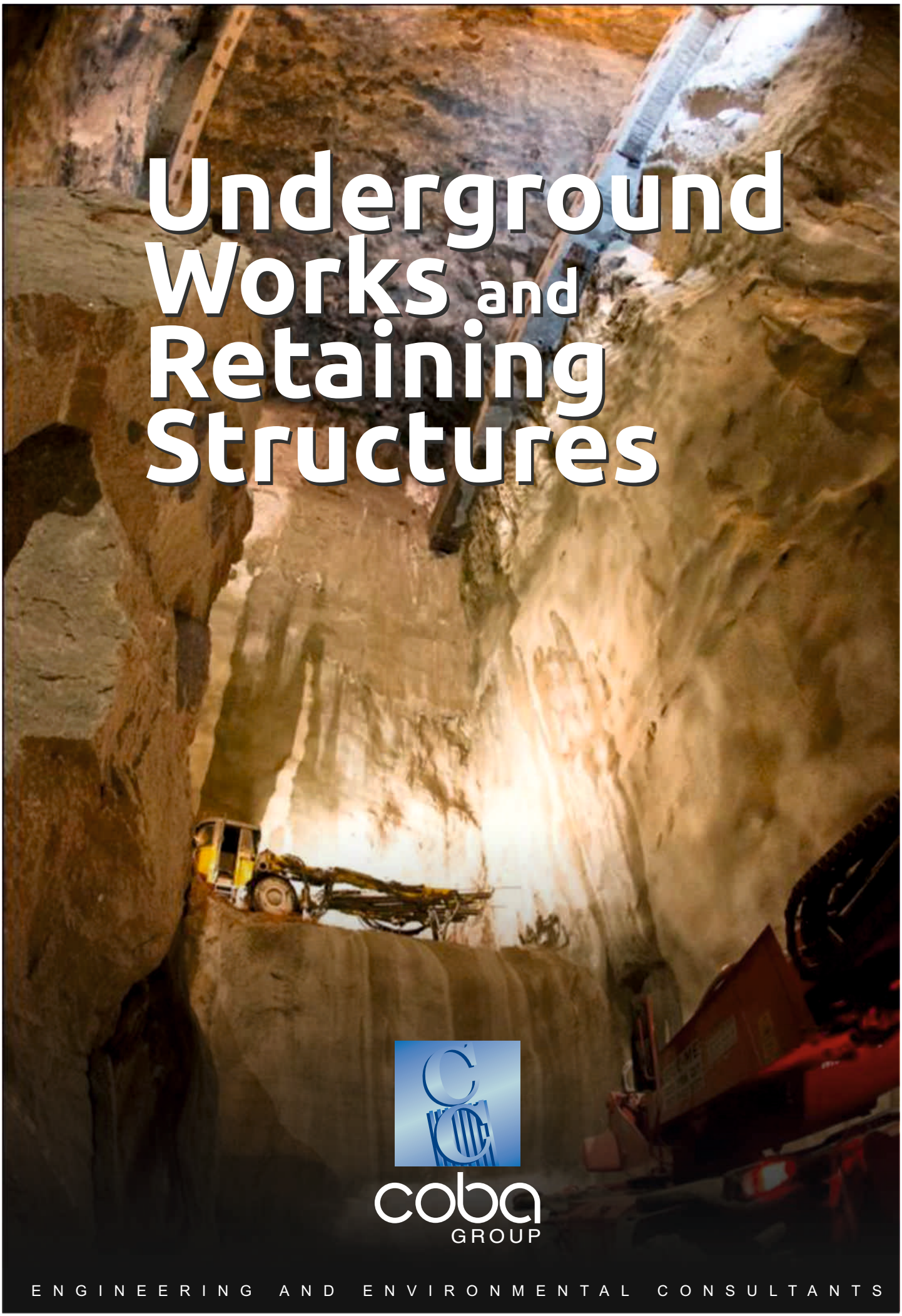

Underground
Works and
Retaining
Structures
coba
GROUP
ENGINEERING AND ENVIRONMENTAL CONSULTANTS

PRESENTATION

COBA is a multinational and multidisciplinary group of Engineering and Environmental Consultants, founded in 1962.

The Group provides engineering consultancy services ranging from basic and planning studies, technical, environmental and economic feasibility studies, design and construction design as well as project management and works supervision, to operation follow-up and behaviour monitoring.

The Group has offices/subsidiaries in three continents and experience in more than fifty countries and encompasses several companies in accordance with functional specializations or geographical areas.

