DETERMINATION OF GEOTECHNICAL PARAMETERS ON LOCATION OF FACILITIES FOR FLUE GAS DESULPHURISATION AT THERMAL POWER PLANT UGLJEVIK 1

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Abstract: *Thermal power plant Ugljevik 1, was built in the eighties of the XX century and it still works at full capacity. In the meantime it was technologically modernized, but not according to today's valid ecological standards. During production it releases surplus of sulfur particles that have a negative effect on the environment, human health and the quality of agricultural products. In order to modernize the production of thermal power plant and bring it into a state that meets ecological standards, it is planned a construction of Facility for flue gas desulphurisation.*

Within the facility are placed several objects that depending on their importance will be shallow or deeply based. Detail geological research and laboratory tests were carried out with the aim of evaluation of characteristics of lithological members in vertical profile of the terrain. Allocated were geological environmnts, and choice of parameters for everz environment was carried out through correlation of data from terrain research and laboratory testing.

Key words: *objects, terrain, geotechnical parameters*

1. INTRODUCTION

Thermal power plant Ugljevik 1 was built in the eighties of the XX century for the exploitation period of 30 years. This period passed and thermal power plant 1 continued its production. Reconstruction of facilities for the following 40 years was carried out. The extension of working life of thermal power plant 1 demanded its modernization in part of acheiving of modenr ecological standards. For this purpose, was planned the construction of a desulphurization facility.

Location of facility is immediately to the object of Thermal power plant 1. Objects have significant characteristics which demanded detail study of terrain geology and geomechanical characteristics of the layers in which will be founded certain objects.

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Earlier researches for existing object of Thermal power plant 1 were not available, therefore research was carried out to the extent that standard related to this type of objects demand. Here are two phases of research, phase of Conceptual solution and phase of Main project.

In the development of the main project, the location was displaced in relation to the earlier conceptual solution, so new research was carried out according to the standards for the main project. In doing so, was used a part of research works that was found on location for which was done a main project.

2. CARRIED OUT RESEARCH AND TESTINGS

On area planned for the construction of Facility for flue gas desulphurisation of Thermal power plant Ugljevik 1, were carried out comlex engineering geological, geomechanical and hydrogeological research in order to obtain engineering geological structure of the terrain, to the depth of mutual influence between object and soil.

Terrain mapping was carried out on wider area of location, with the overview of all open natural rocks and rocks in cuts, with the aim of more detail approach to the geological structure. During mapping attention was given to separation of solid rock mass (rocky and semi rocky) from od semi bounded and unbounded (deluvial, deluvial - eluvial, proluvial, and alluvial) sediments.

Terrain research on location of facility started at the phase of conceptual solution, when were carried out seven (7) boreholes depth of around 25,0 m [1,2,3]. Moving of facility from researched location, and importance of objects, demanded detail research. Eighteen (18) new boreholes depth of around 25,0 m were carried out, and were used the results of three (3) previously done boreholes [4]. Total number of research boreholes is 19, located on characteristic places, in accordance with standards and applicable regulations, figure 1.

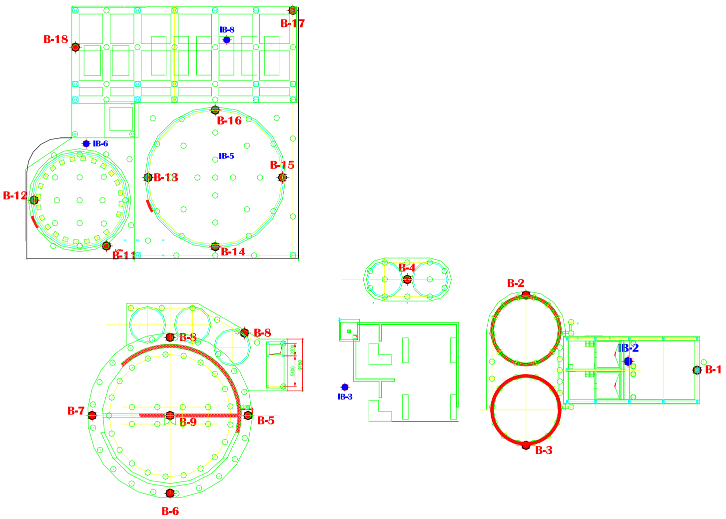

Figure 1. Location of research boreholes for facility of flue gas desulpurisation

