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GEOPHYSICAL INVESTIGATION OF THE FIELD AT THE LOCATION OF THE UGLJEVIK 3 THERMAL POWER PLANT IN UGLJEVIK

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ABSTRACT

Location for the construction of the Ugljevik 3 Thermal Power Plant is planned within the complex of existing Thermal Power Plant Ugljevik 1 and previously commenced Thermal Power Plant Ugljevik 2. During the field research, the presence of the faults was identified, which is particularly significant for the part of planned main facilities of thermal power plant. For a detailed definition of the presence of faults and their elements, geophysical investigations of the field were carried out. Seismic scanning of the field was performed at six profiles as well as geoelectrical investigations. Obtained results showed that faults are not seismogenic, and that thermal power plant facilities can be built in this area.

Key words: *geoelectrical measurement, seismic surveys, fault, hazard*

INTRODUCTION

Ugljevik 3 Thermal Power Plant, with total power of 2 x 300 MW, is situated within the complex of the existing Thermal Power Plant Ugljevik 1. Previously commenced Thermal Power Plant Ugljevik 2 will be built in the future, and in that way the complex of Ugljevik thermal power plants will be completed, with total power of about 1000 MW. Each thermal power plant will operate as a separate unit, using the minimum of common infrastructure.

Significance of the objects that are part of the Thermal Power Plant 3 required more detailed geological investigations, with particular emphasizes on geophysical surveys. Geoelectrical and seismic measurements were carried out in order to define earthquake hazard and seismic design parameters. This paper will evaluate a seismic hazard.

Previous geological investigation ascertained the presence of faults at the location of future Thermal Power Plant Ugljevik. Geophysical investigations, applying the methods of seismic and geoelectrical measurements, more clearly defined properties of the field in the area of identified faults. Data obtained made it possible to connect in more details lithological members in the field, which were identified by exploratory drilling. They also provided more precise orientation of the present faults. In addition, results of geophysical seismic and geoelectrical measurements, as well as geotechnical investigations, should serve for the purpose of determination of engineering design parameters of seismicity.

GENERAL GEOLOGICAL FIELD CONDITIONS

Location of the site where the thermal power plant is going to be built is situated in the northeast part of the Republic of Srpska, Bosnia and Herzegovina. It belongs to the catchment area of the river Janja, which is a part of the catchment area on the left bank of the river Drina, figure 1. Immediate surrounding is built of sediments of Quaternary and Tertiary age [1].

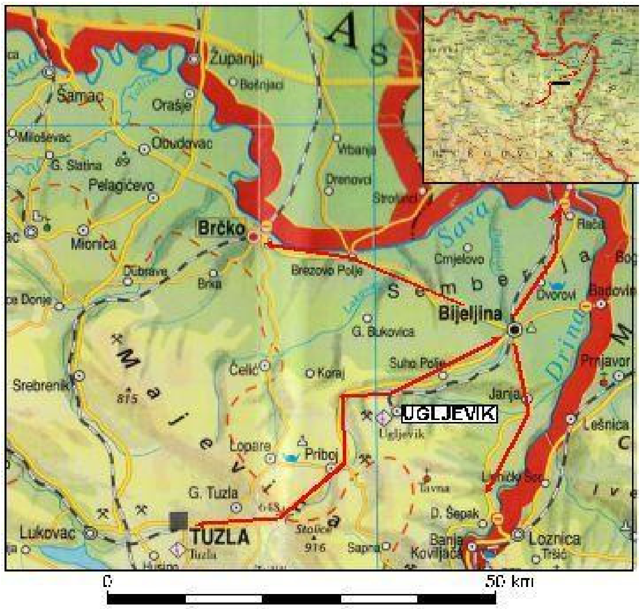

Figure 1. Geographical location of the investigation area

The oldest sediments are of Paleocene – Eocene age (Pc, E_1), represented by alteration of dark grey to black and grey marls, shales and sandstones. Neogene sediments are of Lower Miocene age ($_1M_1^1$), which are built of conglomerates, sandstones, gravel and sandy rocks. They build upper horizon of the field substrate. Subsurface sediments are river sediments (al), presented by gravels and sands.