The competences acquired along the last six decades, together with the state-of-the-art employee expertise, the stability of its permanent staff and the comprehensive international experience allow to find out the best solutions for the full satisfaction of public and private Clients' needs and expectations.

During its existence, the Group has participated together with public authorities or private developers, in the feasibility of multidimensional projects, some of them being structuring projects and with major impacts on the improvement of peoples' life conditions in the several countries where it worked.

At present, the Group has a wide number of competences and technical areas that allow the composition of multidisciplinary teams who share knowledge and experiences in the execution of projects.

FIELDS OF ACTIVITY

HYDRAULIC UNDERTAKINGS
Concrete, Earth-fill and Rock-fill Dams. Weirs and Reservoirs Water Conveyance Systems. Hydraulic Structures.

POWER GENERATION AND TRANSMISSION
Hydroelectric Power Plants. Photovoltaic power plants and wind farms. Small Hydropower Plants. Power Plants Rehabilitation and Modernization. Substations High Voltage Transmission Lines. Cooling Water Systems for Thermoelectric Plants.

WATER SUPPLY AND WASTEWATER SYSTEMS
Catchment, Transport and Distribution of Potable Water. Water Treatment Plants. Drainage Systems. Wastewater Treatment Stations. Pumping Stations.

AGRICULTURES AND RURAL DEVELOPMENT
Irrigation and Drainage Systems. Rural Roads. Production Systems. Mapping and Basic Information.

TRANSPORTATION INFRASTRUCTURES
Roads and highways. Railways. Passenger and Freight Railway Stations. Metro and Light Rail. Airports. Bridges and other engineering structures.

ENVIRONMENT
Environmental Impact Assessment. Environmental Management, Monitoring and Auditing. Pollution Control. Landscaping. Land Management. Recovery of Degraded Areas. Waste Landfills.

GEOTECHNICAL STRUCTURES
Tunnels and Caverns. Slopes in Fill and Cut Section. Special Foundations Breakwaters. Embankment Works.

MARITIME AND FLUVIAL WORKS
Wharfs. River Training. Quay Rehabilitation. Flood and Flow Control.

MINING INDUSTRY
Environmental Studies. Design of Tailings Dams and Related Structures. Safety Assessment of Tailings Dams. Design Review of Tailings Dam Closure. Operations Maintenance and Monitoring Manual for Tailings Dams. Risk Analysis.
Mine Closure Plan. Training.

BUILDINGS
Residential and Services Buildings. Industrial Buildings.
Steel and Mixed Industrial Structures. Rehabilitation and Restoration of Ancient Buildings.

CARTOGRAPHY AND CADASTRE
Geographic Information Systems (GIS). Digital Cartography. Thematic Cartography. Thematic Cadastres. Land Acquisition.

SAFETY CONTROL AND REHABILITATION
Expertise, Monitoring. Inspection and Reinforcement of Dams and Transportation Infrastructures. Works Instrumentation. Project Maintenance and Operation.

PROJECT MANAGEMENT AND CONSTRUCTION SUPERVISION
Project Management. Cost Management. Site Supervision.
Quality Assurance/Quality Control.

Tunnels

HIGHWAY | RAILWAY | HYDRAULIC

PORTUGAL

Carenque

CREL (Lisbon Outer Ring Road)

BRISA – Auto-estradas de Portugal, S.A. was faced with the need to cross an area of palaeontologist interest during the construction of the A9 Motorway – CREL (Lisbon Outer Ring Road).

A limestone slab from the Cretaceous period discovered during excavation activities in a quarry revealed the existence of multiple tracks of dinosaur footprints that comprise on the most important sites of its kind in Europe.

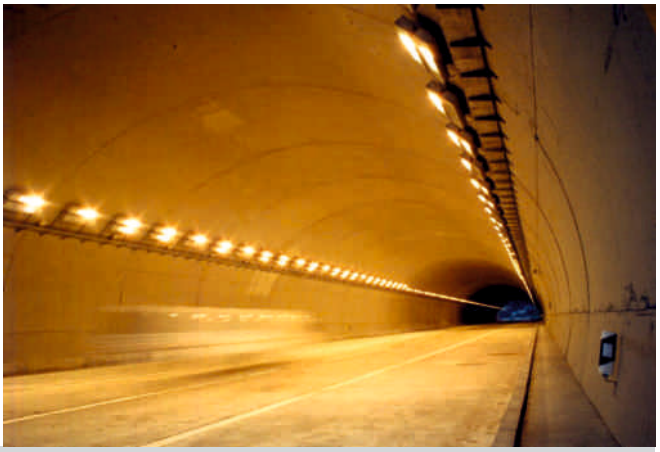
The rock mass is formed by a series of monocline karst limestone, intercalated with weathered marl and clay with very low strength.

