Proceedings of the XVII ECSMGE-2019
Geotechnical Engineering foundation of the future
ISBN 978-9935-9436-1-3

doi: 10.32075/17ECSMGE-2019-1000

XVII European Conference
ECSMGE 2019
Reykjavik
on Soil Mechanics
and Geotechnical Engineering

Study of deep foundation at the power plant of the Public Power Corporation (PPC) in Chios island-Greece

Etude des fondations profondes de la centrale de Public Power Corporation

Michael Bellas
Institute of Geology and Mineral Exploration, Athens, Greece

George Voulgaridis
External Scientific Assosiate, Athens, Greece

Dimitrios Tsagkas
Institute of Geology and Mineral Exploration, Athens, Greece

ABSTRACT: This paper deals with the study of the foundation of a power plant (building 3) of the Public Power Corporation (PPC) in Chios island-Greece. For that, several types of foundations were studied, but finally deep foundations were implemented, as a solution for the least disturbance of the building and its maximum stability due to both the importance of the power plant to the local society as well as the distinct geology of the area.

RÉSUMÉ: Cet article traite de l'étude de la fondation d'une centrale électrique (bâtiment 3) de la Société Publique d'Electricité (SPE) sur l'île de Chios en Grèce. Pour cela, plusieurs types de fondations ont été étudiés, mais enfin des fondations profondes ont été mises en place, afin de réduire au minimum les perturbations du bâtiment et pour sa maximum stabilité, en raison de l'importance de la centrale pour la société locale et de la géologie distincte de la région.

Keywords: Public Power Corporation; Chios; Pile foundation analysis

1 INTRODUCTION

The island of Chios is found in Eastern utmost Aegean sea, East – Northeast of Athens. The geotechnical study was performed for the foundation of a power plant (building 3) of the Public Power Corporation (PPC) in Chios. Thus a full scale geotechnical re-search was conducted, including the drilling of five (5) sampling boreholes 20m deep, continuous measurements of groundwater table level, as well as SPT tests during the drilling procedures. In addition to the above, laboratory tests for the determination of the physical and geomechanical parameters of the foundation site were performed. After that, several foundation analyses were carried out, ending up to the use of piles as the ultimate solution, due to the distinct geological conditions of the foundation site. .

2 GEOGRAPHIC POSITION, MORPHOLOGY AND GEOLOGY

The island of Chios is found in Eastern utmost Aegean sea, East – Northeast of Athens, as it appears in the map below:

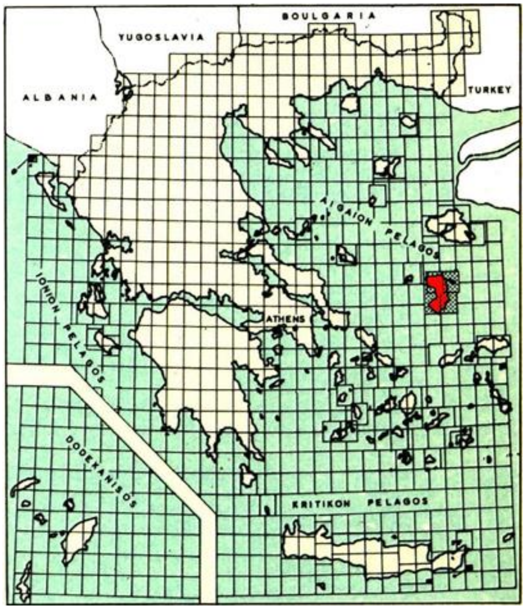

Figure 1. Map of Greece. The island of Chios is highlighted with the red colour, in the eastern part of the map

The entire island is covered by two (2) topographic sheets of G.M.S. (Geographic Military Service) and the equivalent geological sheets of Institute of Geology and Mineral Exploration (I.G.M.E.), by the titles “Northern Chios” and “Southern Chios”. The geographic coordinates of the studied area are given in the table below,

GEOGRAPHIC COORDINATES (UTM)	
Easting	426103.92 m E
Northing	4242841.48 m N

Table 1. Geographic coordinates

as well as the topographic map

Figure 2. Topographic map indicating the location of PPC installations in Chios

As it appears in the above topographic map, the installations of PPC are situated on the beach, right down a low hill, southern of the city of Chios and of the airport, roughly in the middle of the Angalis gulf. There are no torrent flows through the particular area and the morphological inclination in the area of power plant-building 3 is low, at about 5o to the northeast.

