Kennedy Tunnel | Santiago Centro Oriente 2 Program | Chile | COSTANERA NORTE

Excellence in Tunnel Engineering

2020

Energy / Mining / Transport
1. Company Overview

1.1. Introduction

1.2. Mission, vision, values

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1.4. Software tools and facilities

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Las Cruces Mine | Spain | COBRE LAS CRUCES
1.1. Introduction

**SUBTERRA** is an independent private corporate group, unconnected to construction companies, suppliers of equipment or services and financial companies. Their projects are based exclusively on the rigorous analysis of each case, in order to develop technical solutions optimizing the construction costs with the maximum safe and environmental conditions, as well as compromise with the community. **SUBTERRA** is certified in ISO 9001, 14001 and 166002 management systems; and OSHAS 18001.

Since its creation **SUBTERRA** has offer services both in the design stage and during construction. As design engineering, its services include field data collection and interpretation, sophisticated support and lining calculations, functional design and security installations; and applied to all phases of feasibility, basic engineering, and detailed engineering value. In the construction phase, its services extend to the geotechnical monitoring and monitoring of slopes, tunnels and underground spaces.

**SUBTERRA** actually is constituted by the following companies:

- **SUBTERRA Ingeniería Ltda** in Chile,
- **SUBTERRA Ingeniería SAS** in Colombia,
- **SUBTERRA Ingeniería SL** in España,
- **SUBTERRA India Engineering Pvt. Ltd.** and
- **SUBTERRA Ingeniería SAC** in Peru;

that functionally act as a unique company organizing its staff and facilities to offer the best services accordingly to the specific characteristics of each project.

**SUBTERRA** has permanent offices in Delhi, Lima, Madrid, Medellin and Santiago, as well as several site offices; developing also projects during 2019 in fifteen countries. All of them are fully equipped with specific software tools such as FLAC 2D and 3D, UDEC, PFC, EXAMINE 2D and 3D, FAGUS, STEPS, SOLVENT, SAP2000, among others.

**SUBTERRA** group employs, with nine countries's technicians, is constituted for a multidisciplinary staff, from which 81 % has University degree, with more than 30 years of experience.

**SUBTERRA** has consolidated worldwide as one of the leading engineering companies specialized in the field of underground works.
1.2. Mission, vision, values

Vision

To be a benchmark in the Iberoamerican and India geotechnical, tunnelling and underground space engineering.

Mission

To provide geotechnical, tunnelling and underground space engineering services based on a rigorous analysis of each case, in order to develop technical solutions optimizing the construction costs with the maximum safe and environmental conditions, as well as compromise with the community.

Values

- Excellence
- Innovation
- Social Commitment
- Motivation
- Integrity
1.3. Staff

SUBTERRA has an agile structure that allows us to offer our clients top quality services. Our multidisciplinary staff is composed of qualified people of nine countries (Argentina, Bolivia, Chile, Colombia, Guatemala, Spain, India, Peru and Venezuela).

Continuous learning is a major issue for SUBTERRA, which is why different external and internal training programs have been implemented. We also provide our staff with innovative state of the art technical tools, so that they can achieve a complete professional engagement with our clients.

In SUBTERRA we fully support the principle of gender equality thus 40% of our staff is composed by high qualified women.

Our team works on the projects with effort, talent and creativity.
1.4. Software tools and facilities

We have permanent offices in Santiago (Chile), Madrid (Spain), Medellin (Colombia), Delhi (India) and Lima (Peru), all of them are fully equipped and with the advanced technical software that allows to offer innovative solutions:
1.5. Quality and environmental management systems

SUBTERRA INGENIERÍA is Certified in ISO 9001:2015, ISO 14001:2015, and UNE 166002 management systems R&D since 2011 (since 2018 by Bureau Veritas) and OSHAS 18001 in Chile.

This intention reflects the strong commitment with our clients in order to offer them the highest QUALITY in our projects/works, promoting in our team respect and responsibility to the ENVIRONMENT.

We express our commitment to develop our work in optimal conditions of Health and Safety.

Finally, we have an R+D+i project management system, which is so important for us.
1.6. Presence in organizations

SUBTERRA belongs to the following associations:

- AETOS (Asociación Española de Túneles y Obras Subterráneas)
- AIC (Asociación de Empresas Consultoras de Ingeniería de Chile A.G.)
- AMINER (Asociación de Empresas Investigadoras, Extractoras, Transformadoras Minero-Metalúrgicas, Auxiliares y de Servicios)
- CTES (Comité de Túneles y Espacios Subterráneos de Chile)
- SEMR (Sociedad Española de Mecánica de Rocas)
- APTOS (Asociación Peruana de Túneles y Obras Subterráneas)
- ACTOS (Asociación Colombiana de Túneles y Obras Subterráneas)
- PTTP (Plataforma Tecnológica de Túneles)
- EURACOAL (European Association for Coal and Lignite)
- TECNIBERIA (Asociación Española de Empresas de Ingeniería, Consultoría y Servicios Tecnológicos)
- PTES (Plataforma Tecnológica Española de Construcción)

