ENGINEERING, INNOVATION, ARCHAEOLOGY, ARCHITECTURE AND ART: 5 WORDS AND THEIR MEANING APPLIED TO NAPLES UNDERGROUND WORKS

THE NEAPOLITAN SUBSOIL

All the natural deposits within the depths of interest are geologically recent and were formed in a relatively short period of time. The Yellow Tuff and the Pozzolanas were deposited about 12,000 years ago, as a result of the volcanic activity of the nearby Phlegrean complex. The Yellow Tuff is a soft rock characterized by the occurrence of randomly distributed subvertical fractures, locally known as “scarpine”, generated by rapid cooling of the pyroclastic mass after eruption and deposition. Following deposition, erosion of the pyroclastic formations occurred over a period of about 2,000 years, causing material to be transported and redeposited. The remoulded Pozzolanas are very well graded and not easily distinguished from the original intact pyroclastic deposits; they appear layered and sometimes interbedded with in situ Pozzolanas, or sometimes with marine sand deposits, such as encountered in the area of Municipio Station. After erosion and redeposition of the pyroclastic formations, a new explosive phase of the Phlegrean complex deposited the so-called Neapolitan Pyroclastic Pile, which consists of easily eroded alternating layers of pumices, ashes, pozzolana and lapilli and, where not eroded, has a thickness of about 15 m. The pyroclastic deposits are overlain by sands or silty sands of marine or fluvial-lacustrine origin. Most of the coastal areas of the city derive from relatively recent reclamations (1400 – 1800); this is reflected in the thickness of land-fill, which, in some areas, can reach more than 10 m. The water table is relatively close to ground surface. The pyroclastic deposits are very common in the area of Naples and have very well known physical and mechanical properties because of their granular nature, they were characterized mainly by in situ penetration tests, such as CPTs and SPTs. In many ways, the most important aspect of the geotechnical investigation is the definition of the level of the roof of the Yellow Tuff formation.

ARTIFICIAL GROUND FREEZING – AGF

Because of the water table level, very often underground works have to take into account possible water inflow. Municipio, Università, and Garibaldi Metro stations were carried out with the extensive use of the AGF, to ensure stability and waterproofing during excavation below the ground water table, through loose granular soils and the fractured tuff providing a recent example of an extensive and successful application of the AGF. Here the technique was extensively used to ensure stability and control ground water flow during excavation of the station tunnel platforms and passageways and in some instances, the innovative techniques that were implemented had almost the character of full scale experiments; therefore, construction of the line was accompanied by an intense programme of monitoring designed to measure
Application of the Artificial Ground Freezing to support the excavation of tunnel platforms and passageways of the new stations of Metro Line 1 in Naples

and/or control the construction processes and their effects on adjacent structures, which, for its extension and completeness, represented a unique opportunity to collect field data on the performance of AGF.

At present, the use of AGF at Municipio is being considered again, to construct two 40 metres long tunnels connecting the main access shaft and the TBM extraction shaft of Line 6 and preserve the archaeological remnants (fortification walls built in the sixteenth century) emerged on the surface above the tunnels during the works, with a modification to the original design, which was based on dewatering and excavations with conventional methods. At Duomo, where the station develops mostly in the Yellow Tuff, AGF was used only to excavate one inclined passageway, which runs partly in the pozzolanas.

The experience gained in the works of Line 1 of Napoli underground is significant mainly because of the size of the intervention: for each station, a volume of approximately 33,000 m³ of ground was frozen to permit excavation of the four station tunnels, with a cross section of 87 m² and a length of 40 to 70 m, and of the four inclined passageways, with cross section of about 40 m² and a length of 25 m.
THE VERTICAL SHAFT

During the works for the Metro Line 1 an advanced technology was implemented to build ten ventilation shafts. It is a mechanized method to dig and simultaneously case circular shafts, recently developed and called Vertical Shaft Sinking Machine (VSM). The method allows for the safe and controlled construction of shafts with diameters ranging between 4.5 and 9.0 m.

The VSM machine includes an excavation unit, a lifting/lowering unit, a separation plant and a remote control unit. The excavation unit is fixed to the bottom of the final lining while operating. It is composed by a cutting bottom and it works by reverse circulation within a flooded shaft; a submersible slurry pump, located just above the cutting drum, transports the slurry, containing in suspension the disgregated soil, to the separation plant located at the surface.