Tectonic of the field is somewhat complex if observed throughout a small area. According to tectonic zoning in Basic Geological Map, sheet Brcko, explored area and its immediate vicinity belong to borderline area between two structural – facies units. The first structural – facies unit of the folded complex of Majevica is characterized by shales and sandstones. The other unit of Neogene basins, namely Ugljevik Neogene basin, is built of Miocene sediments, mostly marl and marly rocks [1, 2]. By the exploratory drilling and geophysical investigations, tectonic lines were registered. Existence of few faults was determined, out of which the most significant one is the fault R_1, which strikes north north-west – south south-east, figure 2. It extends over the contact area of alluvial plane with Paleocene – Eocene sediments.

Significant objects are planned on the route of the fault striking, especially western turbine and a chimney. Therefore, it was necessary to fully define its propagation and seismicity, and on that basis provide an assessment of location suitability for the construction of facilities of thermal power plant.

More broadly, from the geotectonic point of view, this area covers peripheral part of inner Dinarides. Morphotectonic category border of Pannonian depression is made of cascade system of outer faults. Microlocation itself is situated close to the contact of Pannonian depression with Majevica, namely near the foreland of Majevica.

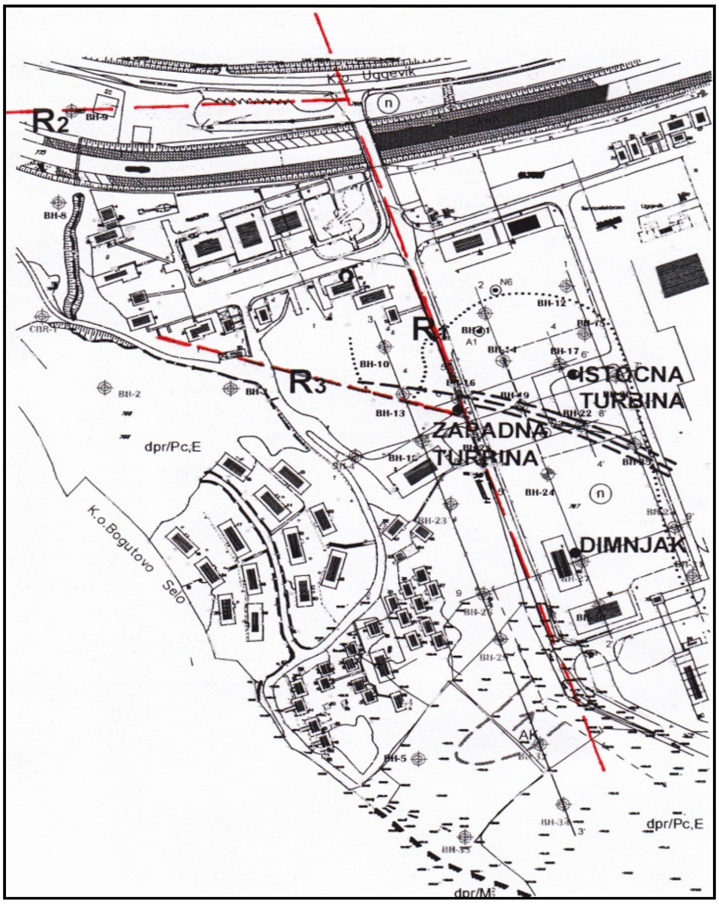

Figure 2. Position of the fault in relation to the location of the Ugljevik 3 Thermal Power Plant

Analysis of wider geotechnical structure of the researched field indicates that the area of aquifer relief is built of Quaternary formations [2]. Quaternary itself can be represented by terraced or basin type of sediments. Basin sediments are especially developed in north Bosnia, that is in the southwest border of the Pannonian basin. Quaternary depressions in intermountain depressions also belong to this type. Their thickness may exceed 300.0 m.