At the same time its members belong, or have belonged to the following organizations:

- AENOR: Comité CTN 103 “Geotecnia”.
- COMITÉ EUROPEO DE NORMALIZACIÓN CETN TG 341 WG5: Geotecnia.
- ASTM: Comité D18.02.07. Ensayos de presiométrie y dilatométrie.
- COMISIÓN EUROPEA: Coal Advisory Group (TGC1-DGXII)

SUBTERRA has personnel affiliated to the following Professional Associations:

- CHILE: Colegio de Ingenieros de Chile A.G.
- COLOMBIA: Consejo Profesional Nacional de Ingeniería
  - Sociedad Antioqueña de Ingenieros y Arquitectos
  - Sociedad Colombiana de Ingenieros
- ESPAÑA: Colegio Oficial de Ingenieros de Minas
  - Colegio de Ingenieros de Caminos, Canales y Puertos
  - Ilustre Colegio Oficial de Geólogos
- PERÚ: Colegio de Ingenieros del Perú
2. Company activities

2.1. Professional capabilities

2.2. R+D+I activities

2.3. Safety installations

2.4. Diagnosis and rehabilitation of tunnels
2.1. Professional capabilities

**Underground excavations**
- Tunnel Design
- Excavation Method Analysis
- Tunnel Boring Machines (TBM)
- Support and Lining Design
- Subsidence Evaluation
- Portals
- False tunnels
- Caverns and Shafts
- Geotechnical Assessment during Construction
- Monitoring
- Diagnosis and Rehabilitation of Tunnels
- Safety Installations (Ventilation, Illumination, etc)

**Mining**
- 3D Geological Modeling
- Resources and Reserves Assessment
- Mine Feasibility Studies
- Open Pit Designs
- Underground Mining Designs
- Mine Decommissioning and Closure
- Dumps and Tailings Studies
- Underground Mine Infrastructure Design (Tunnels, Shafts & Caverns)

**Geotechnical**
- Risk Assessment
- Hydrogeology Studies
- Soil & Rock Mechanics
- Slopes & Earth Structures
- Excavation Assessment
- Aggregates and Quarries

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Excellence in tunnel engineering

Highways and roadways

High-speed railways

Conventional railways

Hydraulic Works

Hydroelectric Works

Mining

Lo Saldes Tunnel | Chile | COSTANERA NORTE
2.2. R+D+I activities

The applied research give us the opportunity to offer our clients the latest ground engineering techniques, improving our designs, enabling them to solve these complexes and challenging problems.

As we said before, we have a UNE 166002 system for the Research and Development projects. During the past we were registered as an innovative PYME.

In the past we collaborated in the following projects:


- Investigation for the competitive improvement of the perforation cycle and blasting in mining and underground works through the definition of new techniques of engineering, explosives, prototypes and advanced tools. (TUÑEL). 2015-2018. Client: Centro para el Desarrollo Tecnológico Industrial (CDTI).

- Advanced methodology based in seismic zoning for evaluating and using the seismicity in underground works. (SYOS). 2017-2019. CONCYTEC.

We have been selected by the European Commission DGXII, by the Dirección General de Transferencia de Tecnología y Desarrollo Empresarial of the Spanish Ministry of Science and Innovation and by Centro para el Desarrollo Tecnológico Industrial (CDTI), for the following projects:


- MINRESCUE. 2020-2024. RFCS.

- Advanced prediction for the behavior of the mass-tunnel complex, through the management and interpretation of geotechnical geological information of underground projects (KNOWTUNNEL). 2017 - 2019. CDTI.


- The impact of EXtreme weather events on MIining operations (TEXMIN). 2019 - 2022. RFCS.
2.3. Safety installations

The engineering of tunnels and underground spaces requires having modern installation systems that enable their functionality in the maximum security conditions.

Because of them, the international normative and the different nationals normative of the tunnel’s safety systems, including the tunnel’s exploitation in normal conditions like in case of fire, are increasingly demanding. It’s necessary to have the following:

- Safety concept.
- Ventilation system.
- Detection and fire detection system.
- Illumination.
- Electromechanical systems.

This requirement is attended by SUBTERRA with the following services:

- Safety installations project: including ventilation, illumination and all electromechanical systems necessaries.
- Exploitation manual, of the tunnels attending its functionality, including operational normally plan, emergency plan and maintenance plan.
- Analysis of risks, versus different scenarios typified in the regulations for cases of accident and fire.
2.4. Diagnosis and rehabilitation of tunnels

SUBTERRA offers a tunnel’s inspection services, diagnosis and rehabilitation, based in its experience in the interaction’s analysis between the ground, governed by its mechanical parameters and the characteristics of the support applied to the tunnel.