The lining is made by rings of precast r.c. segments, installed at the surface and sunk within the excavation as the excavation is deepened. The precast segment lining ensures watertightness due to the seal installed on each segment. The shaft in Naples were 4.5 m dia and 34 to 44 m deep and were all located in the historical centre, in a deeply urbanized area. The average construction performance rate achieved at Naples jobsite was 3 m/d (10 working hours per day) of dug and lined shaft. Nearby buildings monitoring and ground inclinometers adjacent to installed shafts showed negligible displacements with maximum settlement values of the order of 1 mm.
ARCHITECTURE IN A HIGH-TECH UNDEGROUND STRUCTURE DESIGN

During the design of a typical modern subway, engineering aspects prevail since underground structures remain hidden to most humans.

Aligning the advanced architectural concepts with the engineering requirements of the Naples Metro Line 1 called for a thorough rethinking of the design process so that the engineering could be kept aligned with the architecture, integrating seamlessly the two with the construction methods, standards and technology.

The preliminary design process consisted of three major phases:

- geotechnical and geological issues, preselection of construction methods;
- functional scenario based on engineering and construction requirements;
- review and merging of the architectural concept with the functional and engineering aspects.

The last phase proved the most demanding one, matching the first outline sketches with the applicable construction methods. This required continuous alignment of approaches, eventually leading to the design consistent with the original architectural vision, yet fully compliant with the engineering and construction framework.

STRATEGY OF A PROJECT FOR THE CITY RENEWAL

The underground line 1 participates in an integrated system of rail transport, supplementing urban connections with a number of interchange nodes, collected in a ring system. The track meets the main modes of transport (national trains; regional trains; underground trains; port and airport) through both the central and peripheral neighborhoods.

The work becomes a site of intense renewal, where the works of engineering contextualized in major redevelopment of urban scale. In this context, Naples Metro system promotes different levels of study: engineering work alongside the projects of great architects are set up as museum galleries and the Art becomes the leitmotif of the work. The continuous discovery of artifacts in the excavation of the status has turned the work into a major relief work of the archaic stratigraphy, expanding the knowledge of the city's history from its origins to the Middle Ages, up to push for the creation of archeological museum spaces, inside of the stations. The three «A» represent the development of recent works underground; Archaeology, Architecture and Art, creating a new urban environment that affects the entire city, giving a new face to the squares in the centre and in the outskirts (dominated by degradation and carelessness).
This context includes the Toledo station, designed to the architect Oscar Tousquets Blanca of Barcelona. The station proved to be the most beautiful of all the underground stations of Europe, according to a survey conducted by the prestigious English newspaper "The Daily Telegraph" in major European cities. This project represents the synthesis of the design strategy of Naples underground system. This intervention is located between two opposite sides of the city: an historical and poor neighborhood, the Spanish quarters, settled in 1,500 as a military camp for the Spanish soldiers, on one hand, and on the other, via Toledo (commercial and institutional headquarters of the city) that still bears the name of the viceroy (don Pedro de Toledo) that build it. The general design concept is based on the idea of the "sea" level that divides vertically the station. The interior of the station is designed as an excavation, which shows also the Aragonian wall that has been dig up during the work. Below the level of the water, the user has the impression of diving underwater accompanied by the colours and materials used by the architect. All levels are crossed by a large cone of natural light, as a periscope leaning upside down from the road surface, giving the chance to observe the immersed passage of Metro users, for a 30 metres depth, and creating a real underwater architecture. Passengers directed to trains would get attracted from the bottom into the cone of light, coated of mosaic colored in various shades of blue and lit in part by natural light coming from the surface and in part by the light artwork of Bob Wilson consisting of ledlights in various intensities of blue and white. The station is completed with the other art works of Bob Wilson consisting of panels backlighted showing sea weaves in slow motion, and with the works of William Kentridge that, in addition to the two mosaics inside, has produced a wonderful equestrian sculpture for the over ground public spaces. The opening of the second exit of the station, in Montecalvario square, completed the project connecting the Spanish quarters to Toledo with a mechanized corridor where the traveler will meet numerous portraits made by Oliviero Toscani and going toward Piazza Montecalvario the great mosaic of Francesco Clemente in the mezzanine floor.
ARCHAEOLOGY

TUNNELLING MEETS HISTORY. HISTORY MEETS TUNNELS

Naples underground hides an ancient city. During the Greek and Roman periods a labyrinth of tunnels, tanks and cavities was built, providing impressive examples of underground works. In addition to this extraordinarily rich past, today Naples is still heavily involved in this area with recently constructed and ongoing works and of course with several future scenarios to be implemented in the coming years.