On boreholes were carried out tests of standard dynamic penetration (SPT), were taken disturbed and undistrubed soil samples, followed occurrences and levels odf underground water, taken samples of water for chemical analysis for determination of its aggressiveness of concrete and other materials that will be embeded.
During engineering geological mappinf of borehole core was carried out detail identification and classification of drilled material, that included determination of:

- lithological composition
- cracking of rock material
- inclination, size, shape and filling of cracks
- occurrence of water leaking in cracks
- occurrence that would indicate to fault lines or fault zones, as well as other occurrences

Borehole core was photographed before engineering geological mapping and taking samples, and after. Plan of sampling was adjusted based on new data and data from surrounding works. In that way was accoplished the possibility for samples from the same lithoological member to be taken from different depths in surrounding works. This method of taking samples gives opportunity for detail interpretation of certain lithological members, by vertical subsidence and horizontal spreading [5,6,7,8]. The sampling was done in line.
All samples were taken according to standards for taking samples, their packing and transport to the laboratory. In laboratory reception of samples included:

- list of all samples with written data about borehole number, depth of takinf samples, lithological description and date of the reception,
- selection of samples according to type (soil samples and rock samples),
- selection of samples according to projected and rom the supervisory authorities required types of needed laboratory tests
- storage of all samples in special space for sample keeping for containing natural characteristics of rock mass, primarily natural humidity, structure and shape.

The standards by which the tests were carried out are the following:

Natural humidity	JUS U.B1. 012	BAS CEN ISO/TS 17892-1: 2009
Volume weight	JUS U.B1. 013	BAS CEN ISO/TS 17892-2: 2009
Specific weight	JUS U.B1. 014	BAS CEN ISO/TS 17892-3: 2009
Granulometric composition	JUS U.B1. 018	BAS CEN ISO/TS 17892-4: 2009
Consistency boundaries	JUS U.B1. 020	ASTM D4318-10
Shear strenght	JUS U.B1. 028	BAS CEN ISO/TS 17892-10: 2009
Compressibility	JUS U.B1. 032	BAS CEN ISO/TS 17892-5: 2009

Laboratory determination of uniaxial compressive rock strength	JUS B.B7.126/88
Laboratory determination of strength index of rocks in point PLT	ASTM 5731-07
Laboratory determination of impuls speen and ultrasound elastic rocks constants	ASTM D 2845-08

BASIC CHARACTERISTICS OF THE TERRAIN

Wider area of the terrain is built of sediments of Tertiary age that are the base of terrain substrate. Rocks of terrain substrate are covered with Quaternary sediments. On slopes of surrounding hills are deposited slope – deluvial and deluvial – proluvial sediments, ant in the river valleys are deposited alluvial sediments. On the whole area of researched location, alluvial sediments are covered with technogenic products – embankment material.

In vertical profile are present sediments from the oldest to the youngest:

- sediments of paleocene – eocene age (Pc,E_1), that built the biggest part of hilly terrain, west from existing complex of thermal power plant, are represented with alteration of black and dark grey marls, clays and sandstones with features of turbidites sedimentation
- sediments of lower – middle Miocene ($M_{1,2}$), represented with green and red clays, coal layer that contain a lot of mollusc shells, and with marls with ostracods and tuff clays.
- Sediments of middle Miocene (M_2^2) built hilly terrain west from subject location, and are represented with reddish conglomerates in base on which are set marls, clays and oolite limestones that are friable and sometimes breccias
- River sediments (al) that built nearsurface parts of the terrain in the valley of river Janja and stream Mezgrajica, are represented with typical development of river deposits in which lower part of the deposit are gravels and sands and in upper part is fine grained submergence deposit
- technogenic material (n) builts surface area of location, mostly represented with clayey – sandy – gravelly materials with different participation of certain fractions

Neogene basin of Ugljevik is famous for its intensive tectonics, that is determined with reseraches for the purpose of coal exploitation and with geological following of coal exploitation. Also were allocated four (4) fault lines (zones) based on previous geotechnical research, that are in immediate contact with location [9,10,11].

