https://dx.doi.org/10.22161/ijreh.3.1.6 ISSN: 2456-8678

The Modeling of dams' Stability Considering a Seismic Solicitation for the Tailings Ponds

Banu Diana Maria[1], Obreja Ana Maria[1,2], Radu Aura Daniela[1]

[1]Research and Development National Institute for Metals and Radioactive Resources, Carol I Blvd, no.70, District 2, Bucharest, Romania

Email: banudianamaria@yahoo.com

[2] University of Bucharest, Faculty of Geology and Geophysics, Department of Engineering Geology, Traian Vuia Street, no.6, Bucharest, Romania

Abstract— *The activities associated to the mining industry are a major source of risk to the environment, but especially for the local community. In Romania, mining of precious metals (gold, silver and copper) have changed the landscape permanently, having a profound impact both locally and regionally. To determine the behavior of the material inside the tailings ponds dams in case of a major seismic event, two ponds were chosen as study cases, both belonging to Rosia Montana mining region: Valea Salistei tailings pond and Gura Rosiei tailings pond. Rosia Montana mining region is one of the most important Romanian mining regions is the Golden Quadrilateral of the Apuseni Mountains, which it delivered over time significant quantities of nonferrous metals, especially gold and silver. For the two study cases the dams' stability was evaluated by classical methods (analytical and numerical), each method using two hypothesis: static and pseudo-static (seismic). The aim of the study is to monitoring the values of the safety factors when the dams of the tailings ponds are affected by an major seismic event and to observe the potential sliding surfaces through the dam's body, the shear deformations distribution and the total displacements and distribution from the resulted graphics on two random sections chosen for each of the case studies.*

***Keywords*— environment monitoring, seismic, tailing pond, stability**.

I. INTRODUCTION

The activities associated to the mining industry are a major source of risk to the environment, but especially for the local community. In Romania, mining of precious metals (gold, silver and copper) have changed the landscape permanently, having a profound impact both locally and regionally. One of the most important Romanian mining regions is the Golden Quadrilateral of the Apuseni Mountains, which it delivered over time significant quantities of nonferrous metals, especially gold and silver. The Golden Quadrilateral includes mines in Rosia Montana - Bucium, Baia de Aries, Almas - Stanija and Brad - Sacaramb.

II. THEORETICAL

This study will focus on the two tailings ponds belonging to the Rosia Montana mining. The Rosia Montana mining exploitation is within the administrative territory of Rosia Montana locality, at the confluence of creek Red and river Abrud and it incorporates the following mining objectives: the process plant situated at Gura Rosia, two tailing ponds (Gura Rosia and Valea Salistei), 2 mining quarries (Cetate and Calnic) and 17 waste dumps [7].

Until 2006, when the exploitation works were closed, the mining works were made at surface in Cetate pit and the ore processing was made at the Gura Rosie Processing Plant. The flotation tailings resulting from the gold and silver ore processing processes were deposited in Valea Salistei and Gura Rosiei tailings ponds.

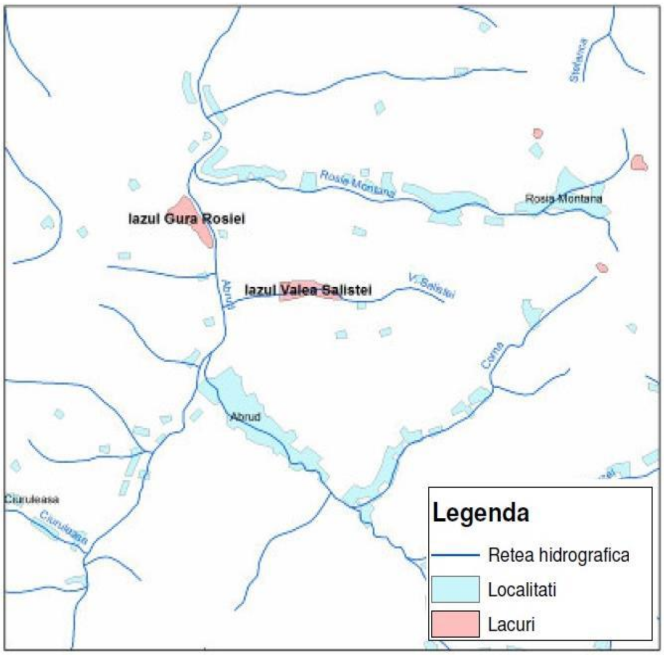

Fig. 1. The location of the two tailings ponds of Rosia Montana Mining Exploitation [3]