LINE 1 EXPERIENCE

The archaeological explorations that for the last years have been accompanying the building work on the Naples Metro stations are proving a very encouraging experience, both for the way in which the work is being conducted and for the perspectives ahead.

An important excavation, still in progress, is in the area of Piazza Municipio. By great good fortune it is being done at the same time as the two other explorations nearby, in Castel Nuovo and the Istituto Navale. Together they are filling in our previously sketchy knowledge of the topography of this area situated outside the Greek and Roman city, of great interest because in ancient times it lay between the settlement of Partenope-Palaepolis, on the spur of Pizzofalcone, and Neapolis. Other excavations taking place on the sites of the new stations Duomo and Università have only been under way for a few months, but hold great promise. In the former, a stretch of the southern defensive wall of Neapolis has come to light, with evidence that can be dated to phases from Greek times to the Middle Ages. The excavation can also tell us a lot about the 19th century buildings on the north side of Piazza Nicola Amore which were demolished during the urban renovation of the Risanamento. Whereas in Piazza Bovio (Università station), the first soundings have produced evidence of urbanization from the end of the 6th century AD, becoming more intensive during the 16th and 17th centuries. This residential quarters continued to develop and evolve until the square as we know it today was laid out during the Risanamento. Naturally this field work is the most obvious link between archaeology and the new Naples Metro but we should also remember that archaeology is going to be a protagonist of the new transport system. For too long now the square known as Piazza Museo has been constantly suffocated by traffic, with traffic jams forming day and night. MN urged the company responsible for the new Metro to create an exit in front of the museum, providing direct access to visitors.
Thus MN was very pleased when the architect Gae Aulenti decided to make the Museo station into a "gateway" for the museum, setting up in the station concourse two of the most famous images from our collections: a large scale reproduction of the Farnese Hercules and the colossal Carafa head. The station will thus become a prestigious entrance hall for the museum: the citizens of Naples will reclaim part of their heritage, and they will also be encouraged to take fuller advantage of the National Museum in their midst. The Municipio station, connecting Lines 1 and 6 to the touristic harbor and facing the City Hall, is the best example to present the nature of the works in depth, as the discovery of archaeological relics in the main shaft during the works provides a good example of the relationship between underground construction works and archaeological research. From the outset, the relevance of discoveries delayed works and lead to an ongoing redesign of the spaces by the architects Alvaro Siza and Eduardo Souto de Moura.

To this regard, a relevant case is the connection segment between Line 6 main shaft and Line 6 TBM extraction shaft: the twin tunnels were designed to be excavated under the ancient fortification walls from the sixteenth century. To overcome this concern of protecting the archaeological findings a double back filling system as ground reinforcement was used to improve stability in rock during the excavation phases: cement and chemical grouting was applied to the sides and inverts of tunnels where tuff was found, and ground freezing was set on top, where sands would easily collapse on the excavation. The compensation grouting technique had been chosen also to protect the historical tuff walls from damage during construction stages. These walls since the first discovery had become the main interest of the architects, who decided to integrate these ancient findings into the project.
A GREAT ARCHAEOLOGICAL EXCAVATION INSIDE A GREAT PUBLIC WORK

The focus of the work is the Piazza Municipio, the site of the main metro station for the new Metro Line 1 that runs through the heart of the city. Dominated by the great Castel Nuovo, and with a view of the always teeming coastline, the crowded piazza is an unlikely place for archaeological excavation. Starting at the modern street level, through the Naples' extraordinary history, into an enormous hole dug for the Metropolitana's tracks a short distance from the castle. Here archaeologists have located the port of Roman Neapolis (Naples' ancient name). The noticeable change in the color of the soil from a medium brown to a much lighter, sandier color, coincide at a layer corresponding to the fifth century AD. At this time, the harbour began to fill with sand and mud sliding down from the hill behind it, a recurring phenomenon in Naples' history. They were found three first-century BC Roman ships, two of the ships as oneraria, or commercial vessels for medium-range trips. The third ship is a rare horeia, a kind of in-harbor shuttle. After removing the ships in a tricky operation that involved slipping huge sheets of fabric underneath and lifting them out of the thick mud, archaeologists continued excavating. In the thick layers of mud under the Roman port, they located traces of the very first harbor dredging, dating to sometime close to 326 BC At this time Neapolis became a kind of naval partner with Rome. The excavations have also added much to the knowledge of the later city of Naples, including new evidence Byzantine, Normans and Angevins, Islamic wares at several sites, testament to the enduring importance of the city as a trading port. More than 3 million artifacts have been found in the Metro excavations; many of the larger remains have been left in situ for future metro passengers to see in the museum-like spaces of the stations, and some of the smaller artifacts will go back to the sites when work is completed. In the future, tens of thousands of Neapolitans who take the metro every day will see their city's history as never before.
Concerning the public open spaces, the digging of underground tunnels became step by step the conception, literally from bottom to the top, of a real revolutionary concept of the city environment: from a simple opportunity of urban redevelopment, it became so far a process of true transformation of the city.

