

ENGINEERING GEOLOGICAL – GEOTECHNICAL CONDITIONS IN PATRAS RING ROAD WIDER AREA, GREECE. COMPILATION OF THE RELEVANT MAP AT SCALE OF 1:5000

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Abstract

In order to evaluate the geotechnical parameters and the mechanical behavior of the Plio-Pleistocene sediments encountered along the Patras Ring Road, the lithology, the structure, the hydrogeological regime, the hydro meteorological data and the seismicity of the wider area were firstly examined.

More specifically, the morphological relief map and the map of slope inclination were compiled on the digitized topographic map, along with the engineering geological – geotechnical map of the area, at a scale of 1:5000, where the distinction of the Plio-Pleistocene deposits is shown. This distinction was based on geological criteria, as far as lithology and stratigraphic sequence are concerned, as well as on engineering geological – geotechnical criteria.

Key words: Patras Ring Road, Pliopleistocene sediments, Geotechnical units, Eng. Geological – Geotechnical mapping.

1. Introduction

Regarding the mechanical behavior of the geological formations that belong to the category of “Hard Soils – Soft Rocks”, the Plio-Pleistocene sediments of Achaia were studied, focusing on the area of Patras Ring Road (Kouki, 2006). The above formations have also been studied in the past, respecting their geological, engineering geological and hydrogeological features, (Doutsos et al, 1987, 1988; Rozos, 1989; Kontopoulos & Zelilidis, 1992, 1997; Voudouris, 1995; Tsiambaos et al, 1997; Koukis et al, 2005, 2007).

The investigation of these formations is of great importance, as there was no previous experience on tunneling through them. Therefore, data from the geological and geotechnical reports for the project were used, along with field investigation and the detailed engineering geological and geotechnical mapping. All data helped to have a general view and a good approach of these formations and led to the division of their fine grained facies into two separate Geotechnical Units, the Upper and the Lower one. These Units are characterized by their different lithology, mineralogical composition, physicommechanical features and mechanical behavior.



Photo 1: General view of the Plio-Pleistocene sediments in the hilly area behind the bridge Γ5. The Alpine formations are visible in the upper part of the photo (Panahaikon Mountain).

2. Location and geomorphologic setting of the study area

The wider study area is located at the NW part of Achaia County, with an average elevation of 600m and an average slope inclination between 6.0 and 15.5%. The morphological relief is a result of combined action of lithology, tectonism, weathering and erosion processes. Especially, the present morphology of the area has been formed by post-Alpine tectonic movements, as well as the evolution of the various morphological cycles, that continue to the present time.

Geologically, the wider area consists, from the west to the east, of formations of Gavrobo-Tripoli and Pindos Geotectonic zones. The hilly areas that surround the high mountains consist of post-alpine sediments. The summits of these hills are usually round-shaped and not sharp-shaped, indicating intense erosion processes (Photo 1).

Hydrographic network has been developed as a result of combination of lithological features, tectonics and morphology, as well as climate. It is mainly oriented along main faults zones.

The engineering geological map of Figure 1 shows, in more detail, the geological conditions along the alignment. It can be concluded that the Ring Road is mainly founded on Plio-pleistocene sediments, coarse and fine – grained and less on Quaternary deposits. The later can be divided into mixed-phase loose, loose mainly coarse-grained, coherent coarse-grained and mixed-phase coherent formations.

After revising and processing of aerial photos and field investigation it was concluded that the main faulting directions are NE-SW and NW-SE.

Due to the tectonic activity, the area is characterized by intense seismicity. The most recent earthquakes of the broader region are the earthquake of Alkyonides in 1981 ($M_s=6.7$) and of Aigion in 1995 ($M_s=6.2$). These magnitudes are relatively high and since they are close to the study area, it is possible that future earthquakes can cause there damages (Sokos, 1998). It is noted that Achaia belongs, according to the Greek Seismic Code (NEAK, 2004) to the zone of seismic hazard II ($a=0.24g$)

3. Hydro meteorological data – Hydrogeological regime

For the investigation of distribution and fluctuation of climatic parameters, meteorological data from the National Meteorological Service were used and especially data from Patra's station, covering the period 1931-2004.