In the area of PPC installations, according to the geological map of IGME, alluvial deposits (Qal) are met, that were reported previously with various grain size composition, constituted from fine grain size soils (clays) to coarse grain material, such as gravel, angular cobles and pebbles of various sizes, mainly of limestone origin, connected with argillaceous material. From plac-es to places this formations enclose lens-shaped sandy or clay-marly brown material. The color of the superficial material is re-dish brown.

As far as the tectonics is concerned, the main systems of faults that are present in the region are developed in directions NW – SE, while more seldom they appear with SW - NE directions (fig.5). On the hill southern of PPC installations, sectors of the first fault system prevail. Inside the alluvial deposits, above which the installations of PPC in Chios are founded, was impossible to locate sectors of the above mentioned faults.

3 HYDROGEOLOGY AND GEOTECHNICS

3.1 Geotechnics

As far as the geotechnics are concerned, the drilling program, during this particular study, included the opening of five (5) sam-pling boreholes, with maximum depth of 20.00m each. The positions of the boreholes appear in the following plot:

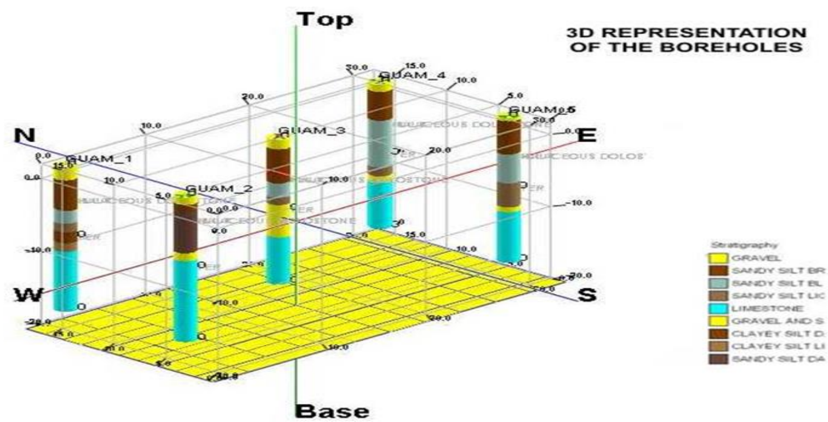

Figure 3. 3D representation of the five (5) boreholes at the position of the raft foundation of the power plant-building 3

Based on the results of the five boreholes, the geological structure of the foundation area, is as follows:

- At the borehole G-1, the first 1.80m are covered by alluvial materials, which consist of sandy clay and silt, with few angu-lar gravels. Its cohesion is very low to medium, with low plasticity. From 1.80m to 9.00m there is a sandy silt formation, which includes a few number of small angular gravels of limestone origin, as well as a small percentage of clay. Its cohe-sion is very low and its plasticity is low as well. From 9m to 11.70m, a clayey silt was found, with organic thin sand with-out gravels. This formation has low to medium plasticity and very low cohesion, and is met only in the first borehole. From 11.70m the Limestone bedrock of light blue color, at places fractured with joints, and no voids, was met.
- At the borehole G-2, the first 2.00m are covered by alluvial materials, which consist of sandy clay and silt with few angu-lar gravels. Its cohesion is low to medium, with low plasticity. From 2.00m to 7.70m there is a sandy silt formation, which includes a few number of small angular gravels of limestone origin. Its cohesion is very low and its plasticity is low as well. From 7.70m to 8.80m, a weathered formation is present with weathered material from the limestone bedrock. From 8.80m to 20m the Limestone bedrock of light blue color, at places fractured with joints, and no voids, was met.
- At the borehole G-2, the first 2.00m are covered by alluvial materials, which consist of sandy clay, silt with few angular gravels. Its cohesion is low to medium, with low plasticity. From 2.00m to 7.70m there is a sandy silt formation, which in-cludes a few number of small angular gravels of limestone origin. Its cohesion is very low and its plasticity is low as well. From 7.70m to 8.80m, a weathered formation is present with weathered material from the limestone bedrock. From 8.80m to 20m the Limestone bedrock of light blue color, at places fractured with joints, and no voids, was met.

