SUSTAINABLE EXTRACTION AND PROCESSING OF RAW MATERIALS

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CONTENTS

SEISMIC EXPLORATIONS FOR DEFINING THE DAMAGE TO THE EARTH DAM PISHICA IN THE REPUBLIC OF NORTH MACEDONIA

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ABSTRACT. The reservoir was built in the middle of the 20th century with a total capacity of 750,000 m^3. The height of the dam from the river terrace is 22 m, the length of the crown is 319 m, and the width of the crown is 6 m. Due to the low resistance of the earth dam and the increase of water level due to heavy rains, the lake has leaked on several occasions, causing floods and environmental disaster in the surrounding settlements. Due to heavy rains and overflow through the dam crown, damage to the downstream slope of the dam has occurred and the overall stability of the dam has been compromised. By controlled discharge of the reservoir it is brought to a stable state and the dam breakage is prevented. At the beginning of 2013, the outflow valves of the dam were opened as a result of heavy rains, with reservoir water flowing to more places and residents of the village and livestock evacuated. At the crown of the dam where there was the largest outflow of water, a gap of about 20 m wide and 3.5-4 m thick appeared. Geophysical - seismic surveys have been conducted to determine dam damage.

Keywords: dam, seismic, reflection, refraction, damage

Introduction

The geophysical seismic surveys were conducted according to the Geotechnical Surveys Programme for the repair of the damaged dam, appropriately supplemented with a number of reflective profiles in order to obtain the best possible results for the construction of the dam.

The research was performed using shallow seismic refractive and reflective profiling, with the following purpose:

- Lithophysical breakdown of the body structure and the geological basis of the dam according to values of seismic Vp and Vs velocities;
- Characterisation of the lithophysical media of the terrain and the embedded materials in the body of the dam with values of elastic, dynamic and geotechnical parameters based on the obtained values of seismic velocities;
- Perception of the occurred deformations of the dam and its physical mechanical condition;
- Defining the dynamic characteristics of the dam for the needs of the analysis of its seismic stability. (Slimak, 1996)

The 24-channel ABEM "TERRALOC SEISMIC SYSTEM - MARK 6" (Sweden) was used for the field research, and the ReflexW computer programme was used for the processing and interpretation of the data.

On the basis of the data from engineering-geological and geomechanical research it is obtained that:

- The terrain at the geological base of the dam is composed of andesite tuffs (θ’) which are cracked to decomposed on the surface and in fault zones, and in depth are weakly cracked to compact (θ).
- The body of the dam is composed of sediments (N) represented by dusty sandy clays with the presence of organic matter and carbonates. The dam is homogeneous , with a drainage prism in the base of the downstream slope, without a built-in filter layer of sand and gravel in the body and with a built-in concrete overflow part on the right side. (Delipetrov, 2003)

Seismic explorations

Seismic explorations are performed using refraction and reflection profiles, arranged according to the purpose of the research.

The refraction profiles are made continuously along the entire length of the dam crown, perpendicular to the upstream and downstream slope near borehole D-4, perpendicular to the upstream and downstream slope in the damaged part of the dam and in the upper part of the upstream slope on the right side. A total of 5 refraction profiles (RF-1 to RF-5) with an overalllength of 530 m were constructed. With these studies, a depth of about 25 m has been achieved and the body of the dam, the geological base of the dam and the parts of the sides of the dam under the access roads are covered.

The reflective profiles are also performed continuously along the entire length (except in the damaged part) along the middle of the crown and perpendicular to the upstream and downstream slopes in the damaged part of the dam. A total of 2 reflective profiles with an overall length of 300 m were performed. These surveys cover the body of the dam and the geological base to a depth of about 100 m.

The arrangement of the refractive (RF) and reflective (RL) profiles is shown at the base of the dam (Fig. 1).

The refractive profiles are performed with an arrangement of the geophones at a distance of 5 m from each other, and the seismic waves are excited by 10 kg hammer blows at every 30 m.