https://dx.doi.org/10.22161/ijreh.3.1.6 *ISSN: 2456-8678*

The two tailings ponds are located in the western side of the Aries middle basin, on the left bank of Abrud River (Gura Rosiei tailings pond) and on the Saliste creek valley (Valea Salistei tailings pond) [1]. Together they cover an area of 40ha and store a volume of 3.4 million m^3 sterile [7].

Valea Salistei tailings pond is an upstream valley impoundment with minor gullies and ravines located on the slope. Gura Rosiei tailings pond is currently preserved and kept as a spare in case of an accident at the Valea Salistei pond. On the pond's slope, can be observed profound erosional processes, landslides and ravines [6].

According to the results of qualitative risk analysis, the risks associated with mining, even after their closure, are moderate or high. The high risk scenarios include dumps slide and tailing ponds failure. The high value is given in particular by the consequences of the production of such a scenario on local communities and on the environment.

To prevent these types of accidents it requires continuous monitoring of the waste dumps and tailings dams for early identification of any irregularity that allowed an appropriate and timely intervention [2].

In order to assess the risks associated to the structural stabilities of the Rosia Montana tailing ponds, it was used a risk matrix that take into account the risk generating processes, to which have been established the risk degree indicators and the risk classes assessment scale.

Centralized results of the matrix risk assessment have framed the studied tailings ponds at a level of "extreme" risk for Valea Salistei and "high" risk for Gura Rosiei (tabel 1). The "extreme" risk level assigned to Valea Salistei tailings pond was justified by its proximity to the community and by the interdependencies between the affected environmental's elements, both leading to maximum values of the risk indicators [7].

Table 1. Centralized results of the risk matrix assessment [7]

Tailings pond	Risk indicators					Specific risk	Risk level
	1	2	3	4	5		
Valea Salistei	4	4	4	4	4	64	extreme
Gura Rosiei	4	4	4	4	2	62	high

The risk degrees were analyzed according to the following risk indicators: the impacts severity (existing or potential), magnitude (relative to space and number of affected people), the persistence of impacts (relative to time), cumulative and synergistic effects, the impacts probability [5].

III. EXPERIMENTAL

That risk levels classification has determined the election in this paper of the two tailings ponds as study cases in order to calculate their dams stability at seismic solicitations. For each of them, the stability calculation (determination of the safety factor) was conducted both by analytical and numerical methods and consider two hypothesis static and pseudo-static conditions (when the zone seismic magnitude intervenes).

In seismic terms, the studied perimeter is framed to a horizontal acceleration value Ks = 0,08 and a corner period Tc = 0,7sec [4].

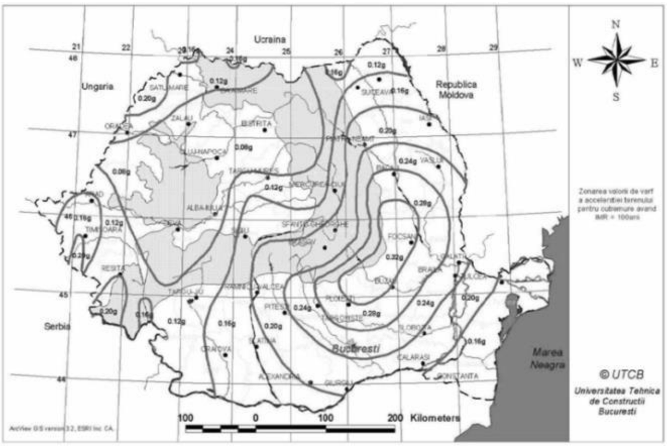

Fig. 2. Maximum values of the design horizontal acceleration [4]

Fig. 3. Maximum values of the corner period [4]

The stability calculations were performed during the monitoring period, after the closure and rehabilitation of the tailings ponds (October 2010): leveling of the external side of the slopes, creating of a drainage system at the base of the slopes, covering of the external slopes with geo-materials and further, with a topsoil layer (Gura Rosiei tailings pond), equalization of the berm on the slope's right side (Valea Salistei tailings pond).