This problem was overcome by drilling two tunnels composed of galleries with sections of about 173 m^3 and lengths of approximately 285 m, with an overburden ranging between 2 m and 20 m.

During construction, the dinosaur footprint tracks were duly protected by geotextile coating and several sand layers, after sealing of the footprints with suitable plastic material.

Finally, the tunnel portals suffered an architectural intervention, consisting of alternate and stylized representation of a dinosaur head and tail, with clear reference to the paleontological heritage above the road, as well as of the technical and economic efforts made to guarantee its preservation.

The Carenque Tunnel was distinguished in 2004 by the "Ordem dos Engenheiros" (Portuguese College of Engineers), who included this tunnel, integrated in the A9 motorway, among the 100 major works of Portuguese Engineering undertaken in the twentieth century.



OTHER CHARACTERISTICS:

• Total length:	2 x 265 m
• Width of each tunnel:	19.44 m
• Cross section:	
- Maximum hight:	8.44 m
- Number of traffic lanes:	3 x 3.80 m + a 4 m bench
• Longitudinal profile:	gradient of 0.658%

Tunnels

HIGHWAY | RAILWAY | HYDRAULIC

PORTUGAL

Gardunha A23 Motorway

Between 1992 and 2003 COBA was involved in the development of the Gardunha Mountain Range Tunnels that are now integrated in the "Beira Interior" Motorway (A23). Studies pertaining to these tunnels were undertaken at Detailed Preliminary Design and Detailed Design Phases, and the due Technical Assistance during the construction works was provided. These infrastructures were essential for the completion and efficiency of the IP2 Highway as an alternative route to international traffic originating from Vilar Formoso.

The first tunnel of this system, the Gardunha I Tunnel, located between Fundão and Alpedrinha, was completed in 1997. During a first phase it ensured light traffic flow in a North-South direction and posteriorly, in both directions. The design of the second gallery, designated Gardunha I-A, began in 1999 and the construction works were completed in 2003.

Between 1994 and 1995 COBA conducted the studies pertaining to the Detailed Preliminary Design and Detailed Design of the Gardunha II Tunnel.

This tunnel was designed to minimize the negative environmental impacts upon Alpedrinha, a town of significant tourist interest.

The geological conditions in which it develops correspond to granites at the tunnel portals and metamorphic rocks in the middle zone of the tunnel.

OTHER CHARACTERISTICS:

- Length: Tunnel I and IA - 1603 m, tunnel II - 320 m
- Maximum overburden: 250 m
- Construction method: Conventional Method
- Cross section
  - Maximum height: 6,80 m
  - Number of carriageways: 2x3,75 m each

Tunnels

HIGHWAY | RAILWAY | HYDRAULIC

PORTUGAL/MADEIRA ISLAND

Access Road to the Funchal Port

The Western Access Road to the Funchal Port comprises a new road that extends throughout an urban environment with vigorous topography, requiring the construction of a tunnel resorting to drilling techniques.

This tunnel is approximately 600 m long, has a 30 m maximum overburden and a section of 84 m^2. We adopted a horseshoe structure with a circular vault that extends below the horizontal axis just to the foundation slabs.

In addition to the limitations imposed by the road layout, the design of the gallery took into consideration a road clearance of 8,0 x 4,7 m (LxH) and a typical cross-section with a 8,0 m carriageway (2x3,5 m and 2x0,5 m shoulders) and walkways.

Due to the fact that the tunnel is inserted in an urban area, great importance was given to the restrictions inherent to the interaction between the construction and operation of the tunnel and the quality of life of the populations that inhabit the area.

LIMITATIONS ON CONSTRUCTION:

- Maximum permissible settlements, envisaging absence of induced damages to neighboring buildings during the construction of the gallery
- Expropriations
- Traffic rerouting
- Noise and vibrations during the construction phase

Tunnels

HIGHWAY | **RAILWAY** | HYDRAULIC

PORTUGAL

Bolhão Station

Oporto Metro Railway

The Bolhão underground station is located at the common section of Lines A, B and C of the Oporto Light Metro, in an urbanised zone with dense population, in the downtown, a major shopping centre of the city. It develops along the Rua Fernandes Tomás, at the junction with Rua Alexandre Braga, under important buildings dating from the beginning of the century and the declared town patrimonial heritage chapel "Capela das Almas".