-- At the borehole G-3, the first 1.30m are covered by alluvial materials, which consist of sandy clay, silt with few angular gravels. Its cohesion is low to medium, with low plasticity. From 1.30m to 9.00m there is a sandy silt formation, which in-cludes clay as well as a few number of small angular gravels of limestone origin. Its cohesion is very low and its plasticity is low as well. From 9.00m to 13.50m, a weathered formation is present with weathered material from the limestone bed-rock. From 13.50m to 20m the Limestone bedrock of light blue color, at places fractured with joints, and no voids, was met.

- At the borehole G-4, the first 1.00m are covered by alluvial materials, which consist of sandy clay, silt with few angular gravels. Its cohesion is low to medium, with low plasticity. From 1.00m to 12.70m there is a sandy silt formation, which includes clay as well as a few number of small angular gravels of limestone origin. Its cohesion is very low and its plastici-ty is low as well. From 12.70m to 13.60m, a weathered formation is present with weathered material from the limestone bedrock. From 13.60m to 20m the Limestone bedrock of light blue color, at places fractured with joints, and no voids, was met.

- At the borehole G-5, the first 1.80m are covered by alluvial materials, which consist of sandy clay, silt with few angular gravels. Its cohesion is low to medium, with low plasticity. From 1.80m to 12.30m there is a sandy silt formation, which includes clay as well as a enough number of angular gravels of limestone origin. Its cohesion is very low and its plasticity is low as well. From 12.30m to 13.00m, a weathered formation is present with weathered material from the limestone bed-rock. From 13.00m to 20m the Limestone bedrock of light blue color, at places fractured with joints, and no voids, was met.

After conducting SPT tests, as well as Geotechnical laboratory tests, we obtained the following results:

Soil Properties	
Description	Properties
Alluvial material (SC)	γ = 20 kNt/m^3 E = 60000 kNt/m^2 ν = 0.39 Φ = 27° c = 30 kNt/m^2 K = 10^{-4} cm/sec
Sandy silt (SW - SM, SC)	γ = 19.5 kNt/m^3 E = 13000 kNt/m^2 ν = 0.35 Φ = 32° c = 5 kNt/m^2 K = 10^{-3} cm/sec
Clayed silt (CH) – Only for borehole G-1	γ = 19.5 kNt/m^3 E = 8700 kNt/m^2 ν = 0.37 Φ = 26° c = 30 kNt/m^2 K = 10^{-6} cm/sec
Weathered material	γ = 20 kNt/m^3 E = 15000 kNt/m2 ν = 0,27 Φ = 34° c = 0 kNt/m^2 K = 10^{-4} cm/sec
Limestone bedrock	γ = 24 kNt/m^3 E = 20,000 MN/m^2 ν = 0.22

Table 2. Soil properties

3.2 Hydrogeology

Because the installations of PPC are founded mainly on coastal deposits near the sea, the hydrogeological conditions result from the absolute elevation of the studied area. That is to say that the underground water table, in the place of work, is the same with the level of the sea. Thus, the water in the place of work is salty. The groundwater table was defined by measurements in the piezometric tubes, installed after the drilling operation, and was found 1.70m under the ground surface.

For better understanding of the foundational conditions at this site, liquefaction analysis was performed for all five (5) borehole data, based on the results of the Standard Penetration Test (SPT). All the five (5) liquefaction analyses, were performed by the use of “Eurocode 8” and in all cases it was assumed an earthquake magnitude of 6.5 Richter and a peak ground acceleration of 0.24g.

