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REFERENZA TECNICA - TECHNICAL REFERENCE

## Project in figures

17 underground stations and 4 service shaft accesses
60,000 m <sup>2</sup> of diaphragm walls
125,000 m of piles
15,000 m of jet grouting
14,000 m of micropiles
195,000 m <sup>3</sup> of concrete
55,000 tons of still cages
240 personel on site
42 SOILMEC machine

# Cityringen Metro Project

Copenhagen, Denmark



Diaphragm  
walls

Cased Secant  
Piles (CSP)

Drilling  
& Grouting

Cliente :  
Owner : **Metroselskabet**

Contrattista principale :  
Main Contractor : **CMT - Copenhagen Metro Team (Salini, Tecnimont, Seli)**

Durata dei lavori :  
Duration of work : **2011 - 2014**

## Introduction

The State of Denmark together with the Municipality of Copenhagen, launched in 2010 a complex Project for the construction of the CITYRINGEN, a new Subway Line.

Copenhagen is the capital of Denmark with a metropolitan population of 1.9 million. **TREVI was the primary foundation subcontractor, involved for the construction of a total 17 stations and 4 ventilation shafts.**

An impressive fleet of equipment was involved for the works: up to 10 drilling rigs for the construction of secant pile walls, and 4 hydromills for diaphragm walls, plus additional small diameter drill rigs and cranes.

the train enters the station.

The trains are driverless but most of them are manned with stewards in order to make the journey comfortable and safe for the passengers. The Cityringen Metro line will serve 240.000 passengers per day. A total of 28 trains with Automatic guidance and control system (ATC) will run at 100 sec. intervals. The average speed of the trains is 40 km/h, stops included. The entire ring tour will take about 24 min.

## The stations

The underground stations for CITYRINGEN are typically around 70 metres long and 20 or 22 metres wide, with 7 or 9 metres wide platforms, typically at approximately 19 metres below ground level. The Metro is characterized by a simple, clear, unpretentious, and



## The new CITYRINGEN line

The CITYRINGEN is a ring placed in the city center, with 17 stations and 4 ventilation shafts.

The construction of the new double tracks line involves the use of a 5.7 metre large tunnel boring machine (TBM) for 13.6 km twin tunnel, 1.3 km sprayed concrete lining (SCL) tunnel and caverns, as well as a 340 metre long cut-and-cover tunnel and ramp section. The Copenhagen Metro is state of the art in the world today from a functional and technical point of view, but also from architectural perspective.

The passengers have been the focal point of the Metro Project. Trains will be running fast and frequently. Furthermore, as the passengers do not only want to be safe but also to feel safe, the Metro stations are designed as open spacious rooms with daylight even down to the underground platforms. Platform screen doors on underground station give extra comfort and a safe feeling when

functional style. Excavation of the stations from surface down to the deepest level was carried out under the protection of diaphragm walls or secant pile walls.

The working phases for the construction are as follows:

- **Phase 1:** construction of diaphragm walls or secant piles walls, and break-in and break-out blocks
- **Phase 2:** Installation of Horizontal Beams and slabs, installation of dewatering wells
- **Phase 3:** TBM Drilling of Tunnel through break-in and break-out blocks.

As primary foundation subcontractor, TREVI deployed approximately 250 workers on 21 separate construction sites managed by the joint venture CMT (Cityringen Metro Team). TREVI was responsible for the construction of the permanent supporting walls for all stations and service shafts.



