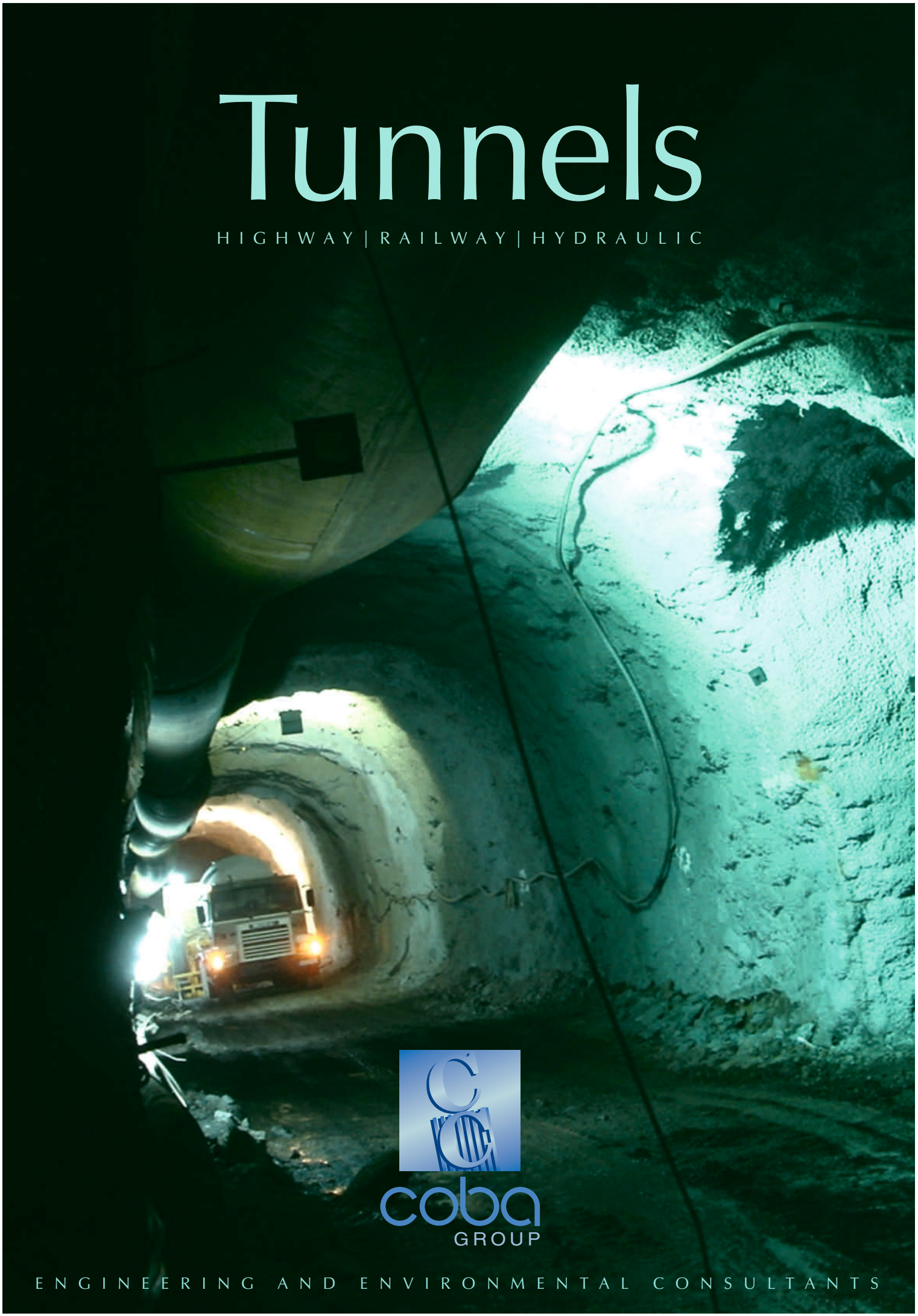
Tunnels

HIGHWAY | RAILWAY | HYDRAULIC



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.