The access shafts are delimited by a retaining structure comprising a secant pile cut off wall that confines the area to be excavated. The Fernandes Tomás shaft has an approximate total length of 44 m, an inner width of about 11 m and a depth of some 26 m. The Alexandre Braga shaft has an identical total length and an inner width of about 9 m. In geological terms, the Bolhão Station is located in an area including fill materials, alluvial soils and granite saprolites, which can reach a total thickness of about 13 m. COBA executed the Final Design of Fernandes Tomás and Alexandre Braga shafts excavation and retaining structures, the final design of the excavation, primary lining and final lining of the cavern and of the transversal gallery, the final design of the station internal structures, the monitoring plan for shafts excavation, the monitoring plan for the execution of the underground station, risk assessment of buildings during the station construction.

In addition, during the works, COBA provided Technical Assistance to the construction works through the mobilisation of a project team to the site that integrated the Follow-up Team responsible for the execution of detailed geological and geotechnical cartography of the excavations, the follow-up of the monitoring work and the adequacy of the design to the exposed rock mass, with special emphasis on the excavation and primary lining works.

THE STATION IS BASICALLY COMPOSED OF:

- a main cavern where is the railway platform
- a transversal gallery for the access to the mezzanine at the platform level
- an access shaft
- operational rooms
- an access shaft and emergency exit to Camélias Parc
- a connection tunnel to the main cavern

Tunnels

HIGHWAY | RAILWAY | **HYDRAULIC**

ANGOLA

Cambambe 2 Hydropower Plant

The Cambambe Hydropower Development is located in the Kwanza River, approximately 180 km southwest from the city of Luanda and about 15 km from the city of Dondo. It was initially designed and built for a phased construction.

Phase II of the project is currently ongoing and includes the construction of the Cambambe 2 Power Plant. The construction of the Cambambe 2 hydroelectric powerhouse presents a very wide and comprehensive geological and geotechnical component. It includes the excavation of four intake tunnels, a drainage tunnel and a temporary access tunnel. Some of the key issues to highlight relate to the definition of tunnel stabilization solutions and, consequently, the geological mapping of excavations, making the necessary support adaptations and adjustments, depending on the real conditions of the rock mass.

The Power plant 2 is an underground plant with an installed capacity of 700 MW. It includes the following main components:

- a new water intake and water conveyance tunnel;

- a power plant, the respective units, transformers, substation and ancillary systems: access tunnel and control building;

- A feeder canal and discharge tunnel located downstream.

OTHER CHARACTERISTICS:

• Length of each gallery :	450 m
• diameter of each gallery / well :	8,5 m
• Extension of each well:	75 m
• Width of the drainage tunnel:	3,2 m
• Extension of the drainage tunnel:	180 m
• Width of the access tunnel:	8,5 m
• Extension of the access tunnel:	255 m

Tunnels

HIGHWAY | RAILWAY | **HYDRAULIC**

ANGOLA

Laúca Hydropower Development

The Laúca Hydropower Development is located in the Kwanza River, about 47 km downstream from the Capanda Hydropower Undertaking, currently under operation, and principally envisages energy generation.

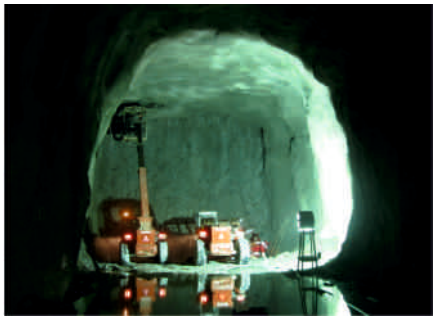
The undertaking is composed of a RCC dam, an underground water conveyance system (energy generation (2004 MW), a toe-of-dam water conveyance system (ecologic flow (65,5 MW)) and a main underground powerplant.

Water Conveyance System (energy generation):

Underground, composed of 6 water intakes, 6 shafts with inner diameter of 7,0 m and depths ranging from 110 m to 115 m; 6 headrace galleries with 9,0 x 12, m and average length of 1900 m each and slope of 4%.

MAIN LAÚCA POWERPLANT:

• Underground cavern:	21 m wide and 273 m long
• Underground excavation:	302 000 m^3
• Capacity: 6 x 334 MW =	2004 MW
• Net head:	200 m
• Nominal flow:	182 m^3/s
• Units:	6 vertical axis Francis Units
• Energy produced:	8 640 GWh/year



Tunnels

HIGHWAY | RAILWAY | **HYDRAULIC**

ARGENTINA

Cildañez Storm Water

The works aim at collecting the water surpluses in the Arroyo Cildañez basin which converge near the General Paz Avenue, in the stretch comprised between the la Noria Bridge and the Mansilla Avenue, by diverting them through buried pipes towards the Matanza river, in order to systematise the surface drainage of the city of Buenos Aires.

