

CHARACTERISTICS OF THE TERRAIN AND EXISTING DEFENSIVE EMBANKMENT ALONG RIVER SAVA ON NORTHEAST PART OF TOWN SAMAC

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Summary: North town area of Samac defends itself from floods with Sava embankment, that is built during the sixties. Embankment has a dual role, on one side it defends the town from floods, and on the other side are located infrastructure and economic objects in elevation of top of embankment. On that part along the embankment route is built parapet wall which firms embankment towards river Sava, and also the other side, where are more important construction objects.

During time, embankment was damaged, and with that also the parapet wall to the extent that it was necessary to revitalize them, and some part completely renew. Damaging of embankment withdrew damaging of parapet wall, that is wavy leaning towards river Sava. Crucial damages caused catastrophic floods during May in 2014 and 2015. Conducted research of the terrain along parapet wall in embankment, gave the characteristics of existing embankment and subsoil, based on which are given propositions of new wall foundation and sanation of existing defensive embankment.

Key words: embankment, parapet wall, natural sediments

1. INTRODUCTION

Protection of town area Samac from the flooding of river Sava provides Defense embankment in which was previously built parapet wall from AB blocks, height of around 0,6 m above embankment, and foundation on depth around 1,2 m, in dusty sandy clay layer. On certain parts along the route of embankment, wall is more or less leaning towards river Sava, blocks are spaced apart or completely removed so the wall does not serve its purpose anymore.

The importance of Defence embankment and the Parapet wall demande certain research in order to evaluate the existing condition and the way of revitalization and their complete renewal on some parts. Conducted were research works with boreholes and trial pits on length of embankment route 956,44 m. Purpose of research was to define geotechnical characteristics of natural sediments that make subsoil to existing embankment, as well as technogenic material in embankment. Also were determined depths of foundation, width

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of foundation foot of existing parapet wall, characteristics of embankment from aspect of slope stability, and load capacity and subsidence of soil under the load of parapet wall.

2. CONDUCTED RESEARCH ON THE TERRAIN

In corridor route of Defense embankment along river Sava, length around 1000 m and width of around 50 m, depending from the terrain configuration and spatial position of natural and created occurrences, detail engineering geological mapping of the terrain was conducted. Because of terrain coverage with residential and business objects and embankments of technogenic origin usually with mapping was not possible to identify the lithological construction of terrain surface, so with prospection of wider area were overviewed basic geological characteristics: Coast of river Sava depending from the water level in relation to defense embankment is differently distant. In summer is from 50,0 – 100,0 m, which indicates a small inclination of terrain surface towards the river. On that area, river often floods, brings, puts and takes away material, creating different relief forms changeable in time function. For more detail identification of lithological construction of natural sediments were studied geological characteristics of wider area. Special attention was paid to monitoring of geomorphological process occurrences and their relation with geological structure. Processed were characteristics of surface flows, lithological members that appear on terrain surface, terrain liability to development of modern geological processes, hydrogeological characteristics of sediments with defining aquifers basic elements [1]. Locations for drilling along the embankment route were chosen, in relation to expected negative geological impact, during sanation of Parapet wall and embankment. Researched embankment route is evenly covered with research works [2]. 9 boreholes depth of 8,0 – 9,0 m and 11 trial pits depth to 1,8 m, deepest to 1,0 – 1,5 m were conducted. From boreholes were taken enough number of undisturbed and disturbed samples from different depths, so every environment is covered with samples. Laboratory testings were done in accordance with valid JUS U.B1. and BAS standards, based on which were defined physical – mechanical characteristics of soil on location of researched terrain [2,3,4]. Parallely with drilling were conducted tests of standard penetration (SPT). They were conducted in unbounded and poorly bounded sediments, in total 24 tests. Occurrence and water level during drilling and after it in period of performing of research works were monitored orderly.