TUNNELS

COBA has designed tunnels since its foundation. Tunnels, caverns and shafts related to hydraulic and hydroelectric tunnels. The deep transformation of the Portugal infrastructure patrimony that started in the 90's, implied the refurbishment of ancient underground works, namely railway tunnels, and the design and construction of new tunnels for metropolitan transport, roads and highways, modern railway facilities and hydraulic and hydroelectric complexes.

Almost 20 km of new highway tunnels were constructed in the last 25 years in the continent and almost 100 km of express-road tunnels in the Madeira Island. Underground facilities were added to the existing Lisbon metro and a new metropolitan system were created for the city of Oporto, where the central lines in the downtown were all designed to be underground. In this entire extensive and intensive infrastructure program, COBA played an important role as a leading engineering company.

In the last 10 years, new hydroelectric facilities and repowering of existing installations were carried out in Portugal. Underground hydraulic circuits were constructed, including powerhouse located in caverns or shafts, headrace and long tailrace tunnels.

COBA exported its know-how in underground construction to several countries in Europe, South America, Arabic peninsula and Africa. Consultancy and design of road and hydraulic tunnels have been developed for countries like, Ireland, Greece, Brazil, Argentina, Morocco, Algeria, Tunisia, Qatar, Angola, among others, always using high design standards and up-to-date approach. COBA participates systematically in the international forum of technical discussion like the International Tunneling Association, National and International Congresses, European Committees for Standards.

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.

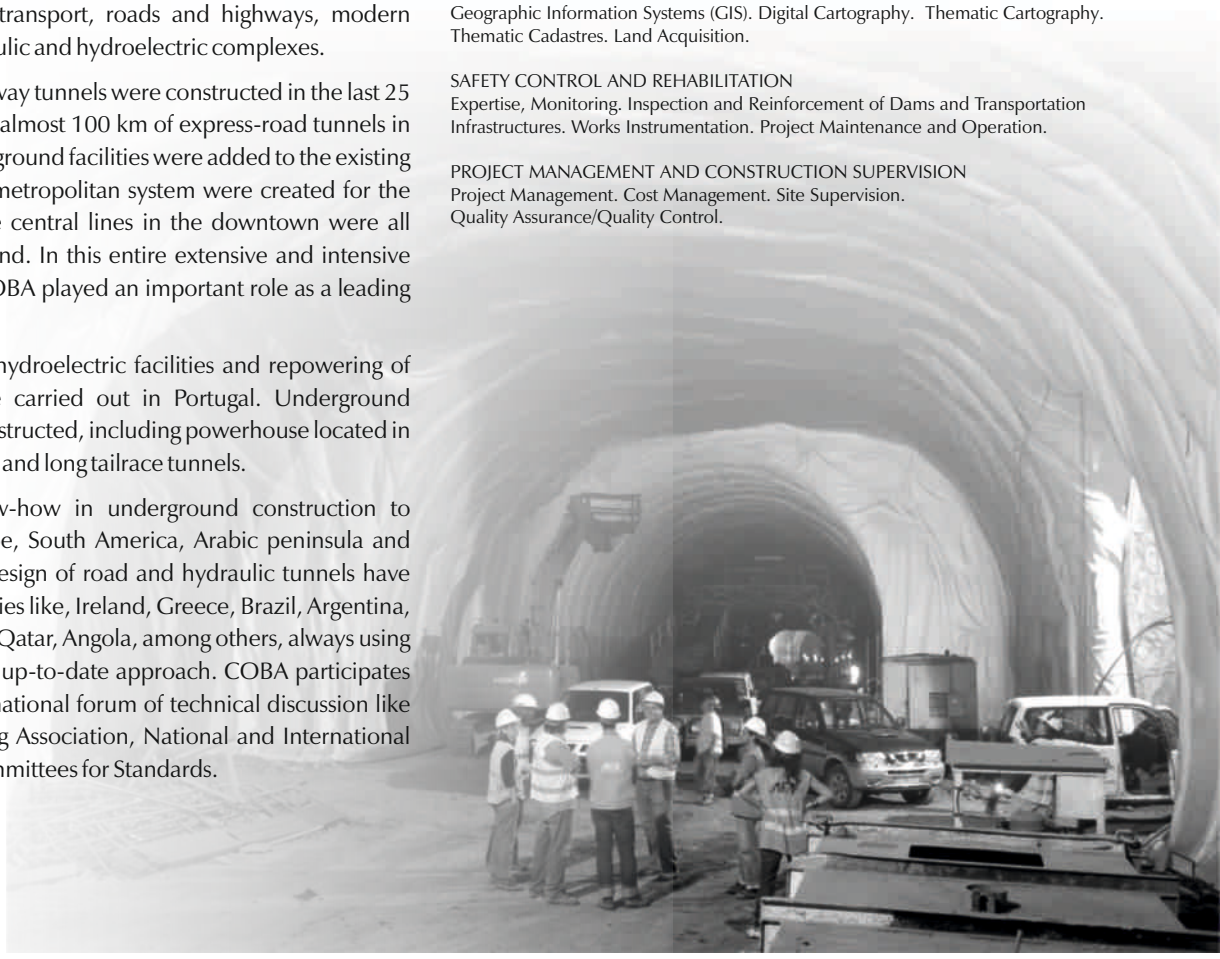
MINING INDUSTRY
Environmental Studies. Design of Tailings Dams and Related Structures. Safety Assessment of Tailings Dams. Design Review of Tailings Dam Closure. Operations Maintenance and Monitoring Manual for Tailings Dams. Risk Analysis.
Mine Closure Plan. Training.

