15th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2011, Prague, Czech Republic, 12-18 September 2011

CONSTRUCTION OF EMBANKMENT DAM "DIVKOVIĆI" BY USING SLAG AND ASH FROM A POWER PLANT TUZLA

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ABSTRACT
In order to build a landfill of slag and ash for the Tuzla power plant an embankment dam was designed and constructed whose body is made up of previously deposited slag and ash. In this way, for the first time, the built dam bounds space for the deposition of new quantities of slag and ash, and provide space for approximately 1,500,000.00 m3 of new quantities of deposited slag.
The total length of the dam is 2000 m, while the width of the dam in the crown is 4.40 m. The body of the dam was designed and built from slag and ash, with the use of geotextile and clayey sand as a protective layer over the dam body. Overflow structure is of reinforced concrete in the form of overflow manhole with the application of reinforced concrete piles from one side.
Conducted field and laboratory testing established the physical and mechanical properties of slag, and volume weight, vertical and horizontal water permeability, the angle of internal friction and moisture, which represent the necessary characteristics of a material for the calculation of embankment dam.
Key Words: embankment dam, slag, clayey sand, geotextile, slope stability.

1. PROJECT DESIGN
Projected width of the dam in the crown is 4.40 m, with an elevation of downstream slope of 1:4 and 1:3 of water slope. The width of a dam at the dam-foot is 35.90 m, while the maximum dam height is 4.40 m. Simultaneously with the construction of dam, downstream slope is coated with geotextile $g=300.00\ g/m^2$ and performs the protection by clayey-sandy material with thickness of 50 cm. The task of geotextile is to prevent the removal of fine particles of slag and ash from the dam body.
Each layer embedded in the body of the dam is horizontally outspread in the longitudinal direction, and in lateral direction each layer has a tilt of 2-3% toward the outer edge. Each layer is tamped in full width where the compaction is performed from the end towards the middle. The thickness of the layers is up to 30 cm. Due to the stability of the dam, the drainage mat in the width of 8.00 m and thickness 0.50 m is placed at the dam-foot from the downstream side.

Drainage mat is made up of granulated gravel, both sides coated with geotextile g=300.00 g/m^2. The task of the drainage mat is to reduce the hydrostatic and hydrodynamic pressure on the embankment dam and to decrease the seepage line in the body of the dam.

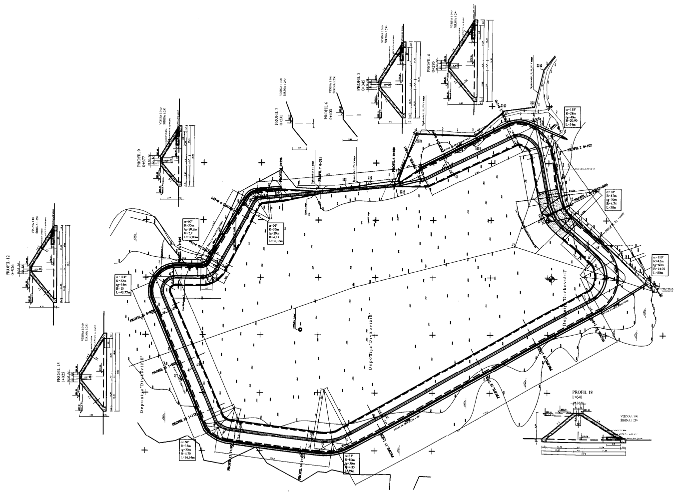

Figure 1. The dam situation

Previously prepared surface of drainage mat is covered by appropriate geotextile, and then a drainage material in the layer of 50 cm, and eventually made its compaction by vibrating rollers of less weight. Final surface drainage mat should be leveled to the accuracy of ± 3 cm.

2. CHARACTERISTICS OF SLAG AND ASH

Ash and slag, based on laboratory tests conducted, consisting mainly of small gray or white particles sizes from 0.06 to 2.00 mm. Based on the texture mark it is the fine sand, which amount ranges from 86.56 to 96.08%. The content of powder (particle from 0.06 to 0.002 mm) and clay (particle < 0.002 mm) is very small and ranges at an average of 1-4%. The size of volume weight is from 0.52 to 0.96 g/cm^2, while the quantity of volume density is from 1.73 to 2.36 g/cm^3.

At the first appearance slag and ash are the same and uniform material, but the values of specific weights are relatively variable because of the heterogenity of coal and combustion conditions. For the purpose of the necessary input data for making the project design, standard and modified Proctor's experiments were made, laboratory testing of volume weight were performed, as well as the horizontal and vertical water permeability, shear, moisture content and angle of internal friction, so we got the picture of slag and ash properties and the possibility of their incorporation into the body of the dam. In fact, based on the above analysis, the natural moisture content is 47.11% to 77.4%, while the volume weight ranges from 13.11 to 14.33 kN/m^3.

The angle of internal friction varies from 30.2^o to 30.8^o. By field and laboratory experiments we obtained results of compaction at optimum moisture content which ranged from 35.2% to 46.80%, while the module of compressibility at the final layer during construction was 30 MPa. Based on the obtained data, the construction company is ordered, according to the design project, to perform the filling of the dam body in layers up to 30cm, and with moisture, which must be around 45%.