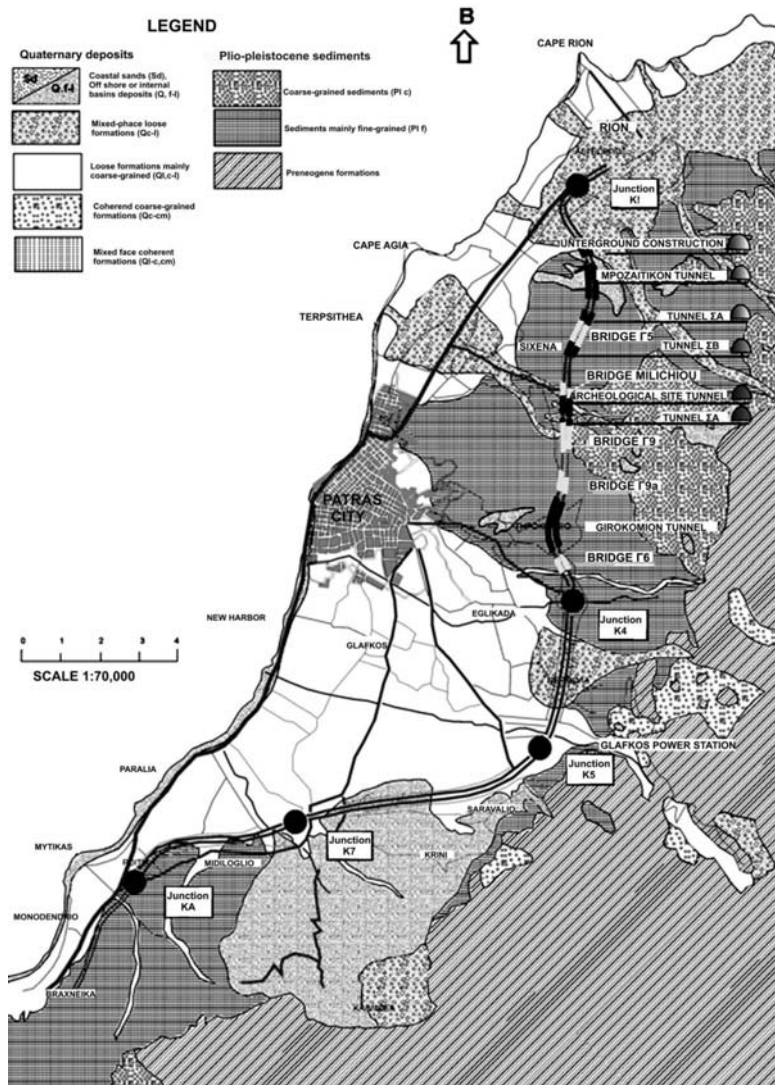


Fig. 1: Engineering geological map of Patras Ring Road wider area.

The lower temperatures dominate during the winter (10,6°C) and the higher during the summer (25.8°C), while autumn temperatures are about three degrees higher than those of spring period.

Annual rainfall heights show large fluctuation from 350mm in dry periods (e.g. 2000) to 1350mm during wet periods, such as 1993 or 2003. Based on these data and the fact that these geological formations are susceptible to erosion, it is concluded that it is the combined effect of thermal weathering and mechanical erosion that causes further loosening and strength reduction. This leads to locally unstable conditions and the manifestation of landslides.

From the hydrogeological point of view, the geological formations were divided into different categories, according to their estimated permeability. They were classified as pervious (e.g. loose Qua-

ternary deposits), permeable with secondary porosity (Karstic limestones), semi-pervious (Plio-pleistocene sediments, coarse-grained, Plc and fine-grained, Plf), and impervious (Flysch and Cherts).

According to the above and by taking into account the possible effects on the Ring Road construction, special attention was given to the Plio-Pleistocene sediments, because the majority of underground excavations took place in these formations. In Plc formations the lithology and stratigraphy result to the creation of aquifers and springs of medium to high discharge, located along the contacts of pervious and impervious beds. In Plf sediments, successive confined or perched aquifers are formed, usually inside coarse lenses. These conditions caused, in some cases, water flow during underground excavations, but the typical clayey and marly facies of these sediments are considered as impervious formations.

Furthermore, after analysis of piezometric curves in the lowland areas it was concluded that even in the most permeable alluvial deposits the water table was very low, so groundwater could not affect the Ring Road.

4. Engineering Geological – Geotechnical mapping at 1:5000 scale

After scanning of the hardcopy map, digitizing was performed in GIS environment. Digital data, such as elevation contours every 20m, rivers, inhabited areas, as well as Ring Road alignment was classified in thematic layers. All data were projected to the Greek Grid (ΕΓΣΑ 87).

Based on the alignment final design drawings two cross-sections along the road axis were drawn at a scale of 1:5000 (length) and 1:1000 (height) that correspond to the left and right branch (Kouki, 2006; Kouki & Rozos, 2010).