Inspection of Tunnels

SUBTERRA carries out detailed surveys of the visible pathologies and the ground to be immediately behind the structure of a tunnel, which reflect its actually state, adapting the working methodology and tools to be used depending on the peculiarities of each tunnel.

The result of this inspection is a clear diagnosis of the tunnel and the state of its structure, which is understood as the support - lining aggregate. As a result a report of the status of the tunnel is issued, ranking the necessary future actions.

Structural Rehabilitation Tunnels Projects

The inspection and diagnosis of the state tunnel are the base for the performance the necessary works of the detailed engineering in order to redact a project of structural rehabilitation tunnels.

The rehabilitation tunnel is performed in order to get the suitability of the same to the new functionality (change the gage, etc) or for rehabilitating the structure of the tunnel. For it, is necessary to carry out sophisticated retrospective analyzes that reproduce the pathologies observed, using special software for stress-strain numerical calculations. Subsequently, the goodness and effectiveness of the proposed rehabilitation measures are analyzed using the same tools.

Maintenance Programs of Tunnels

Many times is possible coexisting with the pathologies existing in a tunnel, however is necessary has a control and following of the same.

For this reason, the execution of maintenance programs based on the inspection and diagnosis of a tunnel conforms a third service in the ambit of tunnel inspection and rehabilitation. It is used auscultation and monitoring techniques that allow knows in real-time the status and evolution of a tunnel, adopting in enough time, the necessary measures.

Main references

2010
- Inspection of Tunnels of the Jabarrella Canal (Huesca, Spain)
- Project of rehabilitation of the Son Sureda railway tunnel (Baleares, Spain)

2011-12
- Inspection, rehabilitation project and assessment during the works of the Portillo tunnel of the La Confl uencia Hydroelectric Plant (VI Region, Chile)

2012
- Rehabilitation project of the Llanes Alternative railway tunnels (Altarea and El Bolao Tunnels) (Asturias, Spain)

2013
- Inspection of the Forcadilha, Sierra Pequeña and El Molino railway tunnels (Orense, Spain)

2013-14
- Inspection and rehabilitation project of the PH Pizarra’s headrace tunnel (Cajamarca, Peru)

2015
- Inspection of the support’s state of the highway Agaete-La Aldea’s Tunnel 1. Tunnel lining and drainage review. (Gran Canaria, Spain)

2016
- Definition of the stabilization’s solutions of the San Lorentzo and Belabieta tunnels in the A-15 Navarra-Gipuzkoa’s Highway. (Guipúzcoa, Spain)

2016-17
- Support inspection of the Asana River’s diversion tunnel. Quellaveco mine. (Peru).

2017
- Inspection and verification of the tunnel state of the Belt 1, draw point and By Pass. Antamina (Peru).
- Specialized advice in tunnels during the construction of the tunnels of the Astigarra-ga-Irún section (Spain)
- Inspection and verification service of CH Pangal Tunnel (Chile)

2018
- Terminal tunnel maintenance. Colca-Sigüas adduction system (Peru)
3. References

3.1. Motorways and road projects

3.2. Railway and metro projects

3.3. Hydraulic projects

3.4. Hydroelectrical projects

3.5. Mining projects
3.1. Motorways and road projects

Since the beginning, SUBTERRA has participated in the design and assessment during the construction of 49 road tunnels, adding up to 99.5 km in length, in 14 countries.
**XALTEPEC TUNNEL (AMOZOC - VERACRUZ MOTORWAY), Mexico**

The Xaltepec tunnel is part of the Motorway Project Amazoc – Veracruz, Xalapa Bypass Stretch.

One of the key issues to tackle at the time construction of the Xaltepec Tunnel is the design of the cross section, because it should embrace four lanes of 3.5 m width and a minimum gauge of 5.5 m height (from shoulder).

This provision is a useful width of 18 m, which is equivalent to an excavation width of approximately 19 m, which can be described as an exceptional width, although there is some precedent, it's clear that this is a tunnel unique in terms of geomechanical quality of the land, the construction of this tunnel will be an important milestone.

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**CONSTRUCTION TUNNEL OF YANANGO AND ACCESS, Peru**

The construction of the Yanango tunnel improves the current deficiencies of the current Tarma-San Ramón highway at its junction with the Yanango river, resolved by means of a suspension bridge that allows the passage of light and medium vehicles, but whose use is not allowed for heavy vehicles, which must use a ford that causes discomfort, insecurity and loss of time to users.

The tunnel, 1,012 m long and 96 m² of useful area, can accommodate three traffic lanes, two up and one down, as well as the berms and sidewalks included in the regulations. In its development, the tunnel is divided into three large blocks: tunnel in colluvial soil, located in the entrance portal, tunnel under the ravine in the intermediate zone and tunnel in rock in the rest. This procedure determines the support to be used in each case. The execution is contemplated, both in the entry portal and in the exit, of two false tunnels; being the exit portal, a half tunnel whose section is completed with the structure.