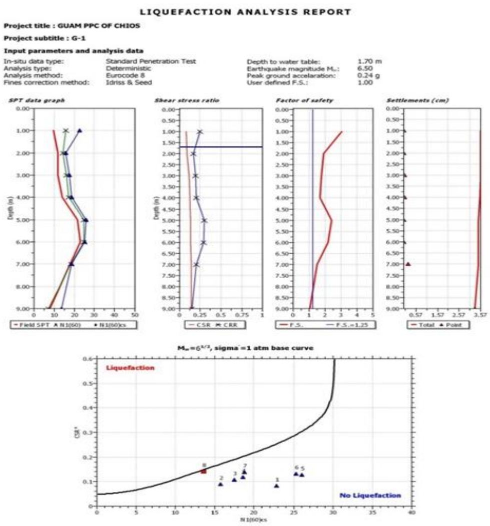

Figure 4. Liquifaction analysis in Borehole G-1

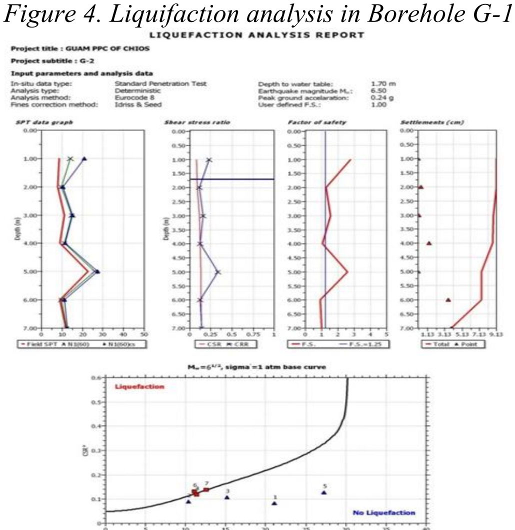

Figure 5. Liquifaction analysis in Borehole G- 2

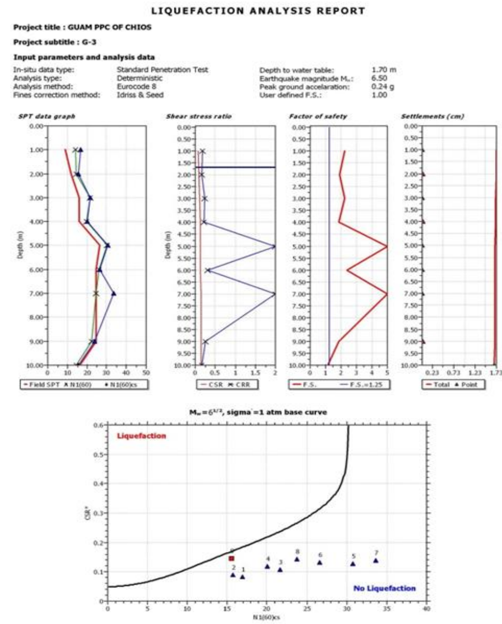

Figure 6. Liquifaction analysis in Borehole G- 3

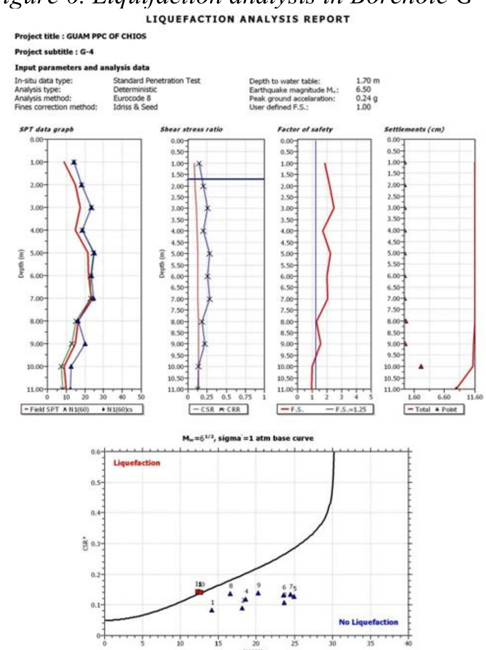

Figure 7. Liquifaction analysis in Borehole G- 4

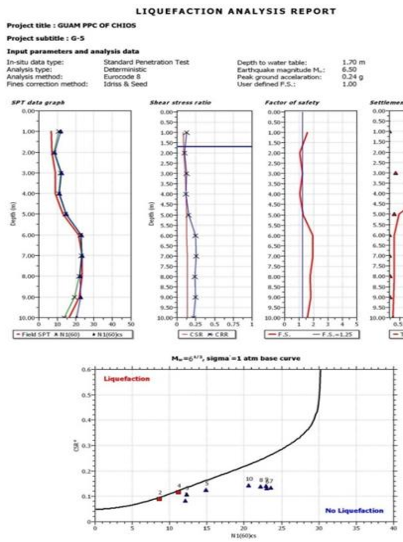

Figure 8. Liquifaction analysis in Borehole G- 5

4 FOUNDATION ANALYSIS

As far as the foundation analysis is concerned, the power plant has to undergo zero settlements. The structural study pro-posed the construction of radier foundation 1.2m thick (dimension 21.1mX33.0m), overlying of 1m of gravely soil layer treatment. A settlement analysis was carried out showing that the maximum value of settlement was 5.84cm, as shown in the below figure

