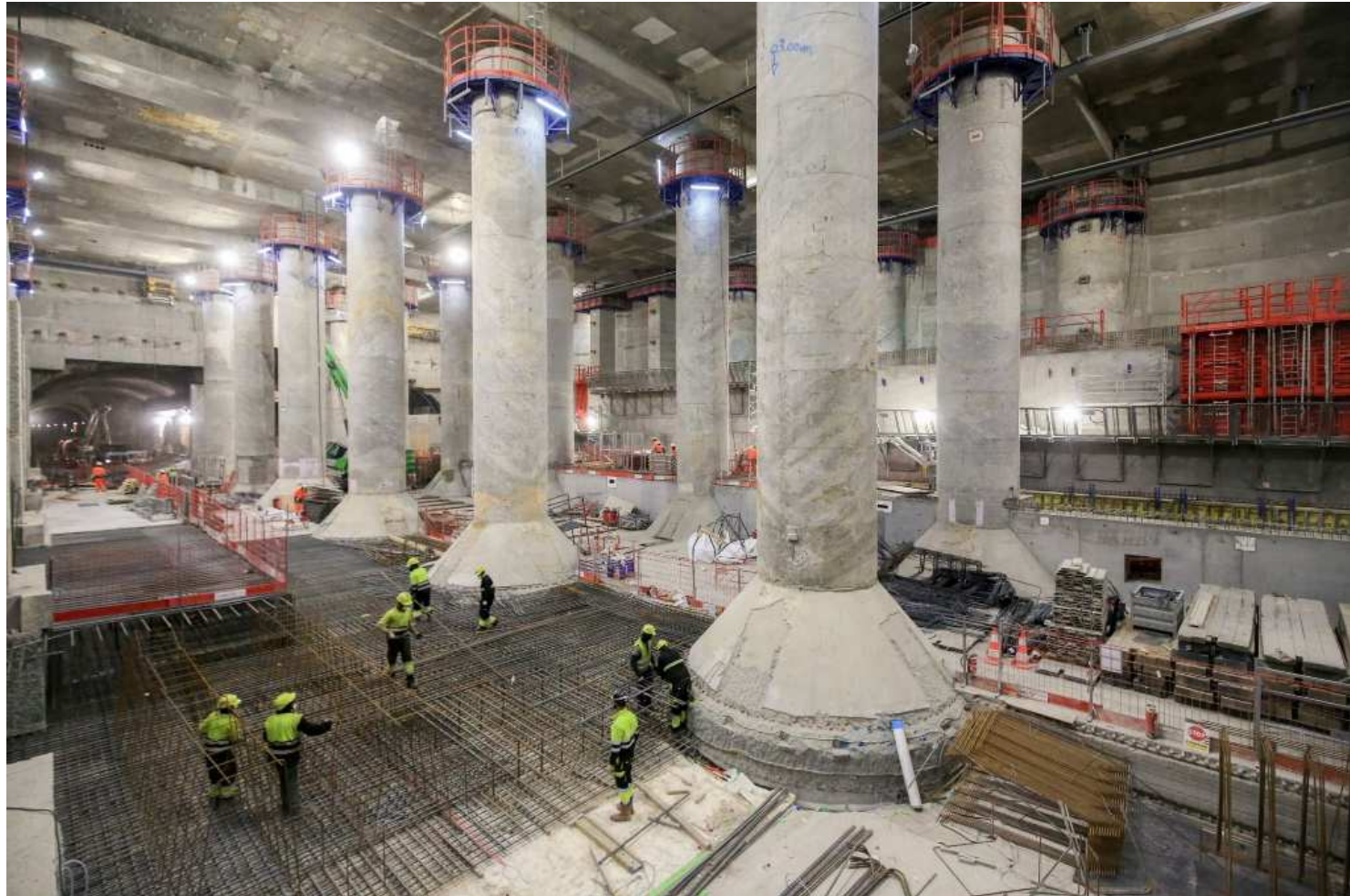
② excavation & civil works

2.E) Finalisation of the excavation and execution of the bottom slab of the “cathedral” part of the mega-station under the transfer slab



precise millimetric controls on an exceptionally large construction site

- Despite the anticipation of settlement, jacks were equipped with **identical stroke capacity** for both settlement and uplift scenarios
- Some **minor uplift effects** were **compensated** during the excavation of the “cathedral”.
- The **pillars’ bases settled of about 15 mm**, and the recorder movements of the existing structure were **within the “natural seasonal breathing”** of the building.