- three (3) faults are registered on previous researches based on material composition and state of rocks in boreholes and based on certain lithological members in listed boreholes in relation to surrounding terrain and seismic tests (Down Hole method)
- one (1) fault is assumed based on mismatching of certain lithological members with surrounding terrain, chaotically arranged fragments of sandstone that are embeded into the marl mass in some boreholes

Detail researches for the last listed fault were carried out for the determination of its position and evaluation of suitability of location for projecting and construction of future objects. Carried out were research drillings with geophysical research (Cross Hole method), taken were samples for paleontological and mineralogical - petrographic tests. Based on correlation of obtained results was carried out superposition of layers and certain elements of the fault. Results showed that fault is not seismic, and that it is not expected its influence on construction of facility.

In relation to the engineering geological features, terrain of researched location, from terrain surface to the depth of research is built from the following sediments:

- Technogenic creations – embankment (n), that spreads on the whole terrain surface of researched location, depth of 1,0 - 2,3 m. Iti is heterogenous and it has an uneven composition, built of clayey gravel and sand in which are common debris and crushed stone material. Material is well compacted.
- Unbounded and subordinate weakly bounded rocks, by genetic affiliation, respresent complex of alluvial sediments (have clayey sands with occasional clay lenses), depth of 1,0 to max 5,8 m, average around 2,5 m, according to construction norms GN200, these rocks belong to II – III group by the gravity of the excavation
- bounded, weakly stoned, subordinate solid stoned rocks of terrain substrate, are represented with marls, sandstones and conglomerates, according to construction norms GN200, rocks of terrain substrate belong to V – VII group by the gravity of the excavation

3. GEOMECHANICAL CHARACTERISTICS OF THE ROCKS

Geomechanical characteristics of mapper engineering geological units were determined with terrain research on borehole core and with laboratory tests on representative samples of certain lithological types of soil [5,7,12,13,14].

In alluvial sediments were allocated several lithological types. Those are: sandy clay (C^{S}), dusty clayey sand, (S^{C}), clayey gravelly sand ($S^{C,G}$), clayey sand with debris ($S^{C,D}$) and clayey sandy gravel ($G^{C,S.}$), figure 2.

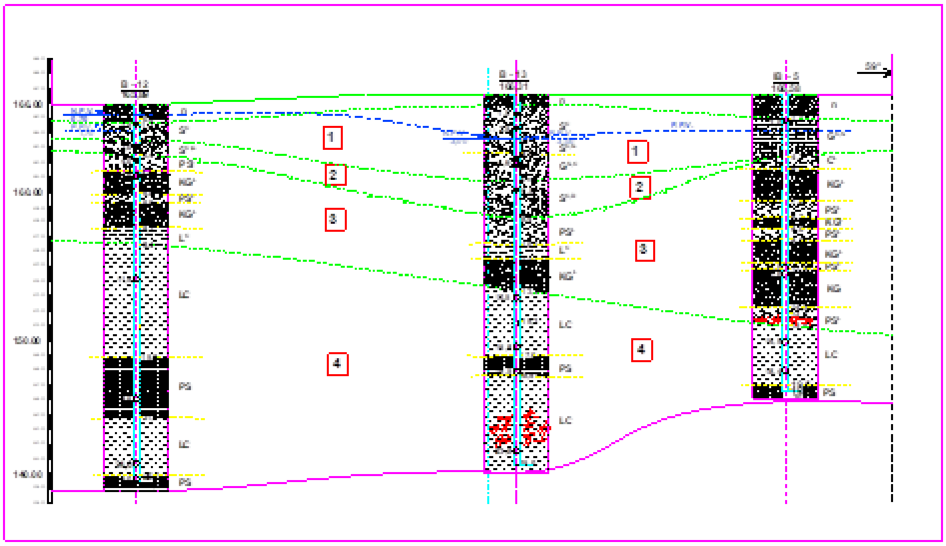

Figure 2. Engineering geological terrain profile, legned is given on figure 3

Sandy clay (CL), is a layer of small thicknes, up to 1,0 m, of uneven spreading, marked as marked as C^{S}. Clay is of low plasticity, mostly in soft or rarely consistent state, very to middle compressible. Values of basic geotechnical parameters are in the following bordesrs:

- volume weight $\gamma = 18{,}1 - 20{,}6$ kN/m³
- angle of internal friction $\varphi = 10^0 - 21{,}7^0$
- cohesion c = 16,5 – 29,9 kPa
- compressibility module $Ms_{(100-200)} = 3838 - 8333$ kPa
- permeability coefficient $k = 6{,}7 \times 10^{-7} - 1{,}4 \times 10^{-6}$ cm/s

Dusty clayey sand (SC – SF) spreads on whole location in very uneven thickness, from 0,6 m – 3,0 m, marked as S^C. Sand is fine grained, weakly compacted, little compressible, poorly to well permeable. Values of parameters are the following:

- volume weight $\gamma = 18{,}6 - 19{,}4$ kN/m³
- angle of internal friction $\varphi = 23{,}6^0$
- cohesion c = 13,8 kPa
- compressibility module $Ms_{(100-200)} = 10.982$ kPa
- permeability coefficient $k = 3{,}5 \times 10^{-6} - 2{,}3 \times 10^{-4}$ cm/s

Clayey gravelly sand (SC) spreads in the way of lenses, in very uneven thickness from 1,0 m – 2,8 m, marked as $S^{C,G}$. Shares of clayey – dusty fractions do not pass 20%. In total mass, appears also gravel with percentage share max to 30%. Sand is weakly to meddium compacted, compressible, well permeable- It has the following parameters:

- volume weight $\gamma = 17{,}8 - 18{,}5$ kN/m³
- angle of internal friction $\varphi = 25 - 28°$
- cohesion c = 10 - 15 kPa
- compressibility module Mv = 4.500 - > 20 000kPa
- permeability coefficient $k = 1{,}8 \times 10^{-3} - 2{,}9 \times 10^{-3}$ cm/s

Clayey sandy gravel (GC) builds the deepest parts of the package of alluvial sediments. It continuously spreads on the whole location and its thickness is about 1,0 do 2,5 m, marked as $G^{C,S}$. Gravel is well compacted, little compressible and well permeable. Aquifer of underground water is formed in this layes. Values of parameters are the following:

- volume weight $\gamma = 18{,}2 - 18{,}3$ kN/m³
- angle of internal friction $\varphi = 30°$
- cohesion c = 5 kPa
- compressibility module Mv > 30 000kPa
- permeability coefficient $k = 6{,}7 \times 10^{-3} - 1{,}2 \times 10^{-1}$ cm/s

Sediments of degraded – upper part of terrain substrate represent transition zone between alluvial sediments and terrain substrate. Those are sediments of crust originated with degradation of surface of paleorelief of terrain substrate. They are represented mostly with clayey sand in which are fractions of rocks with mark $S^{C,D}$, and locally appear marly clay with debris and gravel $C^{L,D}$.

Clayey sand with debris (SC – SF) is the most important part of sediments of crust of terrain substrate, $S^{C,D}$. It appears on almoust whole location, fine grained to coarse grained, well compacted. It is mostly clayeyed, and often contains fractions of sadnstone, conglomerate and marl rocks, that are unevenly places in total mass. Allocated are the following values of parameters:

- volume weight $\gamma = 17{,}3 - 20{,}4$ kN/m³
- angle of internal friction $\varphi = 28°$

- cohesion $c = 10$ kPa
- compressibility module Mv > 25 000kPa
- permeability coefficient $k = 2 \times 10^{-6} – 1{,}4 \times 10^{-1}$ cm/s

Marly clay with debris (CL) appears locally, as lenses, thickness to 2,0 m, marked as $C^{L,D}$. It ordinarily contains sand in percentage share to 47 %, as well as fractions of rocks, that in total mass are places in shappe of nest. It has the following parameters values:

- volume weight $\gamma = 19{,}7 – 20{,}5$ kN/m³
- angle of internal friction $\varphi = 16{,}1 - 21^0$
- cohesion $c = 15{,}4 – 33{,}0$ kPa
- compressibility module $Ms_{(100–200)} = 4.158 – 6.944$ kPa
- permeability coefficient $k = 2{,}1 \times 10^{-6} – 1{,}98 \times 10^{-7}$ cm/s