The works comprise the construction of nine stretches of reinforced concrete pipe, in a total length of about 8 km, nearly all in tunnel. This is a very large and extremely complex work, mainly due to the fact of crossing an urban and sub-urban area, composed of granular soils of the Pampeano formation, and thus a special attention was paid to the control of settlements, by using a primary lining with concrete segments and a secondary inner lining with cast in place concrete. On the other side, it was necessary to define policies and strategies aiming at minimising the interferences between the execution of the works and the development of the normal daily life.

OTHER CHARACTERISTICS:

- Length: 7 830 m
- Inner diameter: Ø 4,40 m throughout 6 000 m; Ø 2,80 m throughout 1 830 m
- Overburden: 5 to 12 m
- Construction method: TBM (Tunnel Boring Machine)
- Geological conditions: detrital soils of the Pampeano formation slightly over-consolidated.

Tunnels

HIGHWAY | RAILWAY | **HYDRAULIC**

PORTUGAL

Odelouca-Funcho

This tunnel is part of the Odelouca-Funcho Development and links the Odelouca and Funcho dams in order to transfer water from the Odelouca reservoir to the Funcho reservoir.

It is 8110 m long and has a 2,40 m circular section. The excavation volume in the gallery is 50.000 m^3 and the total volume of concrete is 16.300 m^3. The design flood is about 1250 m^3/s and the design flow in the tunnel is 9 m^3/s.

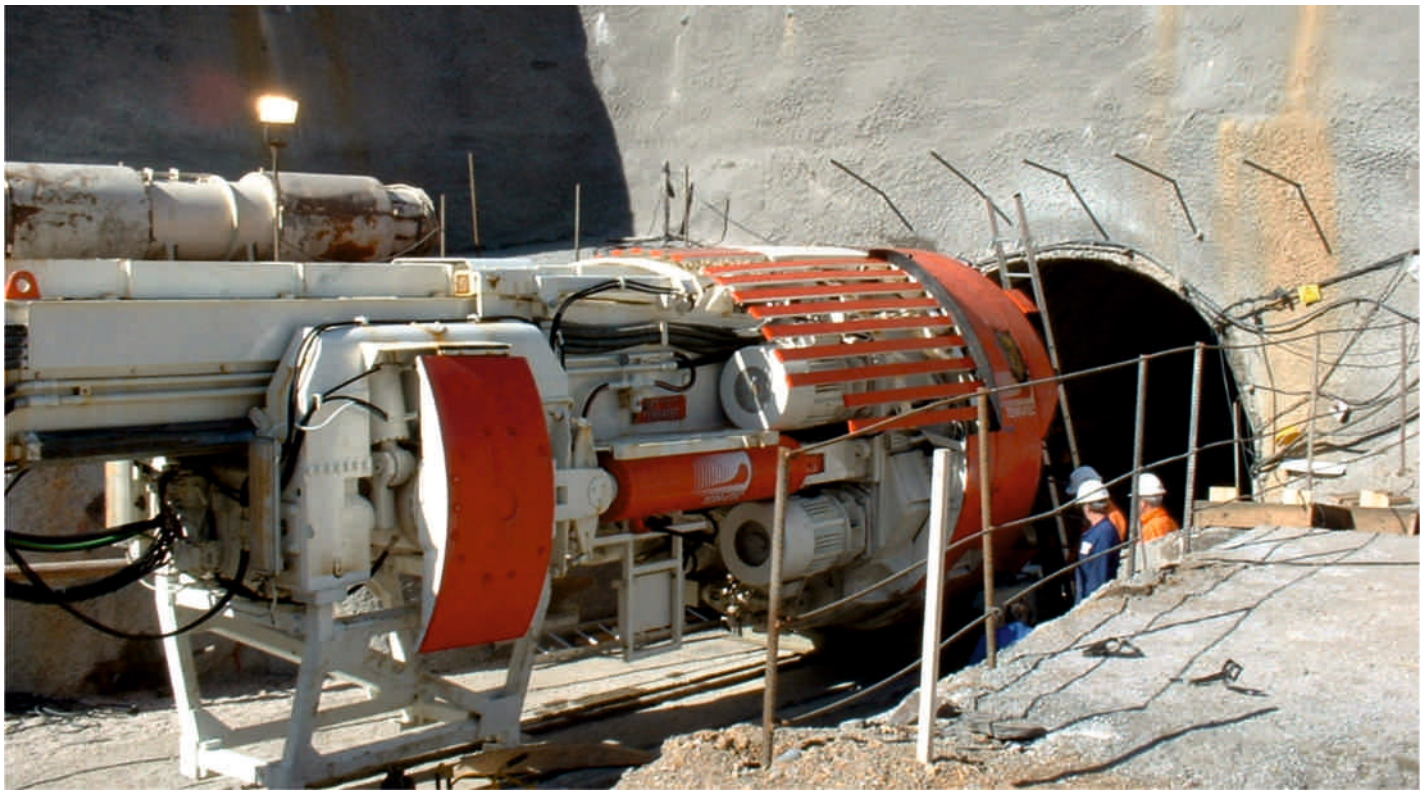
The tunnel crosses a formation of schists and greywackes without important stability problems.