In this paper, the stability calculations were performed on the geotechnical sections illustrated in the two figures below.

Fig. 4. The geotechnical section - Gura Rosiei tailings pond

Fig. 5. The geotechnical section - Valea Salistei tailings pond

The computations executed for assessment of the dams' overall stability took into consideration the piezometric measurements performed for the monitoring of the hydrostatic level oscillation inside the dam's body.

Two scenarios were considered, static and pseudo-static (dynamic / seismic) assumptions. The depression curves used in the computations were calibrated using the piezometric measurements of the hydrostatic levels.

The initial calculation was analyzed by analytical method - Bishop, static analysis that satisfy both static equilibrium of forces and static equilibrium of moments, using Slide Rocscience software version 5. For comparison, the numerical finite element method (SSR - Shear Strength Reduction) was applied, analysis known as the reducing of shear parameters, using Phase Rocscience software version 6.

The analysis was conducted for a number of 5000 sliding surfaces per computation, divided into 25 strips, with convergence of 0,001 and the maximum number of iterations of 50.

IV. RESULTS AND DISCUSSION

The results of stability computations obtained by analytical and numerical methods calculated assuming the two scenarios are illustrated in table 2.

To study the tailings pond's dam behavior in case of earthquake, we represented graphic, by comparing of the two hypothesis, the potential sliding surfaces through the dam's body, the shear deformations distribution and the total displacements distribution.

Table 2. The results of stability computations for the two study cases

	Gura Rosiei tailings pond			
Method	analytical (Bishop)		numerical (finite element - SSR)	
Hypothesis	static	pseudo-static	static	pseudo-static
Safety factor	1.719	1.372	1.69	1.3
	Valea Salistei tailings pond			
Method	analytical (Bishop)		numerical (finite element - SSR)	
Hypothesis	static	pseudo-static	static	pseudo-static
Safety factor	1.566	1.159	1.54	1.14

4.1. Gura Rosiei tailing pond

Table 3. The geotechnical parameters used for the calculation section

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface	Hu Type	Ru
Dep_nisipos		15.79	Mohr-Coulomb	10	33	Water Surface	Constant	
Dep_nisip_prafos		15.79	Mohr-Coulomb	20	30	Water Surface	Constant	
Dig amorsare		19.62	Mohr-Coulomb	0	35	Water Surface	Constant	
Dep_terasa		17.66	Mohr-Coulomb	10	35	Water Surface	Constant	
Masiv		20	Mohr-Coulomb	30	18	None		0

https://dx.doi.org/10.22161/ijreh.3.1.6 *ISSN: 2456-8678*

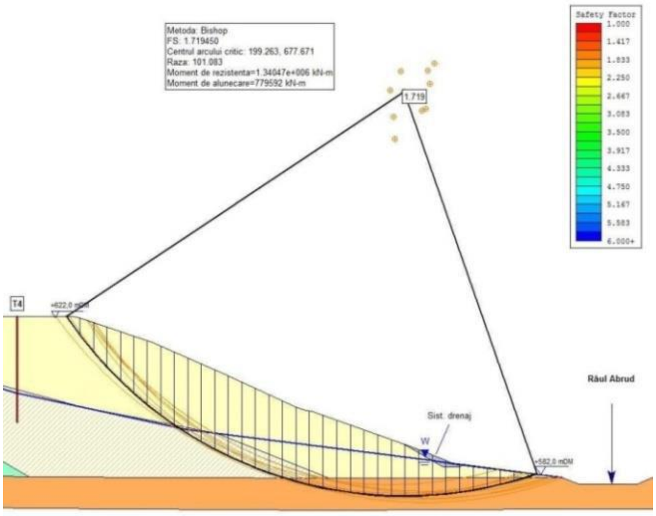

Fig. 6. The potential sliding surfaces through the dam's body - Bishop method. Static hypothesis Fs = 1719