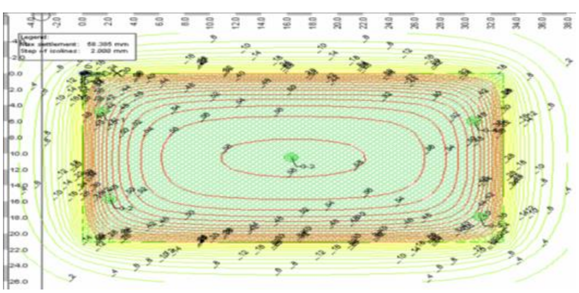

Figure 9. Schematic representation of the settlement calculation in PPC site in Chios island. As it can be seen the maximum subsidence is 58.38mm (5.84cm)

Since this settlement was not acceptable by the PPC, we proceeded in a deep foundation analysis with the use of piles. Based on the above decision, a group of piles was proposed which had to be fixed in the bedrock, at the depth of 14m due to the loading conditions (48934.50kN Dead and live load after the application of the appropriate factors of safety).

Therefore, a 4x8 pile grid was decided (32 piles). Each pile should have a diameter of Φ1000, concrete of quality C30 and steel of S500. The pile analysis was performed for a single pile with the maximum vertical load (worst geotechnical conditions scenario). The analysis resulted in the following behavior of the pile

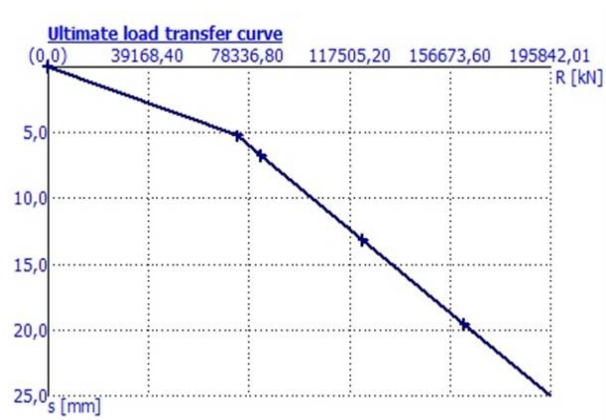

Figure 10. Ultimate load transfer curve

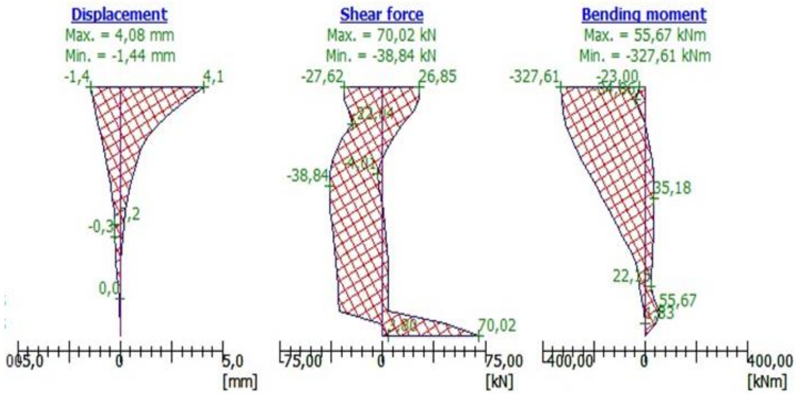

Figure 11. Pile's behavior in terms of shear force, bending moments and displacements

By taking into consideration the above results, the final dimensioning of the piles is as follows:

- The pile reinforcement comprised of 18 equally spaced rods of Φ22 diameter, as well as Φ10 stirrups every 10cm