PRESSURE RELIEF STRUCTURE:

• Type:	Well chamber
• Location:	Downstream

HYDRO-MECHANICAL EQUIPMENT

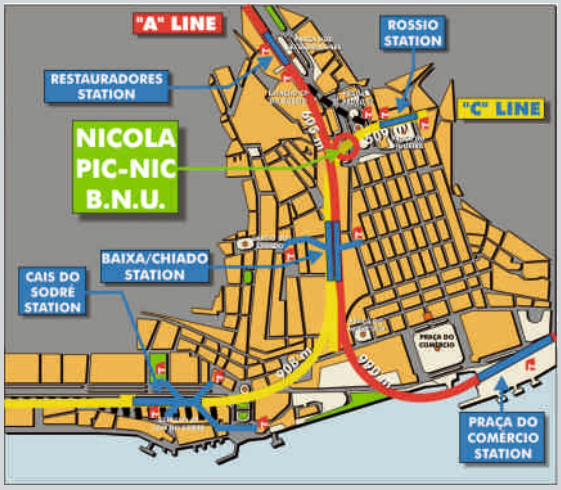
• Upstream:	Mobile racks and fixed wheel gate
• Downstream:	Fixed wheel gate, sealing disk and butterfly valve



Reinforcement Structures

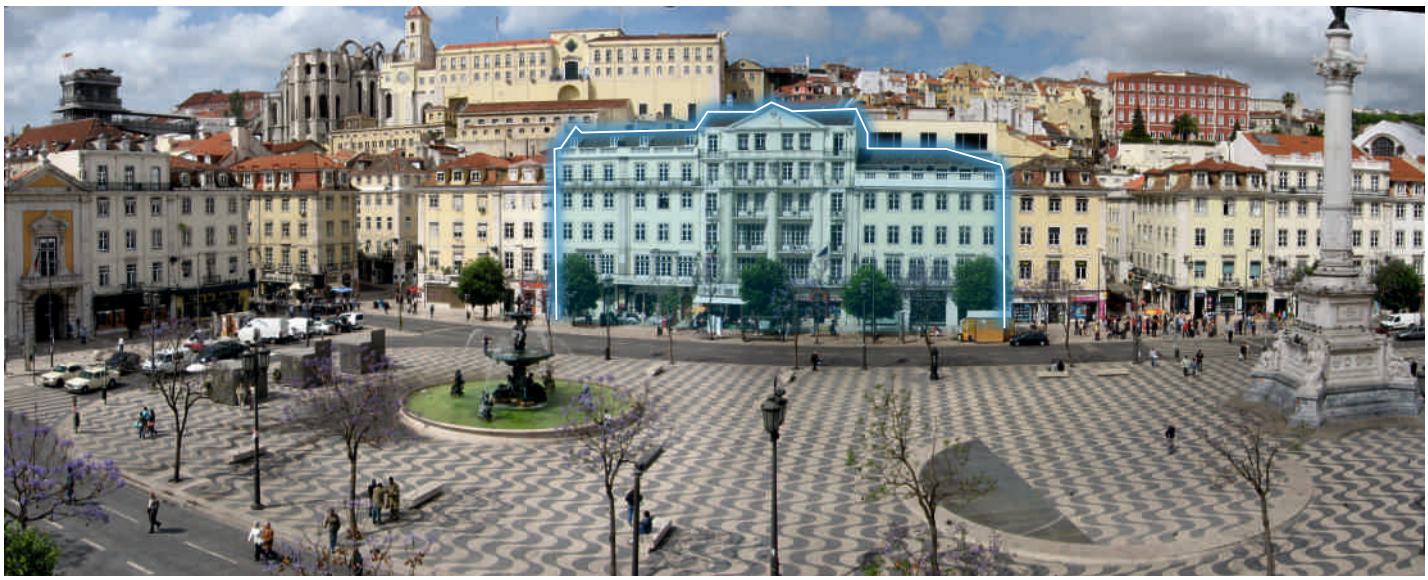
PORTUGAL
Lisbon Metro
Nicola/Pic-Nic/BNU
buildings Lisbon in city centre