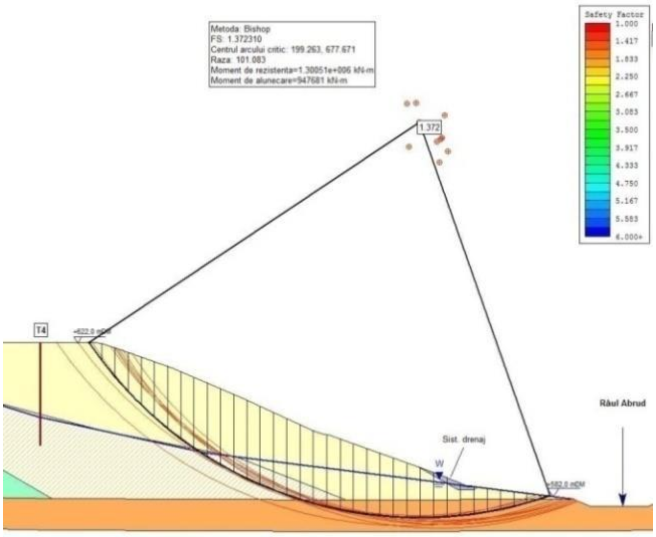

Fig. 7. The potential sliding surfaces through the dam's body - Bishop method. Pseudo-static hypothesis Fs = 1.372

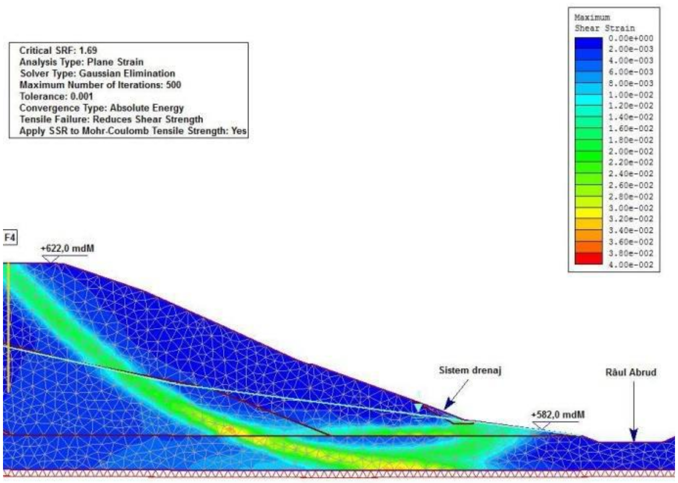

Fig. 8. The shear deformations distribution - SSR finit element method. Static hypothesis Fs = 1.69

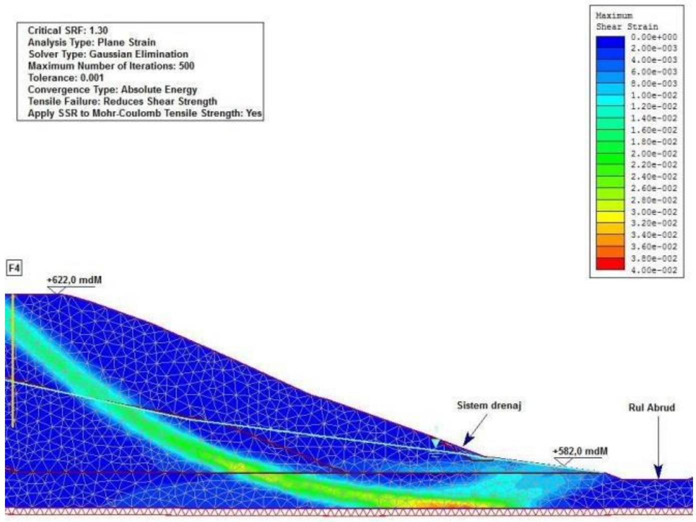

Fig. 9. The shear deformations distribution - SSR finit element metho). Pseudo-static hypothesis Fs = 1.30