The reflective profiles are performed with a geophonic layout of 5 m and with an excitation step of 5 m on the profile RL-1 and 2.5 m on the profile RL - 2. For recording the seismic waves, vertical geophones of 14 Hz are used.

Interpretation of refractive profiles

The interpretation is performed using the P and S wave hodohrones, from which the following parameters are determined:

- The values of Vp and Vs seismic velocities of the embedded materials in the dam body and the geological basis;
- Physical - mechanical and dynamic characteristics of the embedded materials in the dam and the geological basis according to the values of the seismic Vp and Vs velocities.

The physical and geological interpretation is shown in the refractive profiles of Figure 1, Figure 2 and Figure 3. It is shown using the P-wave ray paths, except for Figure 2, which also shows the interpretation with S-wave ray path.

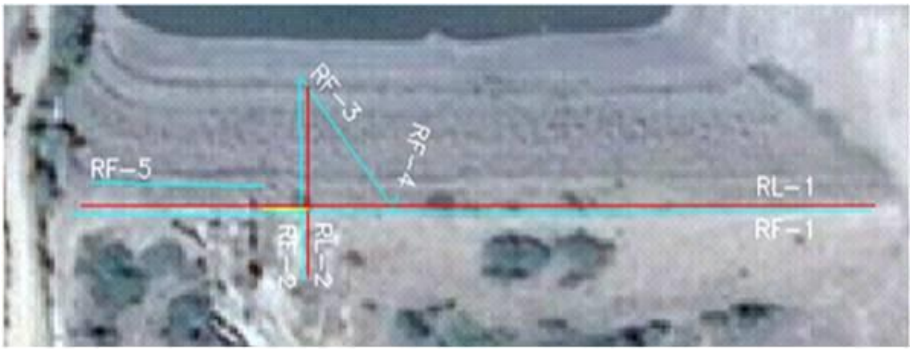


Fig. 1. Refractive (RF) and reflective (RL) profiles along and transverse from the dam crown

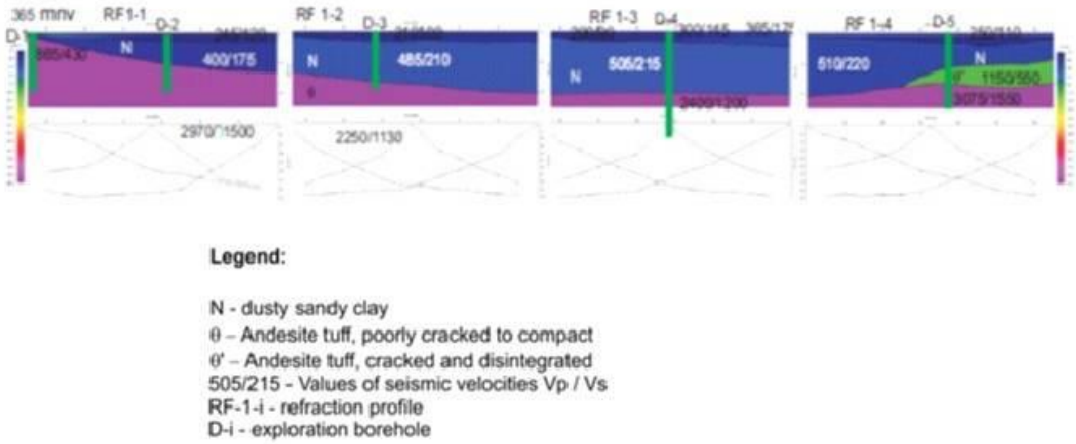


Fig. 2. Seismic refractive profile RF-1 with interpretation

The following frame and mean (in parentheses) values of the seismic velocities Vp and Vs of the embedded materials in the dam and its geological basis have been registered with these surveys:

In the body of the dam:

- The embankment (dusty sandy clay) in the surface part under the crown of the dam with a thickness of 1.0 - 2.0 m is characterised by values of Vp = 200 - 365 (265) m/s and Vs = 90 - 175 (115) m/s;
- The embankment (dusty sandy clay) in the surface part of the slopes of the dam with a thickness of 1.0 –3.0 m is characterised by values of Vp = 170 - 270 (220) m/s and Vs = 80 - 125 (100) m/s;
- The embankment (dusty sandy clay) in the deeper parts of the dam's body with a depth of 10 m on the sides up to 23 m in the deepest part of the riverbed is characterised by Vp = 400 - 565 (500) m/s and Vs = 175 - 250 (215) m/s;
- In the basement of the dam slopes are registered higher values of Vp and Vs (Vp = 600 - 1400 m/s and Vs = 280 - 700 m/s) than the same in the embankment in the body. These values can refer to the geological environment at the base, and to the downstream slope and to the materials of the supporting prism.

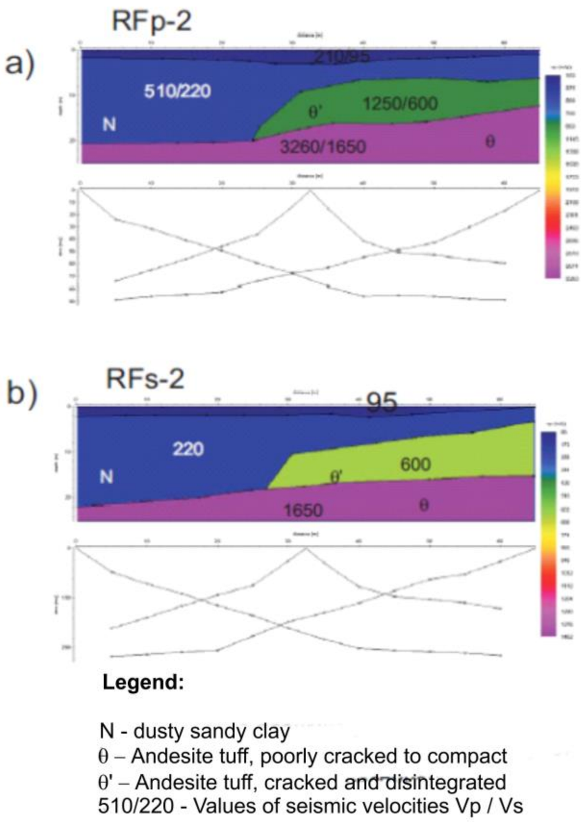
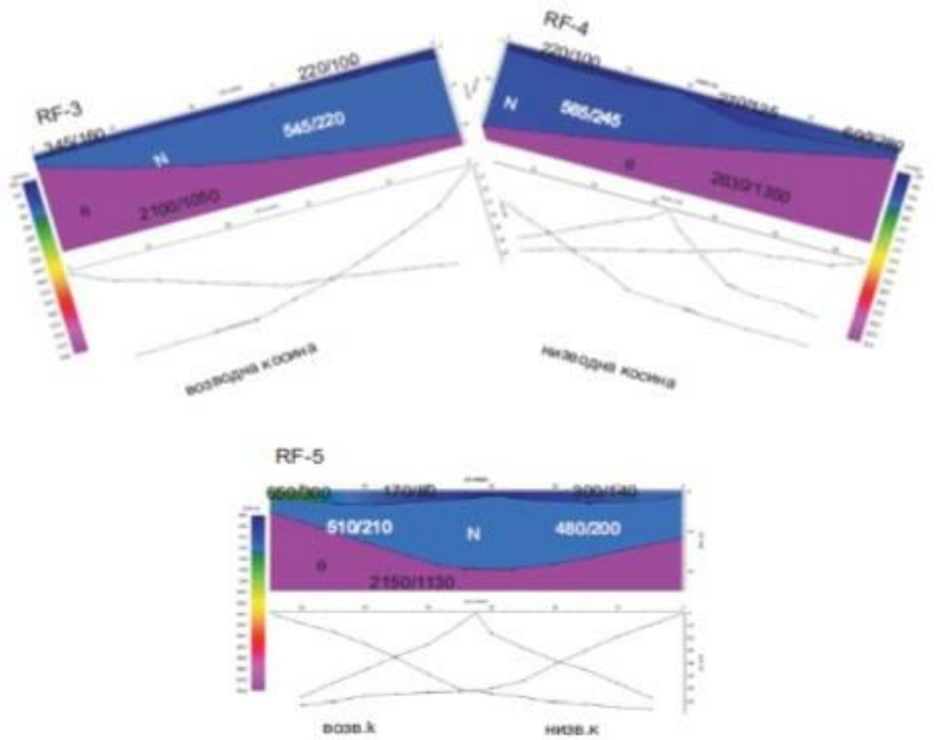