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**SANTIAGO CENTRO - ORIENTE PROJECTS (KENNEDY, COSTANERA N-S, LO SALDES), Chile**

Costanera Norte has been appointed by MOPT (Ministerio de Obras Públicas of Chile) to develop the new traffic system East-West in Santiago de Chile. Detailed design and technical adduce will be came out by Subterra.

- **Lo Saldes Tunnel**, 65 m length and 14.0 m width of excavation.
- **Costanera Norte – Costanera Sur Tunnel**, 292 m length, with 10.0 m width will be two lanes traffic.
- **Kennedy Tunnel**: 1150 m length, between Perez Zujoic round and Américo Vespucio link. The tunnel will be four lanes traffic and its cross section will be about 20 m wide and 200 m² excavation area. The excavation will be came out by NATM.
3.2. Railway and metro projects

SUBTERRA has participated in the design and assessment during the construction of 28 railway tunnels, adding up 175 km of tunnel in 6 countries.

<table>
<thead>
<tr>
<th>Project</th>
<th>Tipology</th>
<th>Section (m²)</th>
<th>Length (m)</th>
<th>Constructive Method</th>
<th>Limestone/gy</th>
<th>Study Level</th>
<th>Year</th>
<th>Client</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Train, (Tunnel 6) San Miguel - Montale de Guaza (Arona), (Tunnel: Tunnel 9a)</td>
<td>Single-Bore</td>
<td>115</td>
<td>2,838</td>
<td>NATIV</td>
<td>Basaltic lava flows, skagi and ignimbrites</td>
<td>Initial Design</td>
<td>2010</td>
<td>EYERI / GETINSA</td>
<td>Spain</td>
</tr>
<tr>
<td>High Speed Atlantic AVE, (Tunnel: Vigo - Porto), (Tunnel: Vigo - Pontevedra)</td>
<td>Single-Bore / Double-Bore</td>
<td>115/77</td>
<td>10,000</td>
<td>NATIM/TVB</td>
<td>Granitites and gneisses</td>
<td>Initial Design</td>
<td>2010</td>
<td>TRN</td>
<td>Spain</td>
</tr>
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<td>High Speed Railway Bobadilla-Granada, (Tunnel: Archidona-Arrano de la Negra, (Tunnel: Archidona)</td>
<td>Single-Bore</td>
<td>120</td>
<td>1,053</td>
<td>NATIV</td>
<td>Marls, limestones, dolomitic breccias and dolomites</td>
<td>Assistance</td>
<td>2010</td>
<td>DRAGADOS</td>
<td>Spain</td>
</tr>
<tr>
<td>Streth 4. Railway Las Palmas - Maspalomas, (Tunnel: El Barco)</td>
<td>Single-Bore</td>
<td>105</td>
<td>2,000+4300</td>
<td>NATIV + CUT&amp;COVER</td>
<td>Basalt and conglomerates</td>
<td>Initial Design</td>
<td>2011-12</td>
<td>EYERI / GETINSA / GSPIC</td>
<td>Spain</td>
</tr>
<tr>
<td>Streth 7. Railway Las Palmas - Maspalomas, (Tunnel: Maspalomas)</td>
<td>Single-Bore</td>
<td>100</td>
<td>3,000</td>
<td>NATIV</td>
<td>Phonolites</td>
<td>Initial Design</td>
<td>2011</td>
<td>PROINTEC / INGENIA</td>
<td>Spain</td>
</tr>
<tr>
<td>High Speed Railway Galicia. (Tunnel: Ourense-Vigo, (Tunnel: O Centallo - O Vigo, (Tunnel: Tunnel 1, Tunnel 2 and Tunnel 3)</td>
<td>Double-Bore</td>
<td>78</td>
<td>2,460</td>
<td>NATIV</td>
<td>Granitites</td>
<td>Initial Design</td>
<td>2011</td>
<td>TRN</td>
<td>Spain</td>
</tr>
<tr>
<td>High Speed Railway Galicia. (Tunnel: Ourense-Vigo, (Tunnel: Cerdredo-Bor, (Tunnel: Os Campas, O Golato and Bor)</td>
<td>Single-Bore</td>
<td>110</td>
<td>2,278</td>
<td>NATIV</td>
<td>Silicites</td>
<td>Initial Design</td>
<td>2011</td>
<td>GOICALTER</td>
<td>Spain</td>
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<tr>
<td>High Speed Railway Asturias. (Tunnel: Pola de Lena-Oviedo, (Tunnel: Pola de Lena)</td>
<td>Double-Bore</td>
<td>71.93</td>
<td>7,792</td>
<td>TBM DOUBLE SHIELD</td>
<td>Granitites, orthogneisses schists</td>
<td>Initial Design</td>
<td>2011</td>
<td>TRN</td>
<td>Spain</td>
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<tr>
<td>Corridor N-NW High Speed Railway Madrid - Galicia, (Tunnel: Prado-Por, (Tunnel: Prado Tunnel)</td>
<td>Double-Bore</td>
<td>72</td>