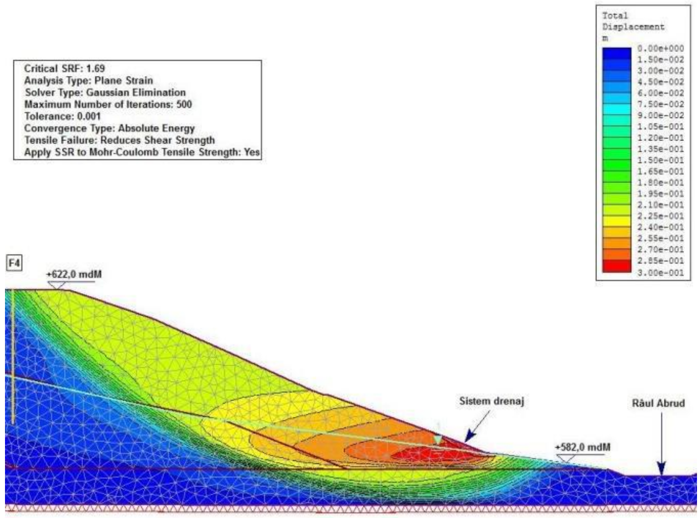

Fig.10. The total displacements distribution - SSR finit element method. Static hypothesis, Fs=1.69

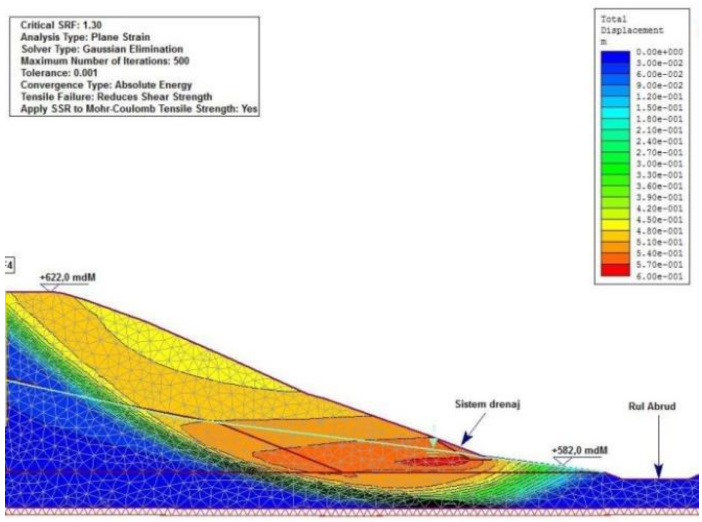

Fig.11. The total displacements distribution - SSR finit element method. Pseudo-static hypothesis, Fs=1.30

4.2. Valea Salistei tailings pond

Material Name	Color	Unit Weight (kN/m3)	Sat. Unit Weight (kN/m3)	Strength Type	Cohesion (kN/m2)	Phi	Water Surface	Hu Type	Ru
Teren		16.7	17.5	Mohr-Coulomb	49	16	None		0
Dig amorsare		18.6	19.53	Mohr-Coulomb	0	36	Water Surface	Constant	
Depozit iaz		15.1	15.86	Mohr-Coulomb	1.96	28	Water Surface	Constant	
Filtru		18	18.9	Mohr-Coulomb	0	30	Water Surface	Constant	
Prism lestare		18	18.9	Mohr-Coulomb	0	35	None		0