Sediments of terrain substrate are marls, sandstones and conglomerates. Marly clays appear as interlayer filling or in layers in cm thickness, very rare in dm. In vertical pole, state of listed rocks is significantly different, by lithological composition and by the level of disintegration and fissures. Allocated are uper and lower horizont of terrain substrate.
Upper horizont of terrain substrate consists of sandy clayey marls, marly sandstones, marly conglomerates and subordinate marly clays. Their mutual changes by depth and in horizontal spreading are common. Rocks are very cracked, devided into smaller blocks and degraded. Parameters of certain lithological members are the following:
Clayey marl (L^C)

- volume weight $\gamma = 22{,}1 – 22{,}8$ kN/m³
- angle of internal friction $\varphi = 26{,}1 – 29{,}2°$
- cohesion $c = 0{,}33 – 1{,}25$ MPa
- compressive strength $\sigma = 1{,}12 – 4{,}62$ MPa
- Poisson number $\nu = 0{,}21 – 0{,}30$

Marly sandstone ($PŠ^L$)

- volume weight $\gamma = 21{,}8 – 27{,}4$ kN/m³
- angle of internal friction $\varphi = 23{,}1 – 28{,}8°$
- cohesion $c = 0{,}11 – 0{,}66$ MPa
- compressive strength $\sigma = 0{,}68 – 2{,}33$ MPa
- Poisson number $\nu = 0{,}21 – 0{,}32$

Marly conglomerate (KG^L)

- volume weight $\gamma = 22{,}9 – 25{,}9$ kN/m³
- angle of internal friction $\varphi = 27{,}5 – 39{,}1°$
- cohesion $c = 0{,}21 – 5{,}22$ MPa
- compressive strength $\sigma = 0{,}48 – 26{,}58$ MPa
- Poisson number $\nu = 0{,}10 – 0{,}29$

Lower horizont of the substrate constists of marls and sandstones, where marsl are dominant. They are mostly compacted and the values of RQD are usually in the range between 60 and 80, and very rarely < 50. In interlayer cracks, clayes of c – dm thickness are present. Sandstones of lower horizont are fine grained, and are of carbonate and silicate binder. They do not have continuous spreading untill the researched depth, and on determined location appear in depth of average:
Marl (LC)

- volume weight $\gamma = 22{,}5 – 25{,}2$ kN/m³

- angle of internal friction $\varphi = 25 – 33{,}7°$
- cohesion $c = 0{,}10 – 0{,}81$ MPa
- compressive strength $\sigma = 0{,}59 – 4{,}42$ MPa
- Poisson number $\nu = 0{,}23 – 0{,}34$

Sandstone (PŠ)

- volume weight $\gamma = 21{,}4 – 25{,}7$ kN/m³
- angle of internal friction $\varphi = 31{,}8 – 50{,}3°$
- cohesion $c = 1{,}49 – 6{,}07$ MPa
- compressive strength $\sigma = 5{,}9 – 37{,}1$ MPa
- Poisson number $\nu = 0{,}23 – 0.32$

Parameters of resistance and deformability are determined od research boreholes with the use of Standard penetration test SPT in mealy sediments of alluvial environment and degraded and cracked sediments of substrate in the following borders:

Pjeskoviti sedimenti (pijesak prašinast, zaglinjen, šljunkovit)

- angle of internal friction $\varphi = 27{,}8 – 33°$
- compressibility module $M_v = 6100 – 14900$ MPa

Šljunkoviti sedimenti (šljunak glinovit, pjeskovit)

- angle of internal friction $\varphi = 39 – 42°$
- compressibility module $M_v = 49600 – 70000$ MPa

Addopted values of parameters for geotechnical analysis of shalow and deep foundation of Facility for flue gas desulphurisation are given in figure 3. For better evaluation of certain lithological members, allocated were four (4) geological environments based on terrain research and laboratory tests.