<td>7,000</td>
<td>NATIV</td>
<td>Quartzites, phyllites, shales, granitites and gneisses</td>
<td>Detailed Design</td>
<td>2012</td>
<td>COMASA ALDEASA / COPASA / AZVI / CUPESA</td>
<td>Spain</td>
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<tr>
<td>Corridor N-NW High Speed Railway Madrid - Galicia, (Tunnel: Cercededo-Prado, (Tunnel: Cercededo Tunnel)</td>
<td>Double-Bore</td>
<td>72</td>
<td>8,510</td>
<td>NATIV</td>
<td>Shales, phyllites, luidites, amphibolites and quartzites</td>
<td>Detailed Design</td>
<td>2012-15</td>
<td>COPROSA / INCOACH / RUBAU</td>
<td>Spain</td>
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<tr>
<td>Corridor N-NW High Speed Railway Madrid - Galicia, (Tunnel: Cercededo-Prado, (Tunnel: Cercedelo Tunnels, (Tunnel: Cercedelo Tunnel)</td>
<td>Double-Bore</td>
<td>90</td>
<td>8,510</td>
<td>NATIV</td>
<td>Shales, phyllites, luidites, amphibolites and quartzites</td>
<td>Assistance</td>
<td>2012-15</td>
<td>COPROSA / INCOACH / RUBAU</td>
<td>Spain</td>
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<tr>
<td>Acces Ferrol Port (Bilbao Tunnel)</td>
<td>Single-Bore</td>
<td>56</td>
<td>5,640</td>
<td>NATIV</td>
<td>Schist and granites</td>
<td>Tender Design</td>
<td>2016</td>
<td>COPASA</td>
<td>Spain</td>
</tr>
<tr>
<td>San Sebastian Subway, La Corriolu Station</td>
<td>Subway and Station</td>
<td>130</td>
<td>130</td>
<td>CAVIER / CALDERONI</td>
<td>Limestones and marls</td>
<td>Detailed Design</td>
<td>2010</td>
<td>TULCRON</td>
<td>Spain</td>
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<tr>
<td>Dublin Subway</td>
<td>Subway and Station</td>
<td>80</td>
<td>7,000</td>
<td>NATIV</td>
<td>Limestones and marls</td>
<td>Tender Design</td>
<td>2013</td>
<td>IDOM</td>
<td>Spain</td>
</tr>
<tr>
<td>Access Project Detalle Trope 2, (Tunnel: (Tunnel: Trope 2, (Tunnel 1 and 2)</td>
<td>Single-Bore</td>
<td>75</td>
<td>19,900</td>
<td>NATIV</td>
<td>Limestones, calcareous sands, sandstones</td>
<td>Initial Design</td>
<td>2015-17</td>
<td>GETINSA</td>
<td>Algeria</td>
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<tr>
<td>-single-Bore</td>
<td>9</td>
<td>Single-Bore</td>
<td>75</td>
<td>19,900</td>
<td>NATIV</td>
<td>Limestones, calcareous sands, sandstones</td>
<td>Initial Design</td>
<td>2015-17</td>
<td>GETINSA</td>
</tr>
<tr>
<td>LC and LD La Meca Subway, (Tunnel: La Meca Subway)</td>
<td>Double-Bore</td>
<td>40-60</td>
<td>16,741</td>
<td>NATIV/COTWBM / CAVE</td>
<td>Granodiorites, tonalites, quartz-diorites, gabbros, amphibolites and volcanic-sedimentary units</td>
<td>Tender Design</td>
<td>2014</td>
<td>SOLUX CORSA</td>
<td>Saudi Arabia</td>
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<tr>
<td>New Line Oudhavari – Vishakhapatanam, (Tunnel: Chennai)</td>
<td>Single-Bore</td>
<td>52</td>
<td>9856/720</td>
<td>NATIV</td>
<td>Phyllites and quartzites</td>
<td>Initial Design</td>
<td>2010</td>
<td>AYESA</td>
<td>India</td>
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<tr>
<td>Ouimet Subway Line 3</td>
<td>Subway and Station</td>
<td>130</td>
<td>4,060</td>
<td>SCREENS / SHOT TBM</td>
<td>Toths and breccias</td>
<td>Detailed Design / Assistance</td>
<td>2010-17</td>
<td>MOTA ENTIL</td>
<td>Russia</td>
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<td>Ho Chi Minh City Urban Mass Rapid Transit Line 2</td>
<td>Subway and Station</td>
<td>70</td>
<td>8,000</td>
<td>EPB</td>
<td>Delta deposits</td>
<td>Tender Design</td>
<td>2018</td>
<td>IDOM</td>
<td>Vietnam</td>
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</tbody>
</table>
DETAILED ENGINEERING OF THE STATIONS OF LINE 3 OF THE GUADALAJARA METRO, Mexico

Line 3 of the Guadalajara metro has a length of 22 km and has 18 stations, 13 of them elevated and the rest underground.