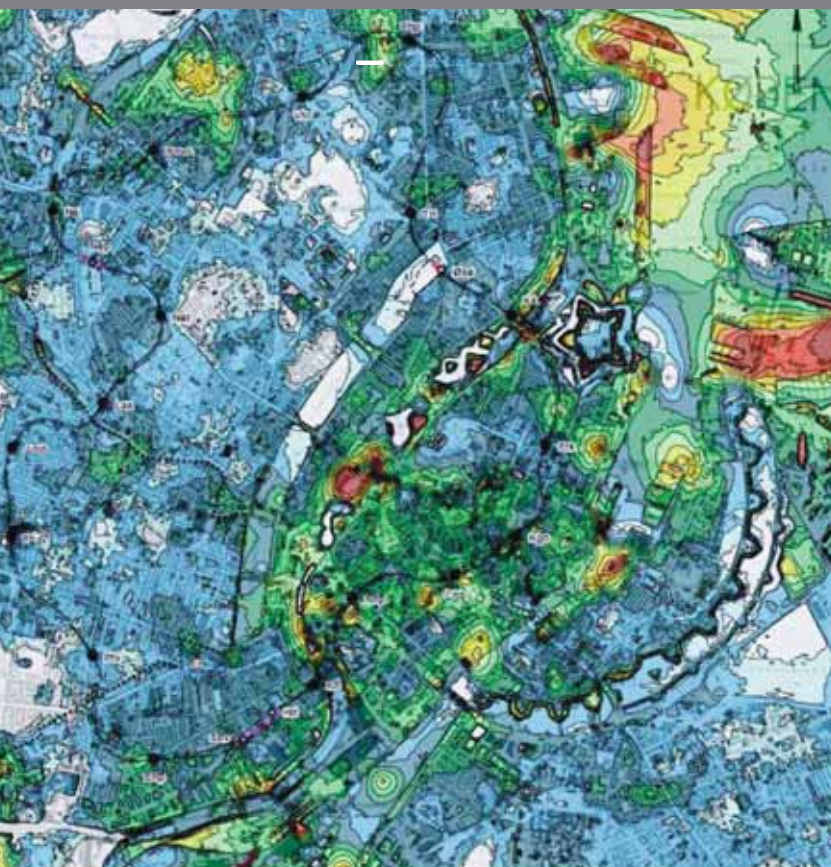
## Geology

The TBM construction will primarily be through the Copenhagen limestone. In the northern part of the tunnel, the TBM will also bore through the overlying quaternary soil. The tunnel depth varies from approximately 20 to 35 metres.

Across the new line, the soil consists of 2 main groups: Upper sediments of the glacial ages, (5-20 m thick), composed by clay, silt, sand, gravel and cobbles. Granite boulders and flint are also present in blocks and layers. Frequency and size of these obstructions cannot be determined.

Limestone, with lenses of flint up to 3 m thick, it is divided in 4 main levels:

- **Upper limestone:** highly fractured, highly permeable;
- **Intermediate limestone:** less fractured, medium permeability;



### Copenhagen Fill layer

#### Legend:

- Track centre line
- Station
- Shaft
- ▭ Cavern
- ▭ Cut and cover
- ▭ Tunnel work site area
- ⋯ Municipal boundary
- Borehole

#### Thickness in meters:

- 0 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- 3.0 to 4.0
- 4.0 to 5.0
- 5.0 to 6.0
- 6.0 to 7.0
- 7.0 to 8.0
- 8.0 to 9.0
- 9.0 to 10.0
- > 10.0



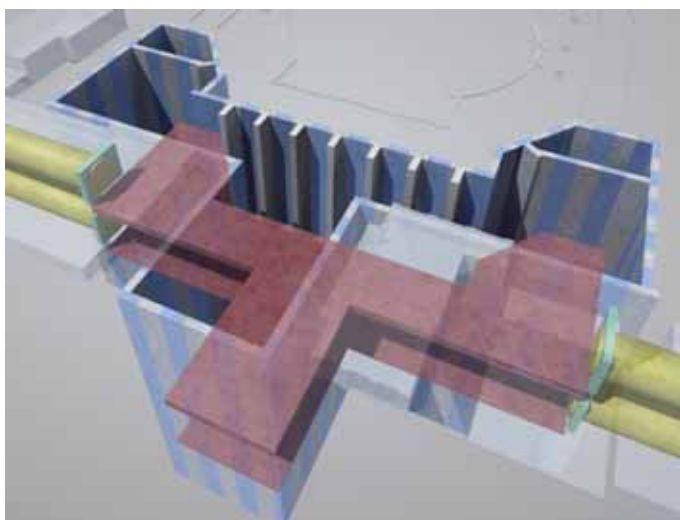
- **Lower limestone:** almost not fractured, low permeability;
- **Bryozoan limestone:** composed by microfossils.