Terraced Quaternary sediments follow the river flows. Previous analyses indicated that sedimentation in depressions formed throughout Quaternary period, was more intense than simple descending of Neogene blocks resulting in very rare formation of lake areas. Quaternary basin has the largest distribution in Semberija, Samacka Posavina and Brodska Posavina, Lijevce Polje and Sprecko Polje. Quaternary of this type is built of fossil and recent alluvial planes and its largest distribution has Upper Pleistocene – second terrace, which is located in Bosnian Posavina and Semberija. Thickness of this terrace is about 15.0 – 30.0 m, which is sandy – gravel in lower part and dusty - loam in upper part.

At the mentioned location, a part of Tertiary and Quaternary "filling" is present, which can be conditionally classified into:

- overlaying bed that is located immediately above the basic rock masses – Tertiary base
- subsurface part with prevailing Quaternary or Tertiary sediments

Overlaying part above the rock material, that is above the basis, absorbs potential movements which might be a consequence of neotectonic activity and impulse tectonics, manifested in forms of earthquakes. Subsurface is a part of geotechnical medium that is suitable for the foundation of structures which are being built.

TYPE AND SCOPE OF INVESTIGATIONS

Geophysical investigations were carried out as a supplement to exploratory drilling that is being conducted for the purpose of geotechnical investigations. Main goal of geophysical measuring was more accurate determination of the route of fractured structures, namely their width and orientation. Apart from that, obtained results, together with geotechnical investigations, are used for determination of seismic design parameters for the purpose of the construction of seismically resistant facilities.

For the purpose of the construction of future industrial objects at the mentioned site, in addition to knowing the facts about geometrical structure of geological medium, it is necessary to understand physical and technical characteristics of lithological members it is built of. They were determined within geotechnical investigations on the basis of spot samples obtained by exploratory drilling and digging of trial pits, as well as by laboratory test that provided static parameters. Dynamic parameters are determined by seismic tests and those are spatial (2D) parameters. For determination of boundaries of other elements of geological medium and a fault, geoelectrical investigation methods were used.

Seismic scanning of the field along seismic profiles – refraction seismic survey using tomography method, was carried out for the purposes of determination of closer orientation of fault propagation waves, which have been noticed by exploratory drilling in the researched area. It was conducted by six profiles set up almost perpendicular to the fault R1, identified by drilling, figure 3.