Subterra collaborates with the Concorcio Túnel Guadalajara S.A.P.I. of CV in the elaboration of the detail engineering of the Bandera, Independencia, Normal, Catedral and Mayor stations; 90 m long and 20 m wide, executed in the shelter of screen walls reinforced with micropiles.

The project is located in the Metropolitan Zone of Guadalajara (ZMG) in the Mexican state of Jalisco. The project runs from Northwest to Southeast through the Metropolitan Zone of Guadalajara, between Zapopan, the municipality of Guadalajara and Tlaquepaque.

The route has an approximate length of 21,447 m and comprises a first section of air of 8,715 m that includes 7 elevated stations and is mostly developed viaduct. It is followed by an underground section of 5,337.83 m in length, which includes five underground stations and four tunnel sections between them. After the underground section, we continue with a second aerial section of 7,393.61 m in length, which, like the previous one, runs for the most part in viaduct and in which 6 air stations are contemplated.

RAILWAY TUNNELS LAS PALMAS-MASPALOMAS LINE, Spain

Railway line between Las Palmas de Gran Canaria and Maspalomas, stretch 4: Polígono Industrial de El Goro - Barranco de Guayadeque y, Stretch 7: Playa del Inglés (El Cañizo) - Estación de Meloneras (Faro de Maspalomas).

Stretch 4: is divided into three tunnels with a total length of 3 km and three false tunnels with 4 km length, which runs under the international Airport of Gran Canaria 10 sections have been required for the design of this stretch that includes tunnel, cut and cover and excavation between diaphragm walls. Furthermore, ventilation system was performed using extraction shafts conditioned by the arrangement of the intermediate stations.

Stretch 7: is a tunnel with 5.6 km length (2.6 km in false tunnel structure). Because of the construction of a shopping mall near the entrance portal, overlays measured from the key of tunnel to the basement of the bulking range between 12 y 13.7 m.

EL CORNO TUNNEL. HIGH SPEED LINE LUBIÁN - ORENSE, Spain

The tunnel of El Corno, projected on the stretch Cerdedelo-Porto High Speed Line Lubián - Ourense, is a twin tube tunnel which has a length of 8.5 km.

The tunnel alignment crosses at several points the current route of the railway line, which is an important milestone to consider when analyzing the stability of the tunnel.

It is designed to an Adit of nearly 800 m in order to carry out the excavation of the tunnel Como from four different faces. In addition it is designed the junction between the tunnel and the Adit in an area where the water infiltration to the excavation is high.
3.3. Hydraulic projects

SUBTERRA has participated in the design, wastewater and supplied of 10 hydraulic tunnels, adding up 53.5 km of tunnel in 3 countries.

<table>
<thead>
<tr>
<th>Project</th>
<th>Typeology</th>
<th>Section (m)</th>
<th>Length (m)</th>
<th>Constructive Method</th>
<th>Lithology</th>
<th>Study Level</th>
<th>Year</th>
<th>Client</th>
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<td>China Railway</td>
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</table>

Initial design of the "Works Header and driving to the drinking water supply for Lima. | Peru | PROINVERSIÓN

Pozuelo de Alarcón's sewer | Spain | EUROCONSULT

Detailed Design of the Majes – Siguas’s tunnels conduction | Peru | COBRA-COSAPI.
To improve the water quality of the Victoria Harbour, the Harbour Area Treatment Scheme (HATS), formerly known as “The Strategic Sewage disposal Scheme” (SSDS), was committed to be implemented in stages to provide treatment for the sewage collected from the urban areas on both sides of the Harbour. It is currently developing the Phase 2A, whose main targets are the upgrading of eight existing preliminary treatment works on Hong Kong and the improving of the existing Stonecutters Island Sewage Treatment Works from the present design treatment capacity of 1.7 million cubic meters per day to cater for the ultimate development scenario of the whole of HATS catchment.

An Effluent Tunnel is proposed to convey the effluent from upgraded treatment facilities on Stonecutter Island to the outfall. This tunnel will be excavated by drill and blast method. It is approximately 880 m long, 8.5 m in inside diameter and has a 60 m deep shaft at each end.

The alignment geology of the tunnel and the shafts is composed by granite of the Lion Rock Suite (Jurassic or Cretaceous in age). The bedrock is generally medium to coarse grained with medium spaced and light to extremely narrow joints. Generally, moderately decomposed or better granite will be encountered at the tunnel level. Superficial deposits mainly comprise reclaimed fill, alluvium and marine deposits and its thickness varies between 15.0 and 25.0 meters.