3. DAM FOUNDATION

The body of the dam relies on previously deposited ash and slag, while the sides of embankment dam are based on autochthon material. On the part where dam rests on previously deposited slag and ash, it is projected that the body of the dam must be buried 50cm into the foundation, while the eastern part of the dam relies on the cover which was represented by plastic clay at a depth of 80cm, with the eventual replacement of poor subsoil, and plans for the treatment of subsoil with compaction and stepped cutting at the higher slopes of the terrain.

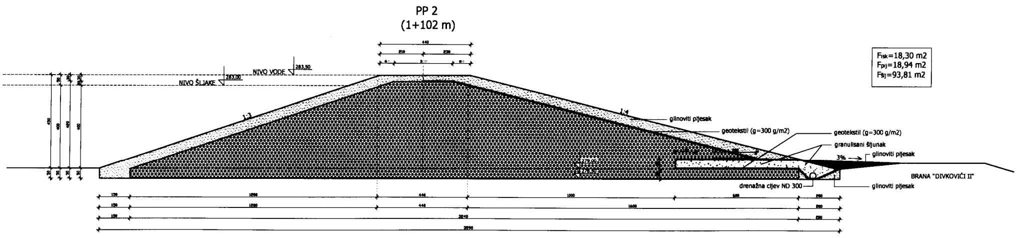

Figure 2. Characteristic cross-section of the dam

4. SURFACE DRAINAGE AND SPILLWAY STRUCTURES

The segment canals were designed and constructed in the existing slag and ash. Canals are built on the west and north side, and their task is possible drainage of seepage water from the drainage mat.

The width of canals is 2.50 m, depth 0.50 to 0.70 m and away from the edge of the dam 2.00 m.

Spillway structure is made by reinforced concrete and it was built as a spillway manhole which is based on the layer of gravel d = 20cm. Spillway structure in its cross-section represents an open rectangular reinforced concrete frame with the walls thickness of 40cm.

One side of the spillway shaft was filled with reinforced concrete piles. The base plate of spillway shaft is made of reinforced concrete and its size is 40cm, while the top plate is also made of reinforced concrete with thickness of 20cm.

Enabling the flow of water to the spillway shaft was designed and carried out by using reinforced concrete wings, while the drainage of water from the spillway shaft was planned and constructed by using the concrete pipes ϕ1000mm.

5. FLOW OF WATER THROUGH THE DAM BODY

Describing the flow of water through a porous medium is calculated with the differential equation in the form:

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial \overline{u}}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial \overline{u}}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial \overline{u}}{\partial z}\right) = 0 \qquad \text{... (1)}$$

Kx, Ky and Kz are the permeability coefficients in the directions of axes x, y and z.

$\overline{u} = \frac{u}{\gamma_w} + z$ represents the height of water or the potential,

u – pore pressure

γ_w – volumetric weight of water

z – elevation

For isotropic soil the equation can be written in the following format:

$$\nabla^2 \overline{u} = 0 \qquad \text{... (2)}$$

where ∇^2 is Laplas operator, respectively: $\nabla^2 \equiv \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ ... (3)

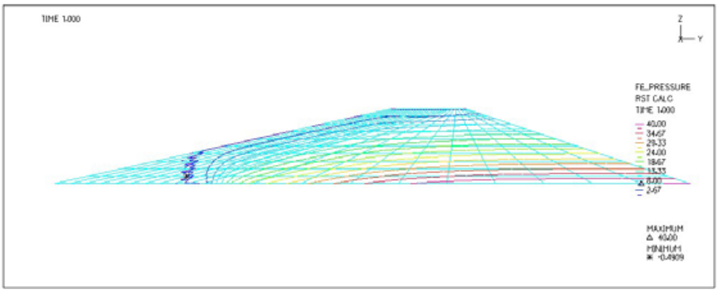

Figure 3. Equipotential lines

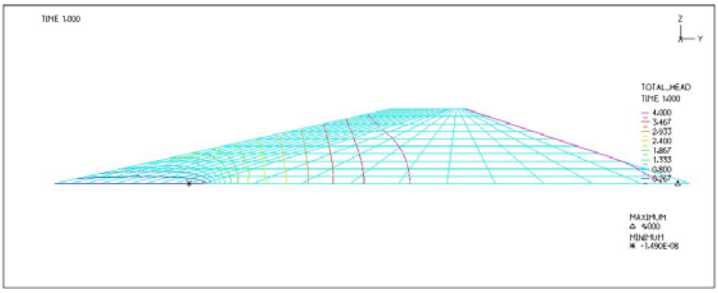

Figure 4. Tension lines

Afore-mentioned results of calculation are given with equipotential lines and tensions in the network of finite elements.

6. SLOPES STABILITY OF THE DAM BODY

Stability calculation was performed for the dam with the height of 4.50 m whose downstream slope is 1:4 and slope of the upstream side 1:3. Calculation of slope stability was performed using the Morgenstern-Price methods of calculation, with the values of obtained safety factors given in the table.

Table 1. The values of parameters and safety factor

	γ (kN/m^3)	c (kN/m$^{2)}$	φ (^{o})	Water level	Fs
1	14.3	0	30.2	max.	1.51
2	14.3	0	32	max.	1.55
3	14.3	0	32	max.	1.55

7. REFERENCES

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