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.

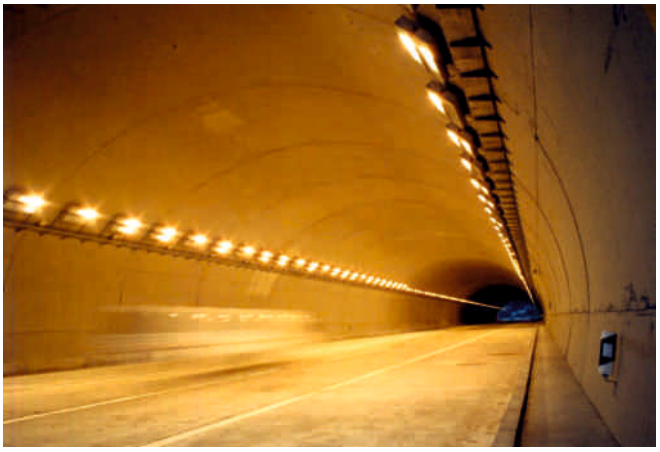
PROJECT MANAGEMENT AND CONSTRUCTION SUPERVISION
Project Management. Cost Management. Site Supervision.
Quality Assurance/Quality Control.



Tunnels

HIGHWAY | RAILWAY | HYDRAULIC

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

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

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

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**

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**

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.

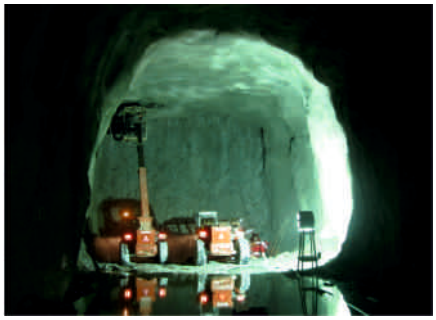
The undertaking is composed of a RCC dam, an underground water conveyance system (energy generation (2004 MW), a toe-of-dam water conveyance system (ecologic flow (65,5 MW)) and a main underground powerplant.