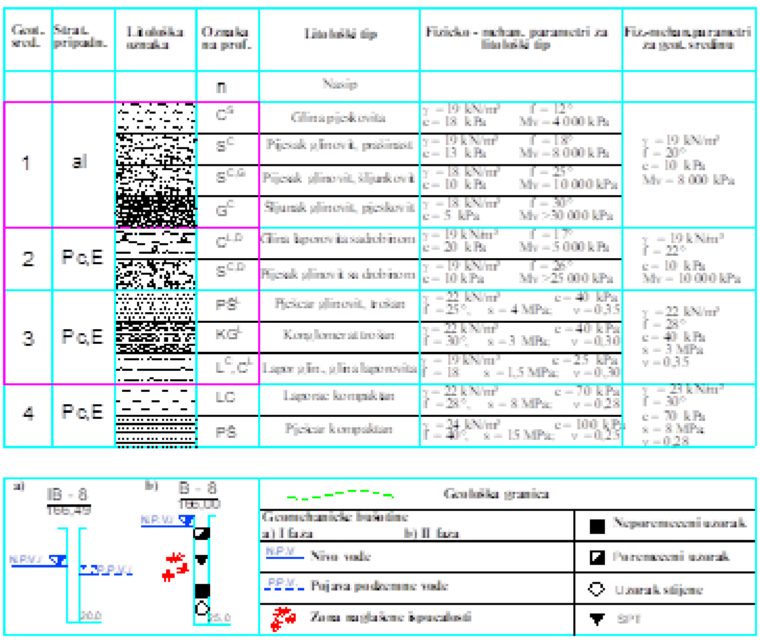

Figure 3. Allocatednical geological environments with geotechnical parameters

Parameters for every environment are chosen based on lithofacial conposition of soil and rocks, their condition in natural state, genetic afiliation and results from the laboratory [15,16,17]. For most parameters were not taken middle values, but were chosen based on the evaluation of previosly mentioned criteria.
In general terrain of location of future objects is built of unbounded, weakly bounded and well bounded rocks that according to genetics affiliation make two different complexes of soil and rocks. Allocater are as complex of alluvial sediments and complexs of rocks of terrain substrate. With the analysis of results of terrain and laboratory research and tests was determine that inside substrate rock complex exists diversity regarding composition and state of certain lithological members, then regarding their spatial distribution and mutual relation in terrain construction. That conditioned their diversity in physical – mechanical characteristis, discontinuity, hydrogeological functions and ... Precisely these differences are the base for allocating the complex of rocks substrate into three geotechnical environments (2, 3 i 4) that are significantly different among themselves and which will behave differently in the conditions of loading or unloading.

4. CONCLUSION

Facility for flue gas desulpurisation on location of today's Thermal power plant Ugljevik 1 is characterized with larger number of objects that wil be in shalow and deep foundations. For that purpose was researched terrain to the depth of about 25,0 m with aim of detail knowing of geological composition and geomechanical characteristics of the soil and rocks. Cariied out research with research boreholes with other terrain investigations and laboratory tests obtained enough data for giving reliable terrain characteristics for projecting.
In selection of parameters for projecting were not taken middle values. The parameters were observed in relation to the environment that they represent. Data of terrain research, especially engineering geological mapping of borehole core gave clearer image about the area and the character of the rocks in vertical profile.
Special meaning of data correlation is attached to the complex of terrain substrate, where are present important differences in different segments. Allocated were three (3) geotechnical environments that differ from one another, so every object foundation should be separately observed.

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ODREĐIVANJE GEOTEHNIČKIH PARAMETARA NA LOKACIJI OBJEKATA POSTROJENJA ZA ODSUMPORAVANJA DIMNIH GASOVA U TERMOELEKTRANI UGLJEVIK 1

Rezime: *Termoelektrana Ugljevik 1, građena je osamdesetih godina XX vijeka i danas radi sa punim kapacitetom. U međuvremenu je tehnološki osavremenjena, ali nije u skladu sa današnjim važećim ekološkim standardima. Tokom rada oslobađa višak čestica sumpora, koje negativno utiču na okolinu, bilo zdravlje stanovništva ili kvalitet poljoprivrednih proizvoda. U cilju osavremenjavanja rada termoelektrane i njeno dovođenje u stanje koje zadovoljava ekološke standarde, predviđena je izgradnja Postrojenja za odsumporavanja dimnih gasova.*

U okviru Postrojenja se nalazi veći broj objekata koji će zavisno od njihovog značaja biti plitko ili duboko temeljeni. Provedena su detaljna geološka istraživanja i laboratorijska ispiticanja u cilju ocjene karakteristika litoloških članova u vertikalnom profilu terena. Izdvojene su geološke sredina, a izbor parametara za svaku sredinu urađen je korelacijom podataka terenskog istraživanja i laboratorijskih ispitivanja.

Ključne riječi: *objekti, teren, geotrehnički parametri*