Fig. 3. Seismic refraction profile RF-2 with interpretation a) with P-wave raypaths b) with S-wave raypaths

In the geological basement:

- Alluvial sediments represented by fine sand, gravelly to dusty, in places clayey;
- Andesite tuffs, cracked and decomposed on the surface, registered on the sides of the dam, on the surface or under the embankment to a depth of 5 -15 m with values of Vp = 865 - 1250 (1100) m/s and Vs = 430 - 600 (525) m/s;
- Andesite tuffs, cracked and fragmented within the fault zones to weakly cracked and compact, located at the base of the dam at a depth greater than 10 m, with values of Vp = 2100 - 3250 (2650) m/s and Vs = 1050 - 1650 (1350) m/s;

The values of the seismic velocities in the part of the damaged embankment of the dam are of the same order of magnitude as in the other parts of the body. They indicate that the weakened parts of the embankment have been washed away by the water.



Legend:

N - dusty sandy clay
θ – Andesite tuff, poorly cracked to compact
510/210 - Values of seismic velocities Vp / Vs

Fig. 4. Seismic refraction profile along the slopes of the dam RF-3, RF-4, RF-5 with interpretation

The observed variation of the values of the seismic velocities of the embankment in the body of the dam is a consequence of the uneven compaction of the embedded materials and the changes of the geostatic load which depends on the height and geometric characteristics of the dam (Dragasevic, 1983).

Interpretation of reflective profiles

By interpretation are determined:

- the contact boundary between the embankment embedded in the body of the dam and the geological base,
- information on the achieved compaction of materials in the body of the dam,
- tectonic disturbances and dislocations (faults) in the geological basis.

The obtained results are shown on Figure 5 which shows the interpretation of the reflective profiles RL-1 and RL-2.

The contact boundary between the body of the dam and the geological base is drawn along the longitudinal axis of the dam (along the crown) of the reflective profile RL-1 and along the cross section in the damaged part of the dam on the reflective profile RL - 2. These surveys determine the height of the dam along its entire length. The withdrawn border was also ascertained with the exploration boreholes.

Tectonic faults and crushed zones have been detected in the geological basis of the dam. Along the dam 7 additional locations have been interpreted. Their directions are approximately determined based on the geomorphological characteristics of the terrain. In the zones of these faults in the geological basis lower values of seismic velocities (25-30%) than the obtained velocities in compact tuffs and significantly smaller amplitudes of reflective waves are measured. However, these dislocations are self-indicating and cannot be classified. To determine them, it is necessary to perform parallel reflective profiles on a wider area of the dam site and other appropriate geo-research methods. (Jakosky, 1963)

The interpreted faults are shown on the reflective profiles RL - 1 and RL - 2 (Figure 5).