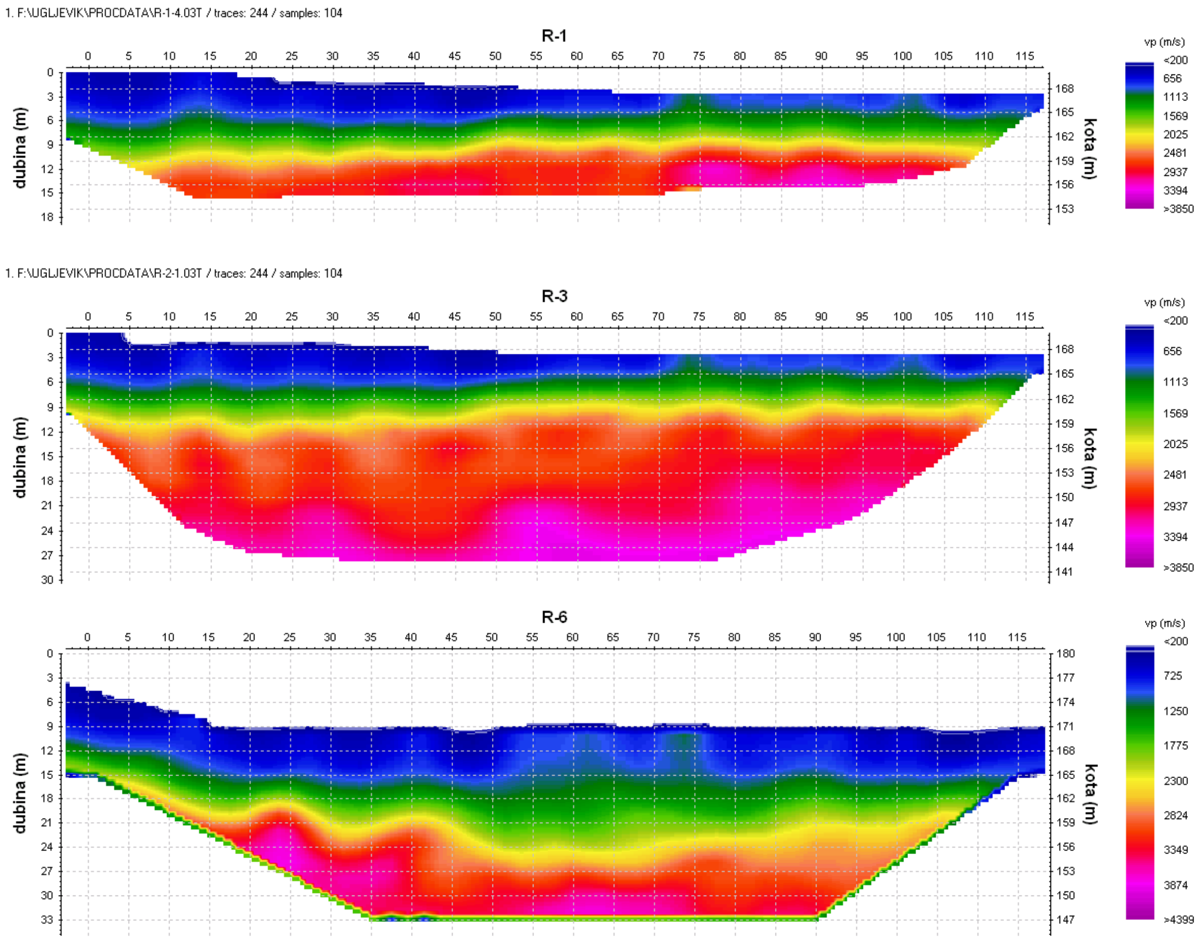

Figure 3. Typical seismic profiles of the field R – 1, R – 3 and R – 6

Seismic profiles were of identical lengths, namely 120 meters each, and every profile consisted of 24 geophones that were stuck into the ground at every 5 meters. Generation of elastic waves at each profile was performed by striking at nine points and that was:

- two (2) points at the ends of a profile – 2.5 meters from the 1st, and the 24th geophone
- seven (7) points within the profile, between following geophones: 3 and 4, 6 and 7, 9 and 10, 12 and 13, 15 and 16, 18 and 19, 21 and 22

While carrying out these types of geophysical tests, a digital 24-channeled seismograph was used, type "Terralock Mark 8" by Swedish company ABEM. The apparatus has an accuracy of measuring of the occurrence of first seismic waves 0.01 milliseconds, possibility to sum up and control a signal, as well as possibility to filtrate seismograms, that is to eliminate possible interference.

Geolectrical investigations, carried out with the aim of detecting faults, required determination of boundaries, thickness, depth and spatial position of geoelectrical mediums, which should be characterized by different specific electrical resistivity, along the given profiles. Contrast of geoelectrical mediums at the location is estimated on the basis of results of geotechnical investigations.

Geoelectrical sonding was performed by standard Stumberg symmetrical arrangement of electrodes A MN B. Maximum distance between current electrodes was AB/2 = 100 m, and according to previous experience, that enables interpretation to depth of about 30.0 – 40.0 m. It was performed 80 geoelectrical probes in total.

RESULTS OF GEOPHYSICAL INVESTIGATIONS

Seismic scanning of the field was performed at six profiles where individual mediums were isolated. Processing of measured data, by application of seismic scanning method, was conducted with a software programme "REFLEXW version 6.0" made by German manufacturer K.J. Sandmeier, Karlsruhe.