Depth of foundation of existing Parapet wall in planum of Defense embankment along river Sava, width of foundation foot and type of material in within is founded, were determined during making of trial pits. Trial pits were made manually with small gabarits in vertical projection for the possibility of deterioration of condition in which Parapet wall was after catastrophic floods. Parallely with digging was conducted detail mapping of open profiles of trial pit walls, and were taken samples from every trial pit.

3. RESEARCH RESULTS

According to geomorfological characteristics wider area belongs to alluvial terraced plane of river Sava, with heights from 86 - 88 masl, figure 1. Terrain has a very slight drop in

direction north – northeast. There are no expressed geomorfological forms in way of terraced section of flood basin riverbed of Sava that spreads immediately to north edge of Defense embankment. Smaller delevellings of the terrain are noted in inundation riverbed that appear on the surface as smaller or greater sags, depth of 1,00 - 2,0 m, in places masked with wild dumps of municipal waste. Delevellings of the terrain are a product of natural and technogenic factors.

Narrower area presents end north parts of mentioned plateau on which along the edge of inundation riverbed of Sava river is laid Defense embankment with Parapet wall in planum of embankment.

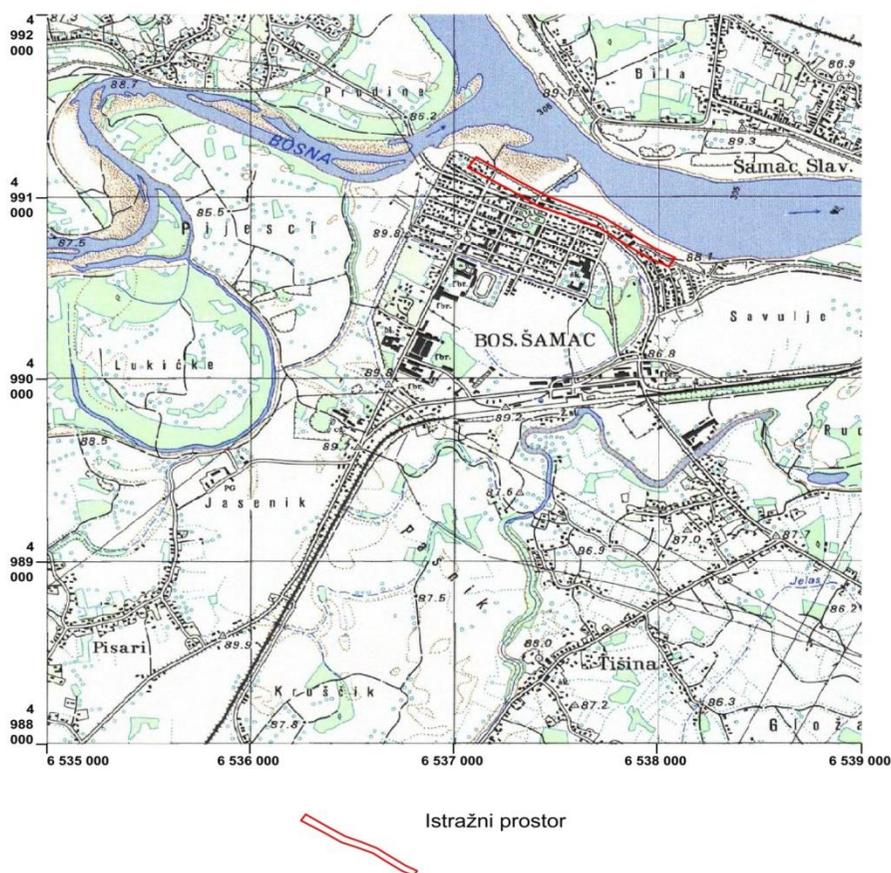


Figure 1. Topographic base wider area of Samac, R 1 : 25 000

Basic hydrographic characteristics of the terrain is its belonging to river Sava confluence, that flows on north edge of researched location, and of river Bosna, that flows in immediate proximity of west edge of researched location. In this flow gravitate all periodically natural and technogenic flows, atmospheric water precipitates and underground waters.