By using the digitized maps, Digital Elevation Models and slope maps were created. These maps show that the Road crosses areas with fully developed hydrographic network, with main directions perpendicular to the alignment. The elevation ranges from 20 to 240m. The greater part of the road crosses relatively plain areas (inclined up to 10°), while the underground works are located in areas of intense relief (inclination from 10° up to more than 30°).

From geological point of view, these Plio-pleistocene sediments have been so far presented in the IGME Geological Sheets of Nafpaktos, Patras and Chalandritsa at a scale of 1:50,000 (IGME, 1971, 1980, 1984), while their engineering geological properties are described by Rozos (1989) and Kouki (2006). The geological and geotechnical studies that were conducted before and during the project of Patras Ring Road did not further divide these sediments. Their geotechnical assessment was based on the results of soil classification tests and data from numerous boreholes, drilled for this purpose.

The present study was focused on the Ring Road wider area, first of all through the engineering geological mapping, using topographical maps at a scale of 1:5000. Previous data was taken under consideration (Rozos, 1989, Koukis and Rozos, 1990; Rozos et al, 2006), as well as data from the 169 boreholes drilled along the project (Kouki, 2006). Mapping was assisted by aerial-photo interpretation, using recent (2002) large-scale aerial photos (at a scale of 1:5000).

The legend of the map provides a rather comprehensive description of the geological formations (Kouki, 2006), as far as lithology, sedimentation type, distribution of different soil facies, degree of diagenesis and cohesiveness, type of soil matrix, color, permeability, as well as fracturing and weathering degree are concerned. Based on the above geological and geotechnical criteria. and the experience gained from the construction of the project, there was a distinction of the fine-grained facies

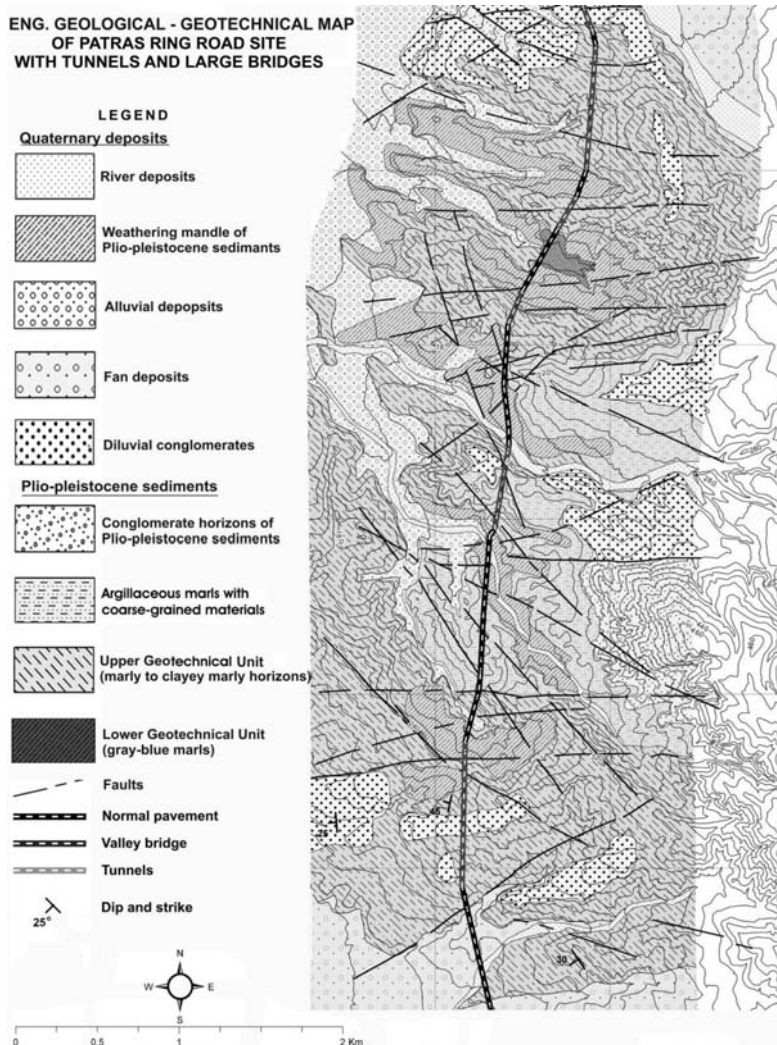


Fig. 2. Engineering Geological - Geotechnical map of Patras Ring Road site.