By processing of measured data, 2D model of isolines distribution of propagation velocity of elastic p-waves was obtained and they were presented at profiles. Distribution of velocity of primary – longitudinal seismic waves is presented in a form of pillars along the profiles, figure 3.
On seismic profiles, mediums were isolated generally with following results:

Medium 1 forms a surface cover that is generally presented on all profiles. Zones typical for their velocity of propagation of elastic waves were isolated:

zone 1a	$V_p < 200$ m/s
zone 1b	$V_p = 656 – 725$ m/s
zone 1c	buffer zone between zones 1b and 2a

Zone 1a is not continuously represented along the route of the profile and it occurs in pockets where its thickness is up to 1.0 m. Zone 1b is presented along the route of the profile with interruptions. Zone 1c is almost continuously presented along the whole route, and in one part, it pinches out to the surface. In fact, by its largest part it makes a roof of the medium 2. Thickness of the zone 1c ranges from 0.5 to 2.0 m.

Medium 2 is divided conditionally into the following zones:

zone 2a	Vp = 1113 – 1250 m/s
zone 2b	$V_p = 1569 – 1775$ m/s
zone 2c	$V_p = 1776$ m/s, situated in the overlying bed of the medium 3

Zone 2a is presented continuously along the route of the profile and it is of small thickness - about 0.5 m, whereas it is thicker only at the parts where it pinches out to the surface of the field. Zone 2b is an underlying bed of the zone 2a and it is continuouslu presented along the route of the profile with thickness ranging from 1.0 to 2.0 m.

Medium 3, according to velocities of longitudinal waves is conditionally divided into following two zones:

zone 3a	V_p = 2025 – 2300 m/s
zone 3b	V_p = 2284 – 2825 m/s
zone 3c	V_p = 2550 – 2937 m/s

Zones 3a and 3b are presented continuously along the route of all profiles, whereas the zone 3b at individual profiles is located in the underlying bed of the zone 3a. Zone 3c is presented in two profiles in the form of underlying bed of the zone 3c.

Medium 4 is conditionally divided in two zones:

zone 4a	V_p = 2811 – 2300 m/s
zone 4b	V_p = 3072 – 3394 m/s
zone 4	V_p = 3350 – 3394m/s for profiles 3 and 4

Zone 4a is presented continuously along the route of all profiles while the zone 4b does not occur in profiles 3 and 4 where medium builds a single zone 4.

Medium 5 is presented in three profiles as a unique one, without separating to the zones. Velocity of longitudinal waves ranges within the limits:

zone 5	$V_p = 3849 \geq 4399$ m/s

Based on the results of seismic measurements, presented in specified mediums, it may be concluded the following:

- specified mediums generally, by velocity of elastic waves parameters, stratify horizontally
- zones with slightly lower elastic properties, which are probably predisposed by the fault, are noticed at the intersections
- based on the results of measurements, velocities of longitudinal seismic waves at individual intersections are less noticeable.

Velocities of elastic waves that have been obtained by geophysical investigations in this field, reveal that materials of the fault zone present a medium of slightly poor geomechanical properties. In spite of that, based on previous experience in the fields of similar geological structure, it can be concluded that this medium is not going to be a limiting factor for the foundation and construction of the facilities of the Ugljevik 3 Thermal Power Plant.

Geoelectrical sonding of the field is characterized by the selection of methods based on results of exploratory drilling. Along with that, geoelectrical contrast of lithological members building a complex up to depth of the research was noticed. Clays and marls differ in electrical resistance several times because resistance of clays is ρ= 10-20 Ωm and of marls ρ= 50-60 Ωm. Resistance of marls and sandstones is ρ>100 Ωm. Present contrasting is adjustified, and it will enable determination of spacial position of these mediums and based on that, define the presence of the fualt.

While conducting geoelectrical sonding of the field, problems - interferences were identified, resulting from the presence of permanent stray currents, which have prevented regular geophysical interpretation of measured curves. Influence of stray currents deformed geoelectrical sonding curves in a way that all of them were extremely jagged. Their "ironing", that is manual filtration of interferences, was impossible. Degree of indeterminacy of depths and structure of lihtological members by "ironing" method overcame usual standard values and errors, which occur during the regular measurement.