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**

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**

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.

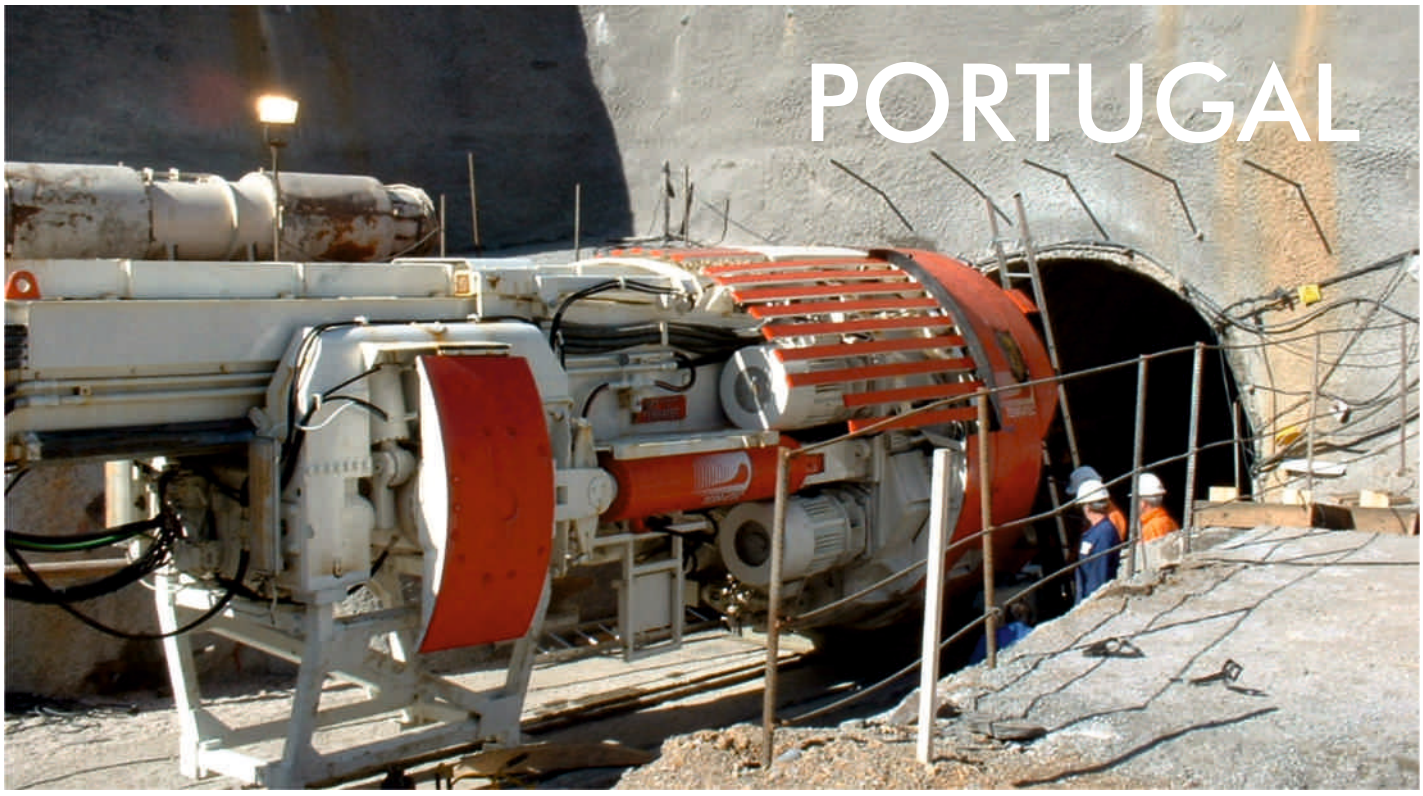
The tunnel crosses a formation of schists and greywackes without important stability problems.

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



JULY | 2023

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