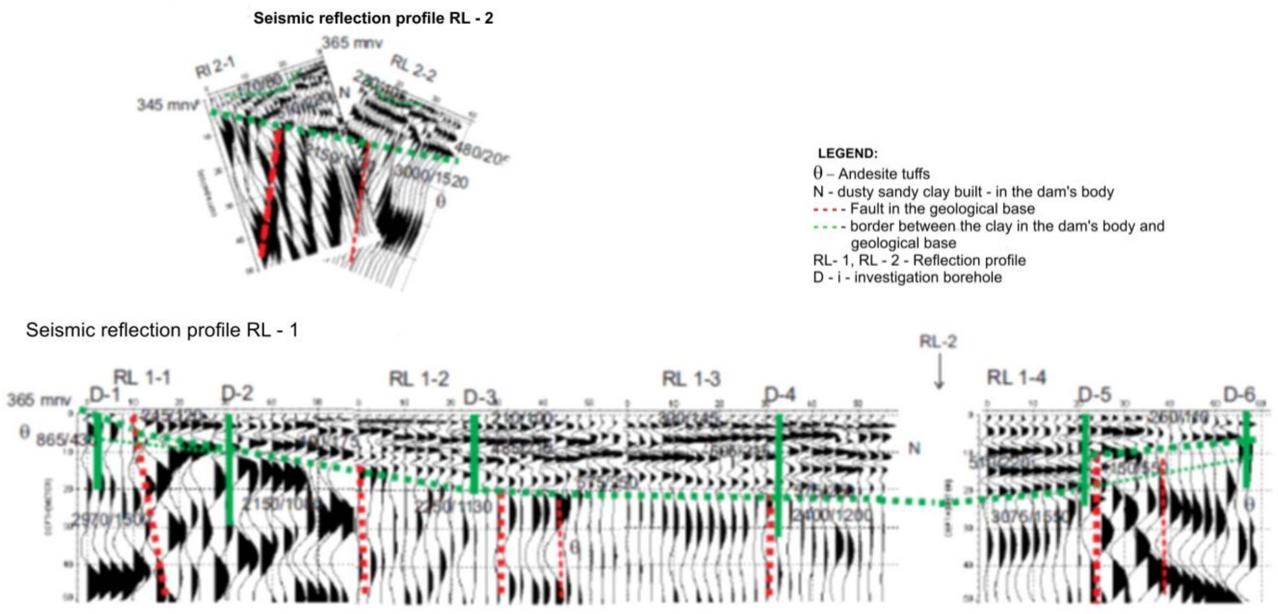


Fig. 5. Seismic reflective profile RL-1 and RL-2 with interpretation

Conclusion

From the conducted research and obtained data from the seismic reflection and refraction measurements, the following can be concluded:

- The engineering - geological and geomechanical research show that the terrain at the geological base of the dam is composed of andesite tuffs and the body of the dam is composed of sediments represented by dusty sandy clay with the presence of organic matter and carbonates;
- Seismic explorations were performed with refraction and reflection profiles, arranged according to the purpose of the research;
- The following results are obtained by means of the refractive profiles:
  a) in the surface parts of the embankment, the mean values of waves velocity are Vp = 220 – 265 m/s and Vs = 100 – 115 m/s;
  b) in the deeper parts of the dam's body, the mean values are Vp = 500 m/s and Vs = 215 m/s;
  c) in the basement of the dam slopes higher values of seismic waves Vp = 600 - 1400 m/s and Vs = 280 - 700 m/s were registered than the same in the embankment in the body. These values can refer to the geological environment at the base, and to the downstream slope and to the materials of the supporting prism.
- The values of the seismic velocities in the part of the damaged embankment of the dam are of the same order of magnitude as in the other parts of the body. They indicate that the weakened parts of the embankment have been washed away by the water.
- By interpretation of the reflective profiles the contact boundary was determined between the embankment embedded in the body of the dam and the geological base and tectonic faults and crushed zones;
- In the zones of the faults in the geological basis lower values of seismic velocities (25-30%) are measured than the obtained velocities in compact tuffs and significantly smaller amplitudes of reflective waves.

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