SEISMIC HAZARD ASSESSMENT

Assessment of seismic-tectonic conditions and seismicity of the microlocation planned for the construction of the Ugljevik 3 Thermal Power Plant in Ugljevik, was provided throughout the analysis of seismic-tectonic conditions [4,5,6.7]. Analysis revealed a degree of seismicity of the faults identified in the location. It also provided an assessment of their potentiality to cause the occurrence of seismic-tectonic deformations in the area of the foundation of facilities for the thermal power plant. Investigated location is situated in the zone of the VII degree of seismic MCS scale.

During extremely strong earthquakes, seismic-tectonic deformations occur among other manifestations, causing the formation of seismogenic fault, meaning that an "appearance" of the magma chamber on the surface happens. These phenomena present a limiting factor for the construction of facilities such as thermal power plants, and these locations are eliminated for the construction of mentioned facilities. However, phenomena are realistic in areas where earthquakes with a magnitude M≥6.5 by the Richter scale [8,9] might be expected.

Conducted studies on the seismicity of this area indicates that the largest realistically assessed value of the magnitude is M = 3.5 which corresponds to intensity of up to 6^0 of the seismic scale for the surface of the field. This value can be expected at the group of faults on the east side of Majevica in the region of Ugljevik [2,6,8,10].

According to conducted analysis, thickness of Tertiary sediments in the area of Ugljevik, exceeds 1000 m. Therefore, this filling absorbs all movements that occur at faulting of blocks in the underlying bed of Tertiary during the earthquakes that may happen at the site. Hence, the presence of faults, even with the expected seismogenic potential of M = 3.5, are not limiting factor for the construction of facilities of the thermal power plant at the mentioned location [11].

Seismic risk includes partial seismic risks that should be individually analyzed, and synthesis of these partial risks provides a general seismic risk. Risk itself caries a certain contradiction. As a measure of risk, a number may be taken, which characterize a degree of possible occurrence of random event and that number is called probability. Risk itself should be useful and that is why a concept of caution risk is introduced, whose application prevents great losses. Utility function of this caution risk takes a following form:

$$P(a) = 1 - e^{-a}$$

In a theory of probability, specified formula corresponds to the occurrence of extremely rare event at least once. Using the utility function it can be decided under what conditions a risk can be undertaken, and when not. It can be said that a risk is a course of action in uncertain conditions, resulting in prevalence of success over failure.

Since the analysis performed proved that identified faults do not present limiting factor for the construction of the planned thermal power plant, it is necessary to approach to the second stage of the investigation, namely to determination of engineering seismic parameters for the calculation of seismic stability of future objects.

CONCLUSION

Research of the field for the purpose of defining geomechanical properties of the site at the location of the Ugljevik 3 Thermal Power Plant, indicated the presence of faults. In order to define them precisely, geophysical investigations were carried out. Their main goal is to accurately determine routes of faulting structures, that is their width and orientation.

By seismic scanning of the field at six profiles, it was extracted five (5) mediums with several zones within individual mediums. Velocities of propagation of elastic waves are different, depending on the medium, while velocity is higher in more compact rocks which underlie at greater depths. In addition, velocities of elastic waves prove that materials of the fault zone represent a medium, of slightly poorer geomechanical properties. However, this medium does not present a limiting factor for the foundation and construction of facilities for the Ugljevik 3 Thermal Power Plant. By geoelectrical sonding of the field, geoelectrical contrast of lithological members was identified, and that will enable defining of spatial position of isolated mediums, as well as defining the presence of the fault.

Conducted investigations revealed that the ascertained faults do not present limiting factor for the construction of the planned thermal power plant. In the next stage of the research for the purpose of foundation of the thermal power plant facilities, in the parts of the field that are close to the fault area, it is necessary to perform additional investigations. By determination of engineering parameters of seismicity, a calculation of seismic stability of future facilities will be enabled.

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