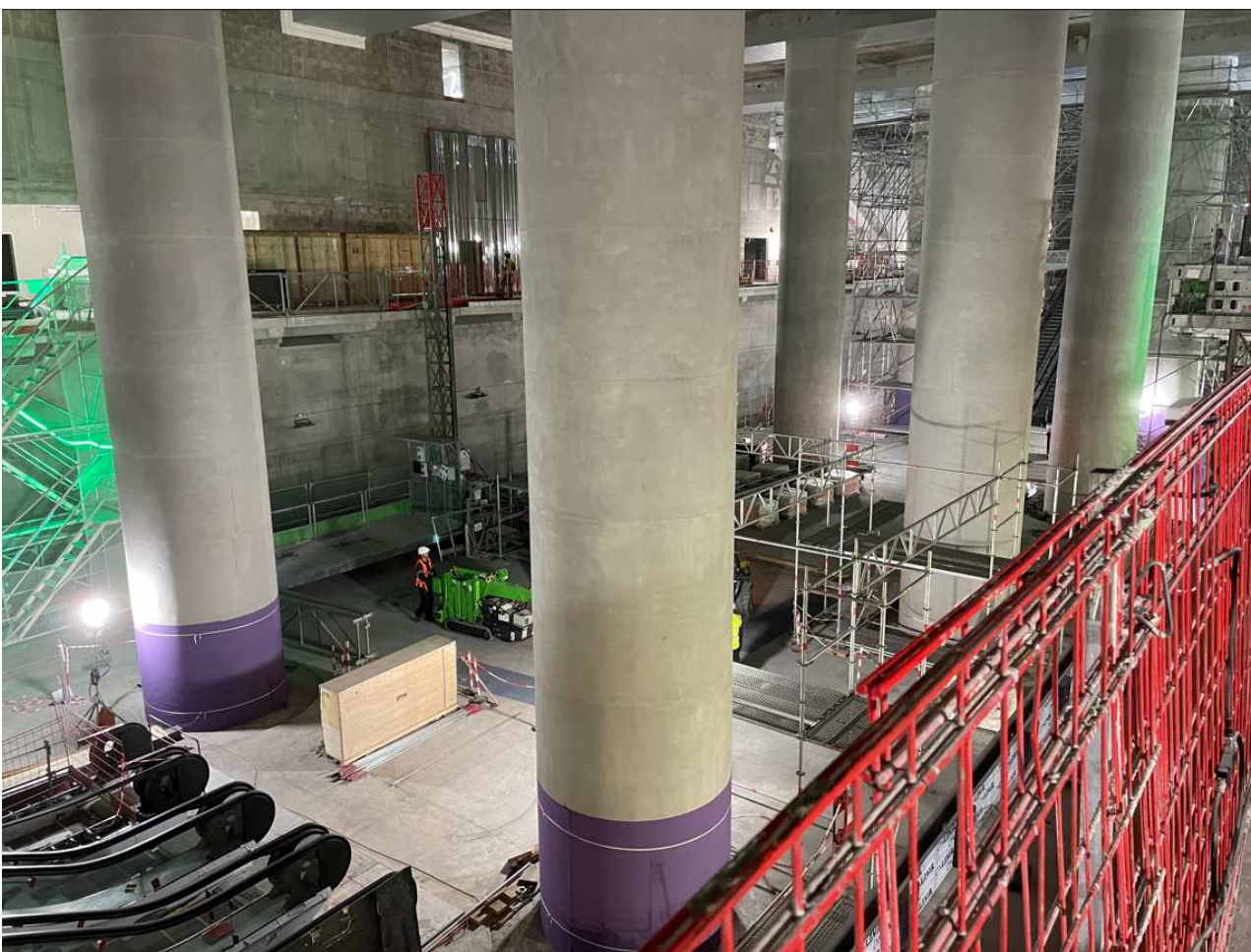