According to Basic geological map sheet Slavonski Brod R 1:100.000, and its Interpreter [5] on terrain surface of narrower area of researched location were allocated Quaternary sediments within which were are:

- Sediments of flood area that have wide distribution, ie are spreaded along right coast of river Sava where they have greater distribution and cover terraced sediments [6]. Flood percipitations consist of fine clastic deposits in which dominate sands, silts and clayey sands. Depth of these deposits does not exceed 5,00 m.
- Alluvial deposits are presented with alluvial deposit of river Sava with fine grained and middle grained sand, silt and gravel, which are deposited in riverbed and on coasts without steep sections.

In structure of terrain of Defense embankment participate deposits of natural materials and materials of technogenic origin. Natural materials are present in sediments of alluvial deposits connected with river watercourses. Materials of technogenic origin are registered in immediate location and present materials built into the hull of Defense embankment and Parapet wall in embankment planum. Structure of terrain in profile of embankment is determined based on results of detail research that included geological mapping of the terrain and investigative geomechanical works, and is shown on transverse profile, figure 2.

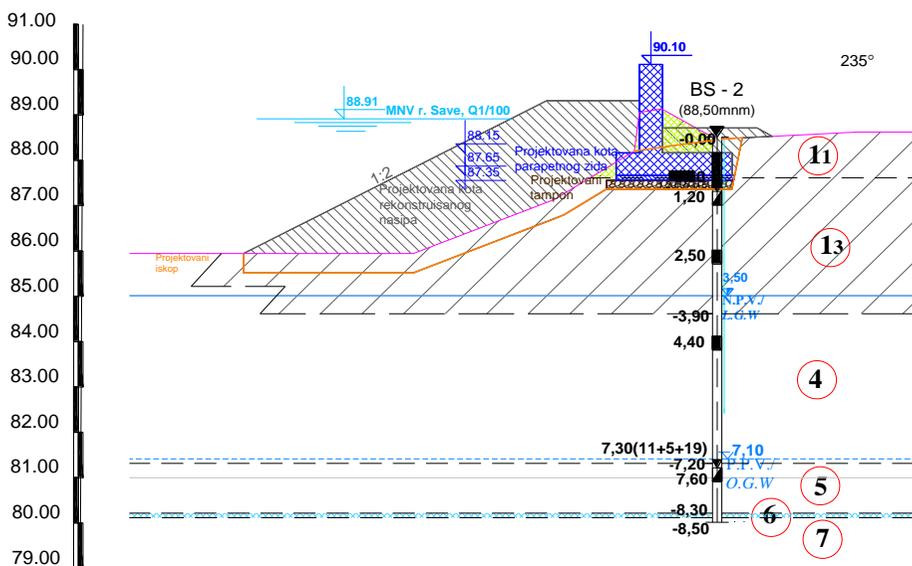


Figure 2. Transversal terrain profile on part of Defense embankment and Parapet wall
 1. embankment – clayey gravelly, 1.3. embankment – dusty sandy clay 4. sand,
 5. sandy clay, 6. sand, 7. sandy gravel

Natural sediments that are the subsoil of defense embankment are sandy gravel, sand middle grained to coarse grained, in places gravelly, sandy clay and dusty sandy clay. Materials of technogenic origin are registered in Parapet wall and in hull of Defense

embankment along the river Sava. Body of embankment does not have uniform structure referring to embedded material layers. Layers are from different materials, they have changeable thickness with frequent changes in vertical pillar and lateral alternation along embankment route. In embankment hull were embedded clayey gravel with fractions of construction debris in near surface horizons, sandy dusty gravel, dusty sandy clay and dusty sand.

In terrain where is laid route of Defense embankment in sandy gravelly layer is formed compacted aquifer of open type, that has hydraulic connection with surface flows. In aquifer roof are clayey layers with more stable water permeability that decrease infiltration of water participate from terrain surface. Mightiness of water bearing layers in not determined, is of regional spatial spreading, and coefficient of filtration by USBR goes from $k = \alpha \cdot 10^{-1}$ to $k = \alpha \cdot 10^{-3}$ cm/sec.

