Cesar

Application to tunnels analyses and design

Croix-Rousse, Lyon

by Setec-TPI

→ The modernisation and the safety upgrade of this urban tunnel leaded to the construction of a second tube with 11 junctions. These works also included a new concrete lining in replacement of the existing masonry.

→ **CESAR 3D** was used for the analysis of the stresses and displacements generated during the drill of the second tube. A specific section with a junction and 2 garages was modelled.
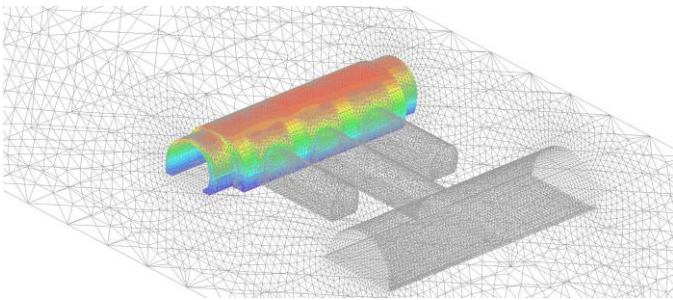
Extension of metro line, Paris

by EGIS
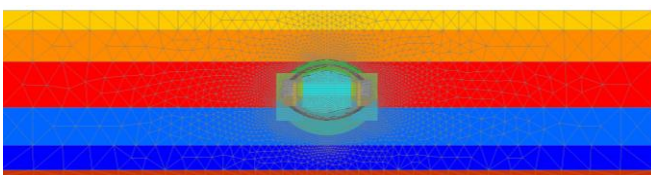
*Global view of the **CESAR 2D** model*

→ Works for extension of an important metro line of Paris are under preparation. Due to existing gallery and surrounded urban environment, traditional method will be used.
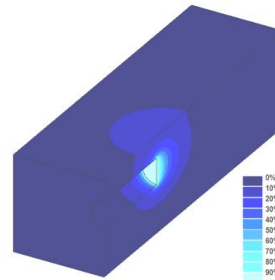
→ **CESAR 2D** is useful for its ability to model the numerous stages of construction and the different types of load cases to be applied.
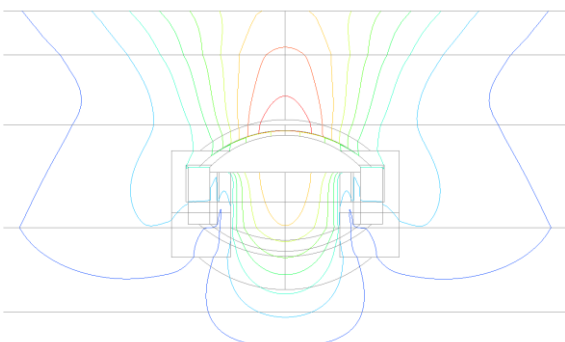
Example of isolines of total displacements results after upper gallery excavation

Groene Hart Tunnel, the Netherlands

by Bouygues–Koop consortium

Diffusion of excess pore pressures at the tunnel face

→ The Netherlands built a high-speed line between Amsterdam and the Belgian border. The solution of boring a tunnel 7.5 km long, 14.50 m in outer diameter, was excavated using a earth-pressure tunneling machine within the highly-unique Dutch hydrogeological environment.

→ A three-dimensional model using **CESAR 3D** was used in order to simulate the hydraulic behaviour of the soil. It was based on a transient analysis of excess pressure diffusion within the soil induced by the excavation. Diffusion of the excess pore pressure was modelled as a hydraulic load.
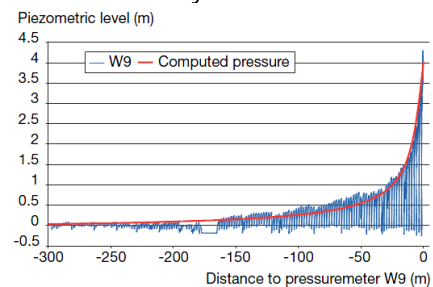
Calibration of finite element computations with the experimental results

AIME R., ARISTAGHES P., AUTUORI P. ET MINEC S., *15 m diameter tunnelling under Netherland Polders*, ITA2004, Singapour, Mai 2004.

Tunnel A89 – Violay

by Vinci Construction Grand Projets

→ The consortium decided the reinforcement of the tunnel opening with a system of umbrella. Traditional method was applied for the excavation.
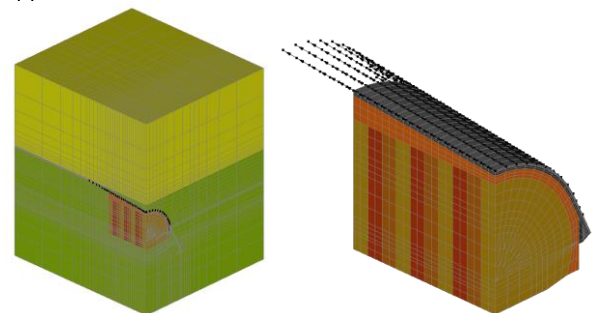
FEM Model of the tunnel opening and detail of the umbrella

→ **CESAR 3D** was helpful for the generation of the complex geometry and mesh model. Various types of elements (volumes, shells, beams) helped for analysis of the soil reinforcement.