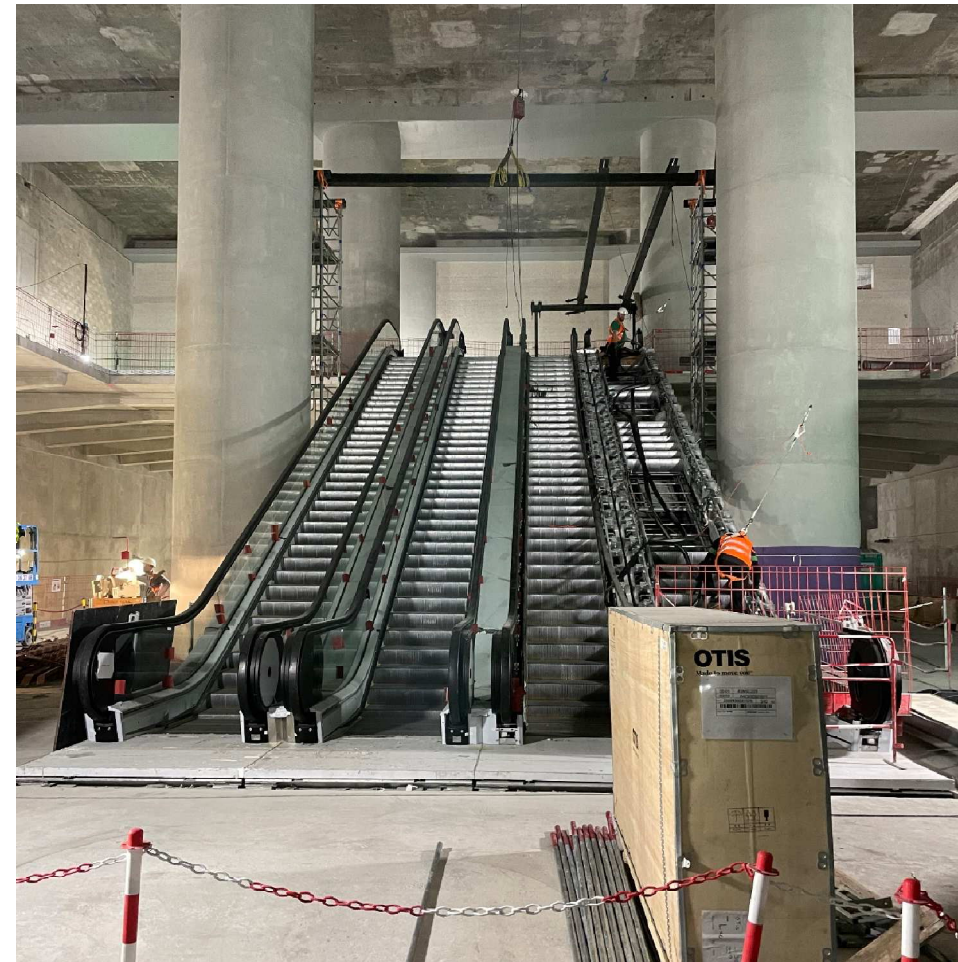