Photo 2: South part of Girokomion tunnel ($\Sigma 2$), right branch. The Diluvial conglomerates cover with unconformity the Upper Geotechnical unit.



Photo 3: Exit of SG tunnel. Stratigraphic column of the Upper Geotechnical Unit at the base, overlaid by conglomerates with distinct bedding (Unit of Argillaceous marls with coarse-grained material).

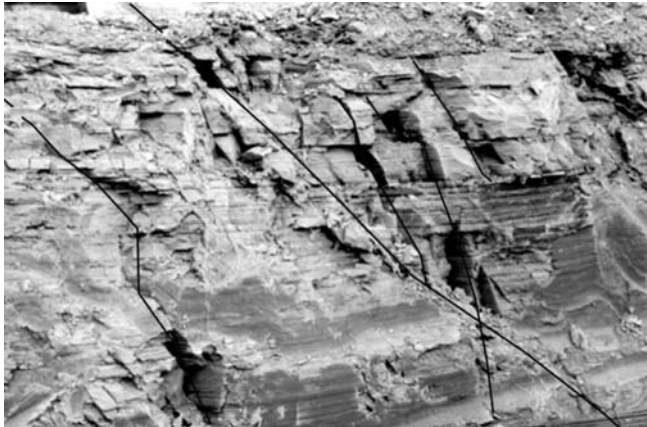


Photo 4: Gray-blue marls horizons of the Lower Geotechnical unit at a slope near a Cut & Cover at the exit of Bozaitika tunnel. The almost horizontal layers and the high fracturing of these weak rocks are shown. The fracturing is due to joint sets almost vertical to the bedding.

of the Plio-pleistocene sediments into two geotechnical units, the Upper and Lower one. In Figure 2, a simplified version of the engineering geological - geotechnical map is given.

It is concluded that the project is mainly hosted in the fine-grained Plio-Pleistocene sediments (Upper and Lower Geotechnical units). Also, a part of it was constructed in the argillaceous marls with coarse grained materials, while the first Cut and Cover of the project in the diluvial conglomerates (Photos 2, 3 and 4).

It is pointed out that the Lower Geotechnical unit appears only in a few places and it would not have been recorded unless it was met during underground excavations. It should be mentioned, that dur-

ing the geological and geotechnical investigations prior to construction, the Plio-Pleistocene sediments were studied geotechnically as a whole, without any further subdivision.

More specifically, the Upper Geotechnical unit is characterized by frequent alternations of brown-yellow to brown-gray clayey marls, sandy marls, sandy silts, sands and sandstones. The Lower unit consists of beds of gray-blue marls, usually stiff, clayey marls with some sparse coarser phases, mainly sands or sandy silts. Problems that are connected to the Upper unit can be attributed to this alternation of horizons with different lithology, cohesiveness, fracturing and weathering degree, as well as permeability. On the contrary, the Lower unit is considered to be an impervious and very cohesive formation, with homogenous and generally very good mechanical behavior during underground excavations.

5. Conclusions – Results

This paper studies the Plio-Pleistocene sediments in the area of Patras Ring Road in Achaia, Greece. It aims to a better knowledge of their mechanical behavior and response during the construction of engineering works of large scale and particularly underground ones.

The area that these formations cover is generally hilly, while the mountainous areas that surround them consist of Alpine bedrock rocks, (i.e. formations of Olonos - Pindos and Gavrobo –Tripoli Geotectonic Zones).

The investigation of these Plio-Pleistocene sediments, which are geomechanically classified as “Hard Soils-Soft Rocks”, was based on their surface appearance and on samples from numerous boreholes. This resulted to the division of their fine-grained facies into two separate Geotechnical units, the Upper and the Lower one, with a Transitional zone between them at places. Both units are characterized by their different lithology, mineralogical composition and physicommechanical properties. It is noted that for the design of Patras Ring Road, the two units, Upper and Lower one, were not dealt as distinct formations with different geotechnical behavior, but were considered as a uniform one.

Aiming to a better understanding of the extent of both units and the importance of their distinction for the design of underground works, engineering geological mapping at a 1:5000 scale was performed. Their vertical extent was presented in two geotechnical cross-sections along the alignment of each branch, including faults and the Transitional zone. The Upper unit formations can cause problems during construction, due to their frequent alternation of different lithological types, fracturing, weathering, as well as due to their locally increased permeability. On the contrary, the Lower unit is an impervious and very cohesive formation, with very good behavior during tunnel excavation and construction. The problems related to this unit are basically located in areas where the formations are saturated (mainly along fault zones), which leads progressively to the loosening of their structure.

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