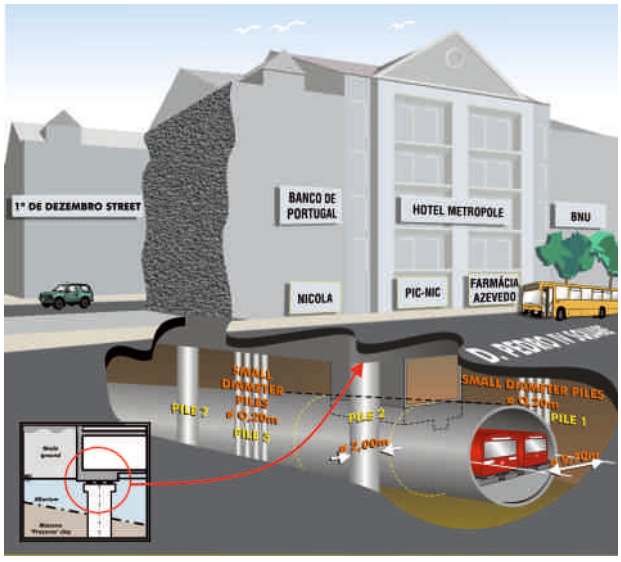
Within the scope of the construction of Lines "C" Rossio - Cais do Sodré and "A" Restauradores - Terreiro do Paço, included in the Lisbon Metro Expansion Plan in the historical city centre, tunnels were constructed with recourse to a "TMB", interfering with buildings located above the metro alignment, with special reference made to the Nicola / Pic-Nic / BNU building. This building is located at D. Pedro V Square, and its original construction date remotes to 1837 - 1845, therefore being part of the national heritage stand.

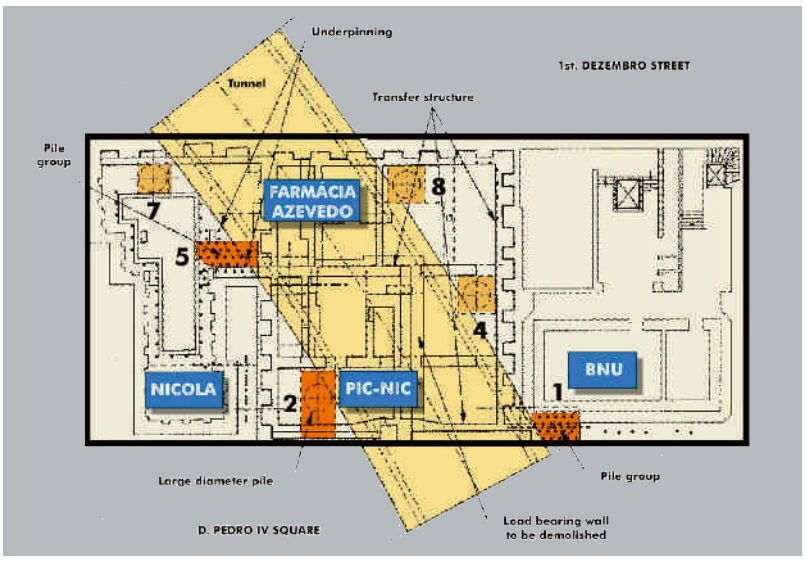


The principal activities developed by coba comprised the following:

- general demolition and excavation;
- pile construction;
- construction of the reinforcement structure, including demolition of wall fends, so as to allow for beam and slab construction;
- demolition of existing walls between the basement and the ground-floor;
- load transfer to new foundations by means of hydraulic systems incorporating flat jacks, including instrumentation;
- removal of the physical interference at basement level, comprising the foundation slab, walls and central nucleus;
- monitoring during the tbm passing, followed by final adjustment by reactivating of the hydraulic system.







PORTUGAL

Alqueva Power Plant II

Guadiana River - Alqueva System

Alqueva II Hydropower Plant

HYDROELECTRIC DEVELOPMENT

In the first phase, the Alqueva power plant development was equipped with two 130 MW reversible units; the Alqueva II hydropower plant has the purpose of duplicating the reversible installed capacity in a way to taking advantage of the conditions created by the combination of the Alqueva large reservoir and the Pedrógão downstream reservoir allowing pumping-turbinating weekly cycles.