3 front caverns

- 3) Excavation the Westbound and Eastbound mined front stations and connection to the “cathedral” part of the La Défense mega-station



Finishes & Equipment





25 m-large central platform

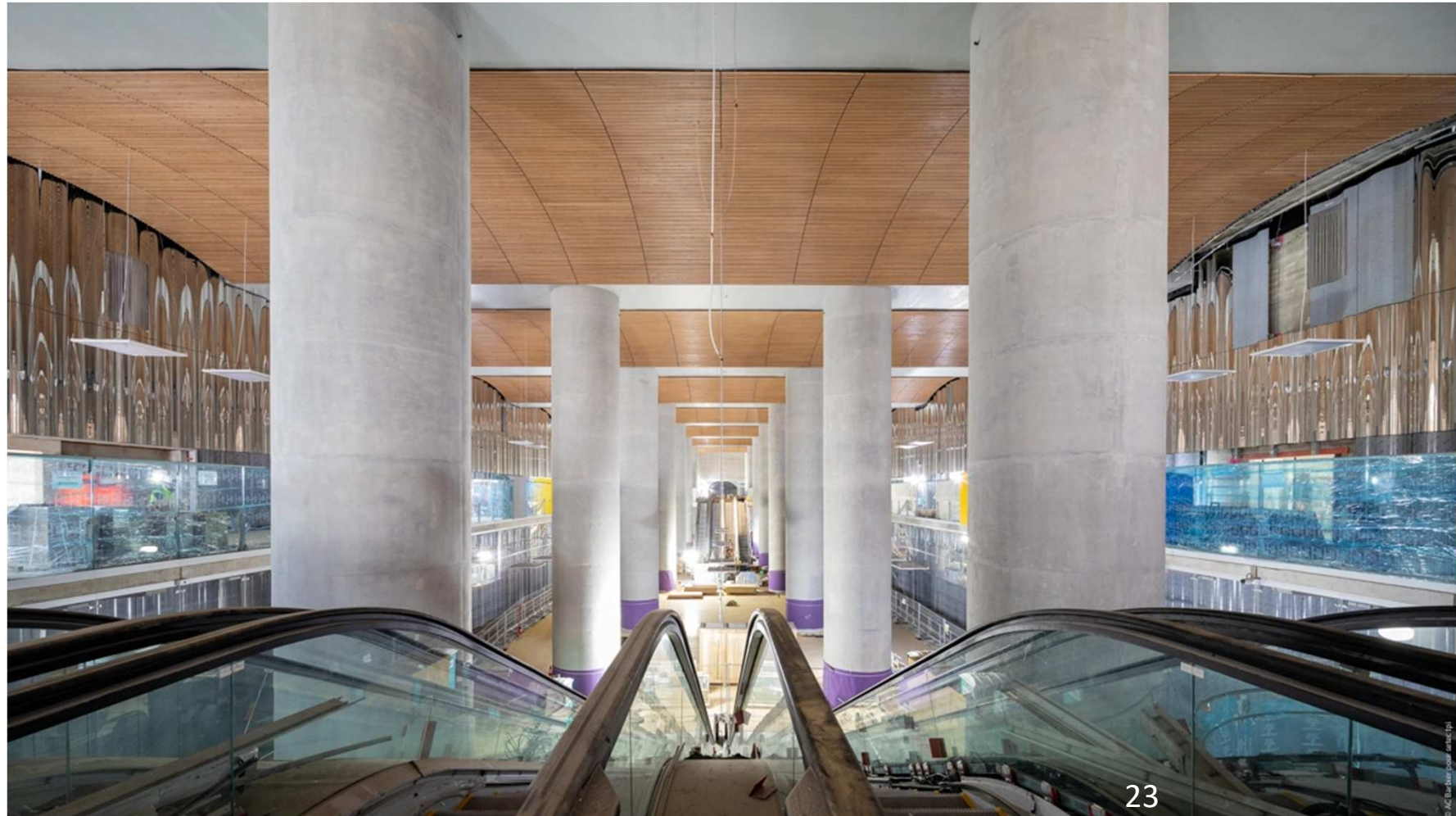
56 escalators

12 elevators

5 correspondances & accesses

70 000 travellers/day

(Quasi) – final aspect of the main hall and platforms

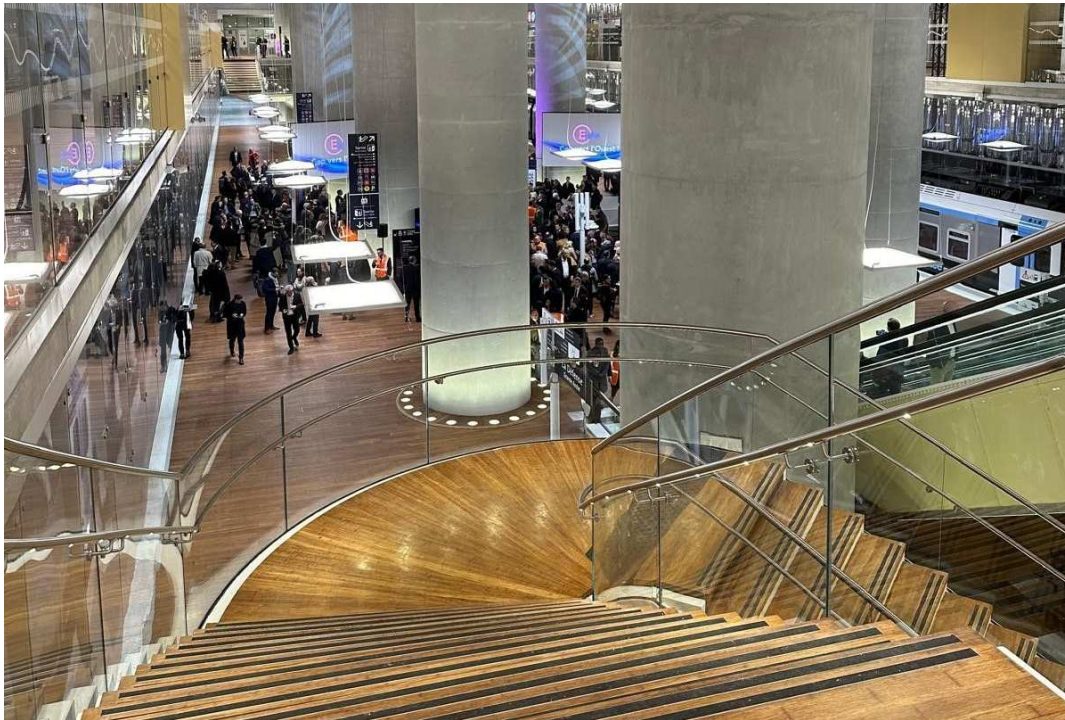


AWARDS



3RD OF MAY 2024

The crowd around the Authorities



Part of the SETEC EOLE team



Thank you for your attention !