Bi-tube tunnels

by Bouygues Construction

→ Bouygues Construction is a long time user of **CESAR-LCPC**. Their engineers developed an analysis process of bi-tubes tunnels bored with TBM, using the numerous modelling features of **CESAR 2D**: stage construction process, excavation forces applications and control, long term actions, analysis of results inside structural elements.
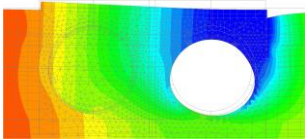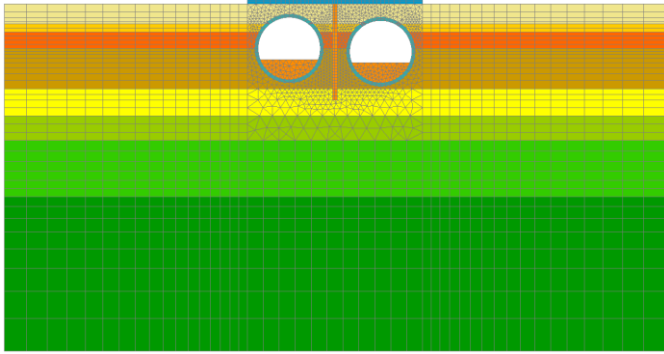
2D FEM model, display of total displacements and bending moment in the lining (after stress integration)
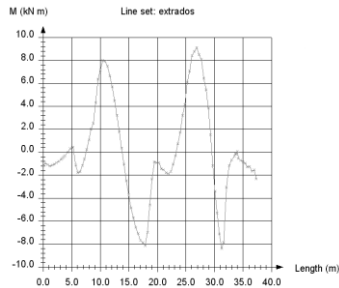
Tamarins road, Reunion Island

by CETE Sud-Ouest

The covered trench after works

→ A covered trench was built on one part of the Tamarins road project on Reunion Island. During backfill works, high efforts occurred in the concrete, questioning the initial design.
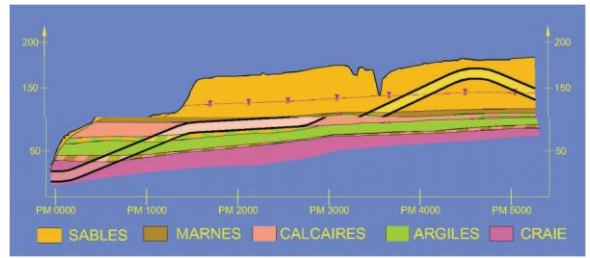
→ The controller used **CESAR 2D** for a sharpest modelling of the soil-structure interaction, integrating interface elements. Their conclusion was a new construction process, limiting the efforts in the concrete.
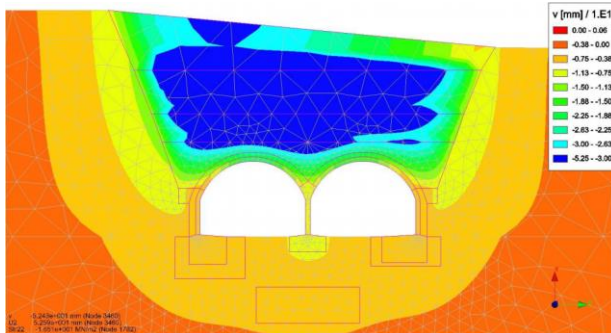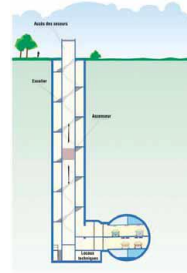

Isoscalar plots of vertical displacements.

# Socatop, Paris

by Terrasol

*Geological conditions of the project*

→ With a length of 10 km, the East tunnel linking Rueil-Malmaison to Versailles crosses the entire geological series of the Paris basin; from the Montian chalk to the Fontainebleau sands. The soil conditions are highly variable (fine sands, marl, plastic clay, rocky limestone) and required the use of a TBM able to work either with slurry shield or earth pressure.

→ The importance and complexity of the niches structures required the construction of several finite element calculation models with **CESAR 3D**. These models include the construction phases of the tunnel and niche.
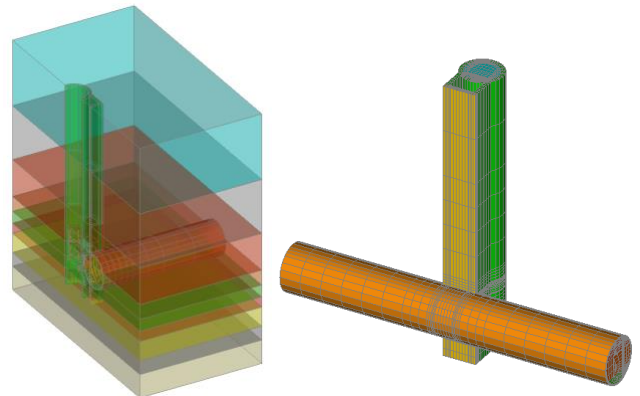
Overviews of the 3D FEM model with main gallery and shaft
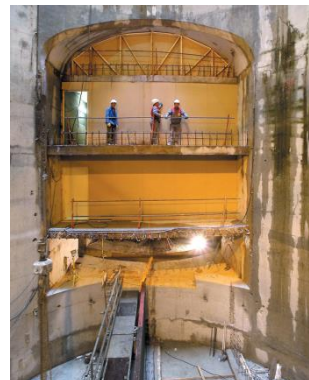
Junction of the shaft to the main tunnel gallery (reality and FEM results)