The Alqueva II units are installed in the new hydropower plant, open and cut on the right bank of the Guadiana River, downstream of the dam right abutment, taking advantage of the existing platform.

The adopted solutions resulted from the feasibility studies (March 2007) together with the option of equipping the power plant with units similar to the existing ones.

The studies, designs and environmental impact studies were awarded to COBA by EDP on April 2007.

The new Alqueva II Power Plant aims to operate essentially as a network regulator, by pumping the water from Pedrógão on to the Alqueva during the off-peak hours, when energy surplus is at low cost, and turbinating the water pumped during the peak period.

The Alqueva Power Plant I shall operate in the same manner when it does not have to turbinate its own inflows, which will occur frequently during the dry season.

Water Intake and Cavern Power Plant

HYDROELECTRIC DEVELOPMENT

PORTUGAL

New Salamonde II Power Plant

Integrated in the Cávado-Rabagão system, the Salamonde development takes advantage of the approximately 120 m head between the Salamonde and the Caniçada reservoirs, immediately downstream.

The Salamonde power plant Salamonde I is equipped with two Francis units with a rated capacity of 21 MW (25 MVA) per unit and a nominal flow of approximately 22 m^3/s per unit under a 115 m head. The annual power generation is of approximately 220 GWh.

Considering an average net head of 115 m and an overall yield of 85%, the theoretical productivity of the site will be in the range of 280 GWh / year; under these conditions, the current average production amounts to about 80% of the theoretical productivity.

The equipped flow in the current power plant is slightly superior to the average inflow (equipment factor 1.33), which implies very high annual operation periods and a very low generation modulation capacity. This feature was compatible with the characteristics of the national power grid in the 50's and 60's, when most of the country's energy generation had hydrolelectric origin and when essentially basic energy was requested from reservoir undertakings.

Currently, the purpose of hydroelectric developments is especially to supply energy during peak periods, as well as to balance the generation fluctuations that result from the variability of aeolian sources, whose total capacity is increasing significantly.

EDP - Produção is currently implementing a program for re-equipping the older developments, both run-of-river power plants (power plants of the International Douro River) and reservoir power plants (developments of the Cávado-Rabagão system). The Salamonde II power plant is within this program.

The studies were awarded to COBA by EDP on July 2009.

The increase of installed capacity of the new Salamonde II power plant does not correspond to a significant increase of the development capacity. On the other hand, the increased capacity will enable to modulate the generation according to demand, thus increasing significantly the flexibility of the development and the energy generated.

During particularly windy days, the increased aeolian energy in the national network will lead to potential surplus energy, especially during the night period. In these conditions, the availability of reversible units will enable to absorb the surplus energy by pumping, accumulating it under the form of potential energy that may be later turbinated to meet the needs during most demanding hours.

The Salamone II power plant includes a new water intake in the Salamonde reservoir, an underground water conveyance structure with a total length of 2 130 m, a cavern power plant and a discharge structure in the Caniçada reservoir. A substation and a support building was built at the surface.

The power plant it's equipped with one unique reversible unit with a Francis vertical turbine pump, with a nominal capacity of 209 MW turbinating a flow of approximately 200 m^3/s under a 115 m head.

Slope Stabilisation and Retaining Structures

PORTUGAL

Slope Stabilisation of RN 379-1

Between Outão and Portinho da Arrábida

The EN379-1 road is located in the foot of the Arrábida Mountains, whose higher point reaches the El. 501m. The intervention area for the slope stabilization is between Outão and Portinho of Arrábida, for almost 4 km.

The road is an axis of great importance for touristic use of the Natural Park of Arrábida, the whole year round, with larger seasonal incidence in the course of the summer, for access to the beautiful beaches of the area.

The geological and geotechnical conditions of the natural hillside have been provoking the permanent occurrence of fall of rock blocks to the road, situation worsened by the accentuated precipitation and for the fires happened in the Summer of 2004 that eliminated substantial part of the vegetation that helped to sustain the blocks.

Due to serious problems of safety, the road was closed during two years. During this time the design of proper stabilization measures and the construction of the works were completed. Three levels of protection were installed: stiff barrier just near the road, reinforced steel mesh with rock bolts in the main rock outcrops and dynamic barriers of medium to high energy to stop eventual rolling blocks falling from inaccessible slopes.

JULY | 2023

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