Laboratory tests on samples of flint resulted in remarkable UCS values between 400 MPa and 700 MPa.

## Environmental and safety issues

Metroselskabet, owner of the Cityringen, has set among its priorities to operate for the construction of the Cityringen protecting the environment and respecting the stakeholders.

Severe safety measures and procedure have been enforced to avoid any accident on site. Stringent limits for the exhausted gas emissions have been set, by far tighter than those applied by the State of Denmark. Tight limits for noise emission have been established. During the works, particular attention was also paid to minimize the impact of vibrations, which was particularly challenging with the reality to deal with the hard flint layers.



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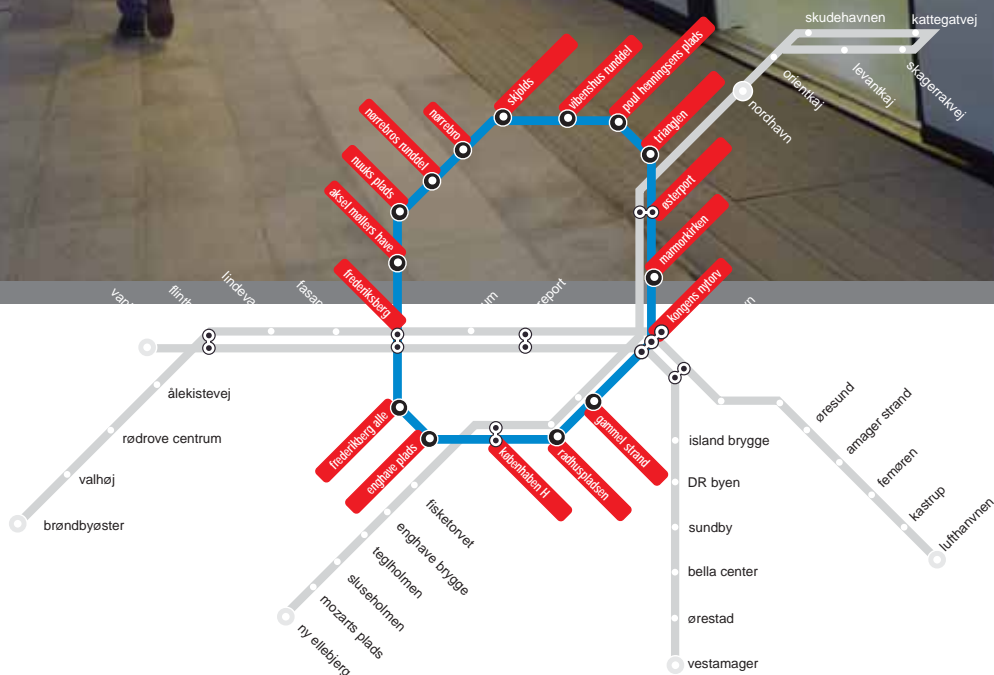
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## Opportunity for Innovation

Copenhagen's city ordinances were more stringent than European legislation on engines requirements. TREVI was required to use engines conforming to Tier Stage IV for Cityringen since the beginning of the work in 2012, whereas these engines started to be used in Europe in January 2014.

SOILMEC has been planning for this milestone for more than two years, and used the opportunity to completely re-vamp its product line. For two years, SOILMEC engineers have been deeply involved in troubleshooting and optimize the new line of drill rigs. The result is that the latest SOILMEC equipment not only exceeds the Tier 4 requirements, but also delivers more power, efficiency, and flexibility.



5819, via Dismano - 47522 Cesena (FC) - Italy  
 Tel. +39.0547.319311 - Fax +39.0547.318542  
 e-mail: [intdept@trevispa.com](mailto:intdept@trevispa.com)  
[www.trevispa.com](http://www.trevispa.com)



TREVI S.p.A.  
 Divisione RODIO