In corridor of embankment and in its wider area, are not present natural limitations for object construction, except erosion process of north slope and in foot of embankment as well as process of suffusion (wash out of fine grained fraction) in periods of oscillation of river water level [7]. Artificial limitations are connected to before built infrastructures, residential and economy objects, on almost along entire embankment route.

4. GEOMECHANICAL CHARACTERISTICS OF TECHNOGENIC MATERIALS AND NATURAL SOIL

In layers defined with terrain research works samples were taken for laboratory tests. Geomechanical characteristics with display of limit values of parameters are given for technogenic materials and natural sediments.

Materials of technogenic origin are embedded in embankment hull, whose position and mightiness in vertical profile along researched route differ. Embedded were layers: clayey gravel (1₁), sandy gravel (1₂), dusty sandy clay (1₃) and dusty sand (1₄). Parameter values allocated for geotechnical calculations are given in table 1.

Table 1. Adopted parameters for sediments of technogenic origin

Sediments	Parameters			
	γ (kN/m ³)	φ^0	c (kN/m ²)	Ms (kN/m ²)
Technogenic materials				
Clayey gravel (1 ₁)	19,1	30*	-	30 000*
Sandy gravel (1 ₂)	18,8	36*	-	35 000*
Dusty sandy clay (1 ₃)	18,1	19	32	4000 ₍₀₋₁₀₀₎
Dusty sand (1 ₄)	18,7	33*	-	10 000*

* values obtained from SPT-a

Clayey gravel (1₁) is located along embankment route in several horizons, represents mix of sandy gravel and clay. Sandy gravel (1₂) is located also in several horizons, while dusty sandy clay (1₃) has the biggest participation in structure of embankment hull, and dusty sand (1₄) is embedded in foot part of embankment and is of small mightiness and distribution.

Natural sediments make embankment subsoil. Allocated are the following sediments of different mightiness: dusty muddy clay, dusty clay, dust, sandy clay, sand and sandy gravel. Values of adopted parameters for geotechnical calculations are given in table 2. They refer to whole route in general, and for some profiles along embankment route can be taken parameters from investigative boreholes, which are more representative, considering that all allocated layers in table 2, do not exist along the entire route of embankment [1,6,8].

Table 2. *Adopted parameters for natural sediments*

Sediments	Parameters			
	γ (kN/m ³)	φ^0	c (kN/m ²)	M_s (kN/m ²)
Natural				
Dusty muddy clay	18,4	14	46	5000 ₍₀₋₁₀₀₎
Sandy clay	18,6	17	38	3500 ₍₀₋₁₀₀₎
Dust	18,8	21	34	2000 ₍₀₋₁₀₀₎
Sandy clay	18,5	22	30	2500 ₍₀₋₁₀₀₎
Sand	19,7	32	-	11000*
Sandy gravel	18,9	40*	-	50 000*

* vrijednosti dobivene iz SPT-a

Dusty muddy clay forms a layer registered in immediate embankment subsoil, ie near surface part of natural terrain. Dusty clay, forms a layer of changeable mightiness, ie it is a clay – dusty material with participation of fine sand fraction. Dust forms a layer of small mightiness, about 0,50 m, and appears occasionally as lens.

Sandy clay is a layer of changeable mightiness that is not equally present along researched embankment route. It contains a high percentage of fine grained, sandy fractions, is of soft consistency, low plasticity, gray to yellow brown color.

Sand is located in shelf of clay layers, is of different mightiness and distribution. On some parts of the embankment route is not determined its final depth. Sandy gravel, fine grained to coarse grained, makes a subsoil of terrain along the embankment route, whose final depth is not registered in research works.