**SEWER STONECUTTER ISLAND, Hong Kong**

**PROJECT MAJES - SIGUAS (PHASE 1), Peru**

COBRA - COSAPI will be developed the “Obras mayores de afianzamiento hídrico y de infraestructura para la irrigación de las pampas de Siguas”, in Peru, a tunnel conduction will the water from Angostura dam to Chalhuanca river. The called conduction Pucará - Transandino is formed by two tunnel: Pucará tunnel and Transandino tunnel, 6341.24 m and 9617. long respectively. Their cross section, horseshoes shape are 5.95 m wide.

Due to their length, one adit in each has been designed, 67 and 750 m Pucará tunnel and Transandino respectively. Their cross section, square with archer ceiling are 6.5 m length and 6.5 m wide.

The diversion tunnel has been defined also, 394.70 m, which will allow the construction Angostura's dam and later it will work as water intake tunnel after the execution of a slope shaft of 45 m length.

**POZUELO’S SEWER, Spain**

In order to be carried the rainwater to the new urban areas, the Pozuelo de Alarcón’s sewer has been designed underground. For it SUBTERRA proposed the construction of a tunnel of 4,543 m length.

It was realized a detailed analysis of the stability of the front of the excavation by TBM and the link of the precast concrete segments.

In addition, it was designed a unique connection between the sewer, the Adit, and the ventilation duct.

The lithologies affected by the Pozuelo’s sewer belong to the so-called “Material detrítico de Madrid” (clays and sands).
3.4. Hydroelectric projects

Because of the energetic demand has been increased in Latin America in the last years, SUBTERRA has been involved in the design and assessment of the construction of 33 hydroelectric plants, from Mexico to Chile, totaling 193 km of tunnel.

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<th>Study Level</th>
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</table>
HYDROELECTRIC PROJECT CHEVES, Peru

Cheves Hydropower Project is located at Huaura river, between the settlements of Sayán and Churín (Peru). Cheves Hydropower Project will divert water from the Huaura and Checras rivers, some 2 km upstream their confluence at an altitude of about 2.170 masl and back to Huaura River through the tailrace tunnel about 1.5 km downstream at elevation 1.548 masl.

This project has been done to use the Huaura’s driver resources to generate energy with an installed capacity of 168 MW divided into two Pelton units utilizing the gross head of 599 m and a flow design of 33 m³/s.

The construction on the following tunnels has been projected:
- Transfer Tunnel: 2,580 meters.
- Headrace Tunnel: 9,915 m.
- Power House: 31.5 x 15.5 x 62.7 m (high x wide x length).
- Tailrace Tunnel: 3,700 m.
- Access Tunnel: 960 m.
- Addittunnel 1: 860 m.
- Surge Tunnel: 697 m.

The lithotypes affected by the Cheves Hydropower Project are constituted by the Chimú Formation (quartzite banks interbedded with thin quartzose sandstone strata, bituminous shale and occasional coal lenses), the Casma Group (stratified sequences of volcanic rocks, mainly andesites, with interbedded sedimentary rocks) and Churín bajo Stock (intrusive rocks with tonalite/quartz-monzonite composition).

HYDROELECTRIC PROJECT ALTO MAIPO, Chile

Alto Maipo Hydroelectric Project (PHAM) is located in the municipality of San José de Maipo, Provincia Cordillera, Región Metropolitana de Santiago, Chile. Undergroun works included in the PHAM are:

- Tunnel “Alfalafal II” of 6,250 m in length which the initial 3,250 m will be excavated with D+B method in section of 4,75 x 4,90 m (20,8 m²), and the rest with TBM of about 4,10 m of diameter (13,2 m³).
- Tunnel “Suelo” of 1.020 m in length fully excavated by conventional methods, in a section of 4,0 x 4,0 m (13 m²).
- Tunnel “El Volcán” of 14.100 m in length of which 7.100 m will be excavated with D+B method in a section of 3,80 x 4,90 (4,60) m (17/16 m²), and the rest with TBM of 4,10 m of diameter (13,2 m³).

The area is composed of sequences of stratified sedimentary, volcanic and volcanoclastic rocks with granitoid inclusions. Covering these materials there are large deposits of Quaternary unconsolidated materials.

Also it is included the geotechnical monitoring of all underground works of the hydroelectric project.

HYDROELECTRIC PROJECT RENACE II AND III, Guatemala

Renace II Hydroelectric Project, is located immediately downstream of the powerhouse of Renace I.

It is the second of the three elements of the cascade utilization Cahabón River, located in the municipality of San Pedro Carchá, Alta Verapaz department, Guatemala.

The tunnel will conduct an approximate length of 4,1 km.