Tabel 4. The geotechnical parameters used for the calculation section

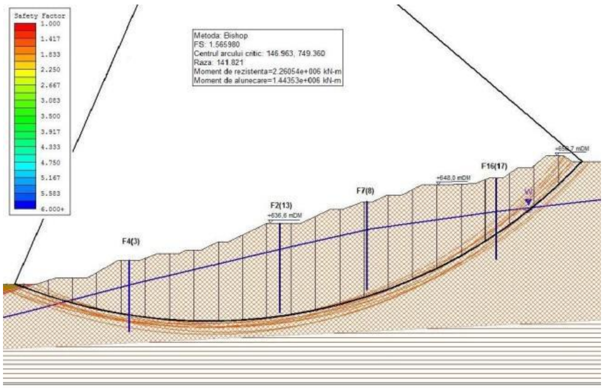

Fig. 12. The potential sliding surfaces through the dam's body - Bishop method. Static hypothesis, Fs = 1,566

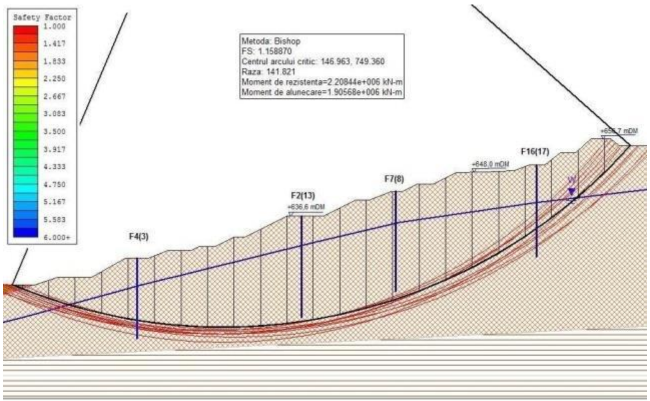

Fig. 13. The potential sliding surfaces through the dam's body - Bishop method. Pseudo-static hypothesis, Fs = 1,159

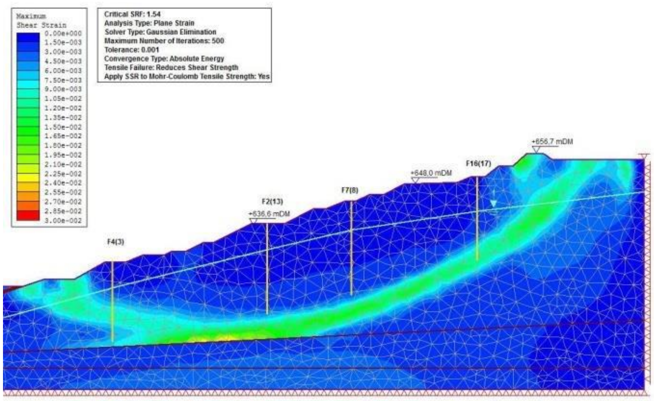

Fig. 14. The shear deformations distribution - SSR finit element method. Static hypothesis, Fs=1.54

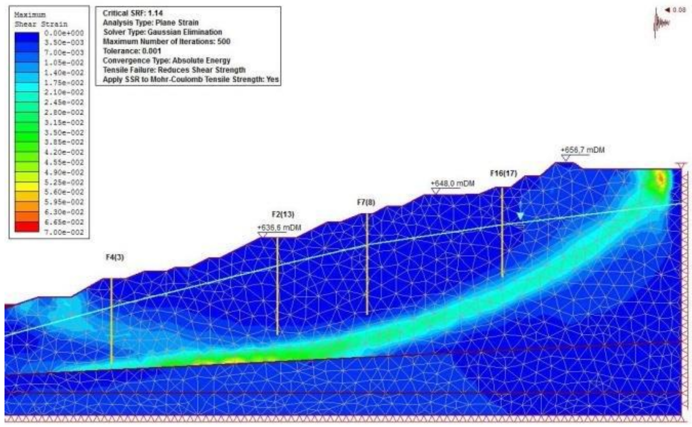

Fig. 15. The shear deformations distribution - SSR finit element method. Pseudo-static hypothesis, Fs=1.14