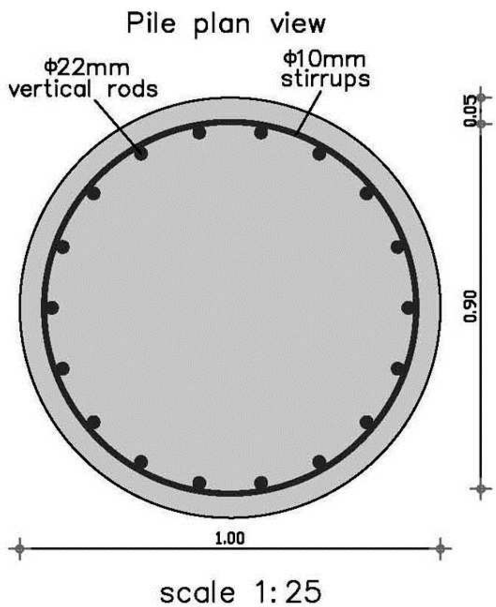

Figure 12. Plan view of the constructed pile

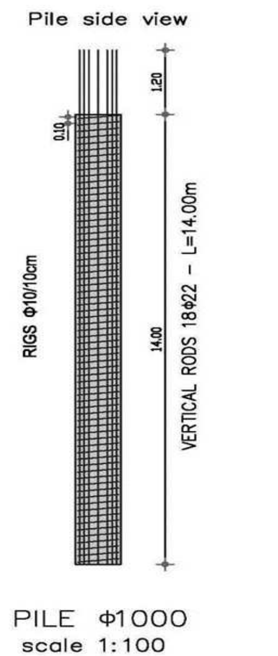

Figure 13. Side view of the constructed pile

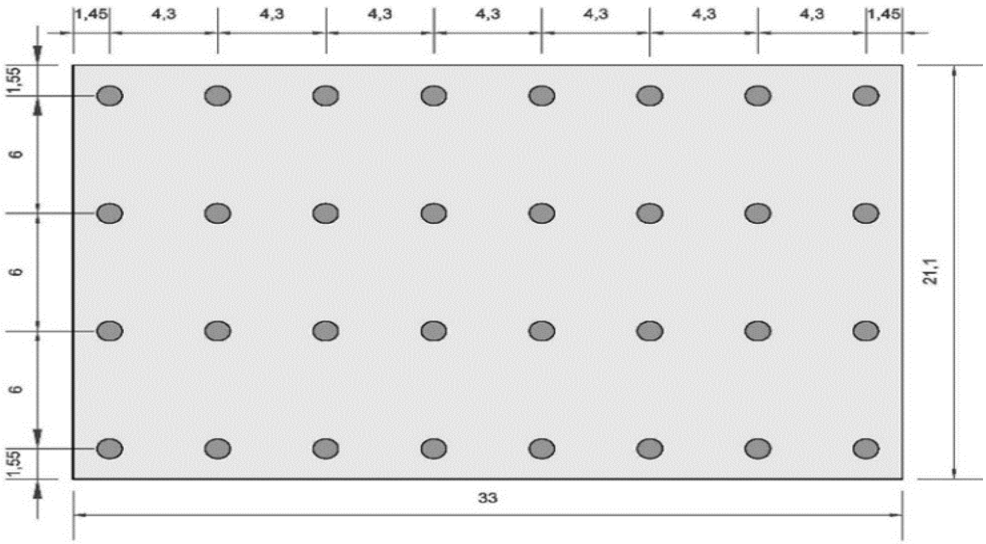

Figure 14. Plan view of the pile foundation

5 CONCLUSIONS

The foundation of the power plant (building 3) of the hellenic Public Power Corporation (PPC) in Chios island-Greece was an important and challenging project, not only due to the work that the powering generator had to perform to the local community, but also because of the non–homogeneous stratigraphy of the site where the foundation had to be installed and the shallow water table, due to the proximity of the construction area to the sea. For this reason, the best foundation solution, in order to eliminate settlement, was chosen that included an orthogonal radier plate of 1.2m thickness, on top of thirty two (32) piles of 1m diameter and 14m depth, constructed in four (4) rows, of eight (8) piles in each row. These piles, according to the geotech-nical research had to be fixed within the limestone bedrock formation and comprise eighteen (18) vertical steel rods of 22mm diameter, whereas the stirrups should consist of 10mm diameter steel which are spaced apart by 10cm. The entire proposed so-lution was constructed after the completion of the geotechnical research and its performance is excellent.

6 ACKNOWLEDGEMENTS

The study in this research paper was funded by the Hellenic Public Power Corporation (PPC)

7 REFERENCES

Budhu, Muni. 2008. Foundations and Earth Retaining Structures, John Wiley & Sons.

Ath. Tataris, Nik. Maragoudakis, G. Katsikatsos, Geological map of Greece, scale 1:50.000, “SOUTHERN CHIOS” sheet, IGME publishing, Athens, 1970.

OASP (2000, 2003 revision), “Hellenic Seismic regulation”, OASP publishing, pp. 173-183.

Hellenic military Geographical service, Topographic map of Greece, scale 1:50.000, “SOUTHERN CHIOS” sheet, 1971, G.Y.S publishing.