Since the first landscaping projects, with only the reuse of spaces with public access or the reorganization of car lanes and the realization of garden spots, the urban renovation started to put the emphasis to pedestrian use of squares and to give a new collective image of the city, with a monumental public space. This was breaking new frontiers.

The underground project started to spread across the public domain, barely connected to station spaces. The example of Municipio Square should be considered in the dimension of its outside spaces: the visual connection, between the City Hall and the Maritime station, is a virtual imprinting of rediscovering the real heritage of the nature of this gorgeous bay: the sea. A continuous pedestrian alley bordered by parallel trees rows, determines a monumental Metaphysics Square, which allows a double fountain design scheme.

Since the first opening in 2014 of the City Hall side of the square, the space has taken a life of its own and heavily used by the public.

The Metro station projects, within the archaeological pattern, open a new view to another dimension of landscaping.

Municipio station is not the only one revealing striking archaic traces. Toledo station works uncovered the foundation of the city of Palepolis (very first foundation of Naples) about a thousand years old.

Duomo station is now a large archaeological campaign in progress to let a huge Roman temple (found during the shaft digging) to create a suggestive setting for people climbing upstairs from the platform level.

Università station excavations revealed the ancient beaches with an incredible discovery: the footprint of a baby and its mother, walking in the sands. Architects were at the forefront of discovering a new face of the underground traces of our culture and finally they had to give a new aspect to the actual city: by designing the connection layout between the existing city and new realizations involving all main squares of the city, a new culture of urban renovation has sprung.

The underground landscape has become the pivot from which to pursue the sustainability of the infrastructure: it is not an unconscious walking path driving users through the tube. Walking through the hallways of the new Naples Metro has become an emotional journey, to find and preserve our interior landmarks. The underground Line 1 represents an integrated project: Art staging the empty walking lanes,
Architecture improving the quality of living in the urban setting. This theme was projected to the outside: each urban design has a different approach, the project by Dominique Perrault is one of the most ambitious of the underground stations. The so-called Five Stations Square project connects the existing stations of National rails, Regional rails to Line 1: an enormous square of 300 m length was constructed as a double level space, the northern side as a garden, with a car parking underneath and the southern side, with an underground shopping arcade covered by a geometrical iron wood, connecting at -1 floor all stations. The circle Line 1, by the end of works, will establish a continuous landscape from downstairs upward.
The five stations of the Metro line 1 (Museo, Piazza Dante, Salvator Rosa, Materdei and Piazza Quattro Giornate) have been designed by the architects Aulenti, Mendini and Orlacchio but have been integrated, both inside and outside, with works of contemporary art commissioned from artists from Campania, without imposing any requirements in terms of age or style. This experiment is without precedent in Italy, and even internationally there have been few such initiatives. We shall witness the creation of works which can truly be described as "public art", not mere decorations or appositions to the architectonic core, but structures which interact with it, a splendid trompe l’oeil for all who pass through these premises. The result is the "stations of contemporary art". In the words of Martin Heidegger, "sculpture is the materialization of places which, fostering and conserving a community, gather round themselves a freedom which grants a dwelling to all things, and to men an existence in the midst of things". This provides us with the philosophical grounding for the "Erratic itineraries" installed in the Naples Metro. An art venue is created which does not have to conform to the traditional genres nor rely on reference to painting, sculpture, design or architecture pure and simple. This feature distinguishes works belonging to different styles, linked by the need to break out of the discrete disciplines in order to achieve an aesthetical peripatus associated with a process of acquiring knowledge. The erratic itinerary necessarily leads to erratic knowledge, a process that plays on dislocation and hence cannot be instantaneous. Here the work is circular and the spectator is free to advance or step back according to the dynamics of the work itself. Thus we see that the course of art itself is uneven, constituted by leaps forwards and backwards, great or small as the case may be, in space and time. This mobility is the product of the untrammelled movement of language embodied in form, where past, present and future are condensed.
The technical presentations will last 20 minutes each.