5. POSSIBILITIES OF EMBANKMENT UPGRADING AND CONSTRUCTION OF NEW PARAPET WALL

Conducted terrain research and laboratory tests gave enough parameters needed for analysis of stability of existing embankment [1,3,4,5]. Analysis were conducted on profiles of investigative boreholes with aim to include whole embankment route considering its changeable characteristics at presence of technogenic and natural materials. Analysis were done by Bishop method [9,10,11,12,13,14]. Minimal safety coefficient on sliding goes from 4,2 - 6,5.

Safety factors for sliding are relatively high, which is a result of consolidation of embankment, built during the sixties. Over time consolidation of embankment resulted

with higher value of cohesion in dusty sandy clay layers (I_3) embedded in embankment hull and in layer of autohtone soil that is built of dusty, muddy clay, of high plasticity, through which by calculation pass critical sliding surfaces.

Existing parapet wall will be removed and a new wall on the same depth with other characteristics will be founded. Calculations of permitted soil load under foundation of newly projected parapet wall were done with Brinch – Hansen method on more characteristic profiles [9,12,15,16]. For foundation depth of 2,5 m and foundation foot of 2,0 m permitted values of soil load goes from 224,0 - 262,0 kN/m². Prognosis calculations of consolidated subsidence of soil under the foundations of the newly projected parapet wall gave values in permitted limits, 0,7 - 2,4 cm.

6. CONCLUSION

Defense embankment that protects the town area of Samac from river Sava, during years have been damaged because of poor maintenance, and also frequent increases of water levels that impair its stability. In embankment was built parapet wall from AB blocks, which is damaged to the extent that it cannot be sanitized, so a new one has to be built. With construction will also be built an embankment up to level of centennial maximum rainfall, and height of the wall will be 0,8 m above the embankment.

Evaluation of existing condition of embankment is given based on conducted research works on terrain and laboratory testing of samples from embankment and natural sediments. Materials from the embankment are of technogenic origin and consist of clayey gravel with fractions of constructive debris in near surface horizons, sandy, dusty gravel and dusty sand. Natural sediments make a subsoil of embankment where alternate layers of different mightiness from dusty muddy clay, dusty clay, sandy clay, sand and sandy gravel. Research results shown that defense embankment and parapet wall were damaged over time, but embankment is still well consolidated and is of favorable characteristics for construction of newly projected embankment. Conducted stability analysis showed that minimal safety coefficient on sliding is favorable and is in limits from 4,2 - 6,5. Also, load of newly projected parapet wall will not create larger subsidence from permitted.

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KARAKTERISTIKE TERENA I POSTOJEĆEG ODBRAMBENOG NASIPA DUŽ RIJEKE SAVE NA SJEVERNOM DIJELU GRADSKOG NASELJA ŠAMAC

Rezime: Sjeverno gradsko područje Šamca od poplava se brani savskim nasipom koji je izgrađen šezdesetih godina. Nasip ima dvostruku ulogu, sa jedne strane brani grad od poplava, a sa druge strane se nalaze infrastrukturni i privredni objekti u nivou kote vrha nasipa. Na tom dijelu duž trase nasipa izgrađen je parapetni zid koji učvršćuje nasip prema rijeci Savi, ali i drugu stranu gdje su značajniji građevinski objekti. Verući je nasip oštećen, a time i parapetni zid do te mjere da je neophodno uraditi njihovu revitalizaciju, a u nekim dijelovima i potpunu obnovu. Oštećenja nasipa su za sobom povukla i oštećenje Parapetnog zida, koji je talasasto naget u pravcu rijeke Save. Presudna oštećenja su izazvale katastrofalne poplave tokom mjeseca maja 2014 i 2015. godine. Provedena istraživanja terena duž trase parapetnog zida u nasipu, dala su karakteristike postojećeg nasipa i podtla, na osnovu kojih su dati prijedlozi temeljenja novog zida i sanacija postojećeg odbrambenog nasipa.

Ključne riječi: nasip, parapetni zid, prirodni sedimenti