Renace III: The most outstanding works to be performed are: Headrace tunnel about 4.750 m, with two stretches, 3.600 m length one of them and the other of 1.150 m of middle pressure; armored section about 100 m length; surge tunnel of 275 m of depth; adit of 72 m length and headrace tunnel and the adit's gateway and exit.
3.5. Mining projects

The mining projects, as underground as open pit, are very important for SUBTERRA.

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**OPEN PIT MINING / DUMPS**

- Detailed design of the mine dump. West, South, North, Spanish, La Ramina, and Temporal East. COBRE LAS CRUCES (INMET). 2010-12.
- Geotechnical analysis of the tailings dams 1 and 3. XISTRATA. 2012.
- Geotechnical analysis of the mine dump. North, South, and Alatala. SACYR-ACONTECENDA. 2012.
- Evaluation of the tailing dam. MATSA (MUSADALA & TRAPAL) 2016.
- Due diligence of the tailing dams AGUABLANCA, LUMIN MINING. 2016.
- Detailed design and tailing facilities. COBRE LAS CRUCES (FIRST QUANTUM). 2010-17.
- Closeness plan and technical report for the environmental remediation project of the impacted areas by mining activities. Carthagockmin Mine. AMG SAC. 2017-19.

**UNDERGROUND MINING**

- Basic design of the pit ramp. COBRE LAS CRUCES (INMET). 2010.
- Detailed design and construction of the Transport Tunnel 1 and 2. SOUTHERN COPPER. 2011-13.
- Detailed design research ramp. COBRE LAS CRUCES (FIRST QUANTUM). 2016.
- Geotechnical study of the Cerro Colorado Mine research ramp. COBRE LAS CRUCES. 2016.
- Ventilation Shaft Study - Coronado Phase. ICI IBERRICA. 2017-19.
- Expansion for reinforcement works for the tunnel Pitt. ANTAMIRA. 2017.
- Technical-economic analysis for the transport belt of the Cerro Colorado underground mine by TIM. ANTAMIRA. 2017.
- Design of the feasibility study for environmental assessment. COBRE LAS CRUCES. 2019.
The Cobre Las Cruces's aim is the exploitation of the secondary copper ore reserves of a massive sulphide mineralization, embedded in volcanic and sedimentary Paleozoic rocks, hidden under tertiary sediments. The secondary copper ore reserves (HC Zone), object of the mine project, is estimated in 17,625,000 tonelates of ore with a 6.22% of pure copper, totalling of 1,096,275 tonelates of extrable copper and 978,504 tonelates of retrievable copper and commercialised like copper cathodes. The support is formed by 140 m of Tertiary marl, under which there are a layer of sandstones, calcarenites and conglomerates with a variable thickness of 5 to 10 m, which constitutes the Niebla-Posadas aquifer. The deposit is exploited by the method of Open Pit, which will allow the removal of 97% of the copper metal contained in the reserves. The final pit will have an oval shape with 1500 m length in the East-West direction, 900 m width in a north-south direction and a maximum depth of 245 m.

SUBTERRA is the responsible of the exploitation's geotechnical following, including both open pit and dumpsites. It includes the mapping, the stability calculations and the geotechnical monitoring.

The Atacama Kozan mine is situated in the Tierra amarilla area, Chile. SUBTERRA has carried out a geomechanical characterization of the production sector called Manto Norte, which includes drilling levels at a depth of 165 and output at quota 136, Caserones Manto Norte 01, 04, 05, 06 and Manto Noreste and adjacent galleries. The aim of this study was the improvement of a prediction model following the geotechnical and geomechanical recommendations for predicting to the potential risk associated with development the tunnels, the exploitation and the extraction sequences of the stopes. It was carry up a lithological study and a structural mapping of 13335 m of tunnel, distributed in different galleries of the mine, allowing the geotechnical characterization of the rock mass 's quality and including stability analysis of the stopes and support. From the obtained information of the field's works was defined the used support sections in the geotechnical quality of rock mass, using empirics, analytics and numerical models. It has used the following geotechnical software: Dips, Unwedge, Rocsupport, Examine 2D and 3D and 2D Flac.

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The project is located within the geographics area of the mining concession Toquepala mine (in the south of Peru), department of Tacna, comprising a tunnel in a straight line from the southwest of the pit to he existing mill site. The mine is located and altitude of 3,300 meters. The project includes constructions of a tunnel of 2,19 km length, stretching from the projected location of the primary crushing building up the pile of intermediates, which will be connected to the transport of ore through a conveyor belt. In addition it is performed two tunnels, a short mine tunnel of 155 m length and a false tunnel crossing under current rail tracks. The lithotypes affected by the tunnels are andesites, rhyolites, intrusives rock and quaternary deposits. Finally it is made the final project of the tunnel ventilation to ensure the safety of the workers.
4. Clients