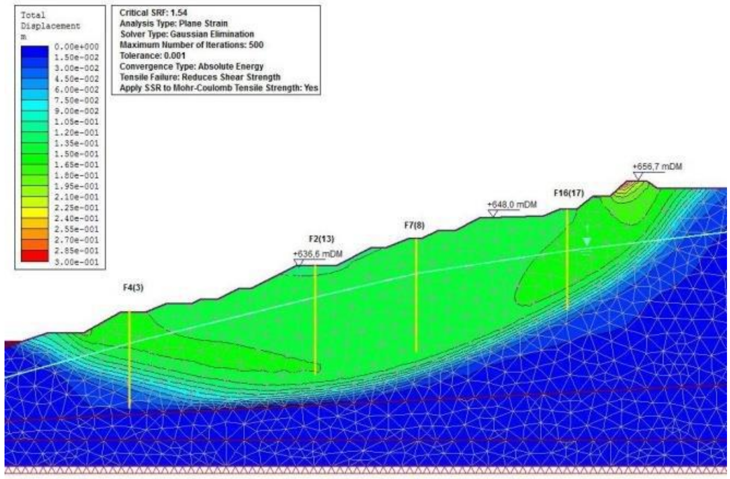

Fig. 16. The total displacements distribution - SSR finit element method. Static hypothesis, Fs=1.54

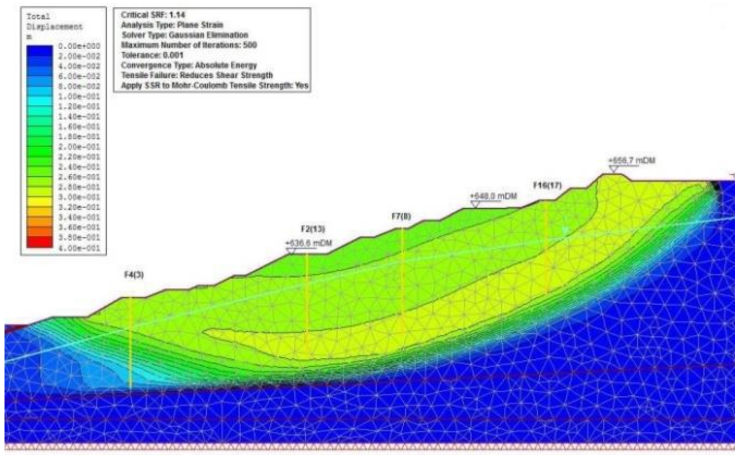

Fig. 17. The total displacements distribution - SSR finit element method. Pseudo-static hypothesis, Fs=1.14

V. CONCLUSIONS

The stability calculation for dams of the two tailings ponds was done on sections perpendicular to the exterior slope (Gura Rosiei tailings pond), respectively perpendicular to the retention dam (Valea Salistei tailings pond).

The data obtained from the monitoring of curve depression level do not exceed the alarm and attention levels.

The stability assessment was realised presuming two hypotheses, static and pseudo-static (the second one consider the seismic loading for the gradient zone, according to Normative P100-1, 2006).

For a better characterization of the sliding phenomenon kinematics, at the assessment of the dams' stability it was also applied the finite element method, which allows the evaluation of total displacements magnitude, that quantizes the emergence and development of the collapse phenomenon.

From graphs, it can be concluded that the safety factors values are covering for both hydro technical constructions. These values are within safety boundaries imposed by regulations in force, both static and pseuso-static assumptions.

Assuming pseudo static hypothesis, the safety factor values for the calculation profile are centered on values higher than 1.1 irrespective of the method chosen, which indicates a geomechanic balance inside the tailings ponds' body when it presume an earthquake with the area intensity.

It recommended the monitoring of the realized stabilization works and the periodic tracking of the hydrostatic level oscillations in the existing piezometers network in order to prevent any risk that may intervene, including the seismic factor.

REFERENCES

[1] Botezan C, Ozunu A, Stefanie H "Vulnerability assessment: the case of the Aries river middle basin", Journal of Environmental Protection and Ecology 16, No 4, 2015, pp 1326–1336

[2] Costan C "Natural and technologic risks in the Arieş river middle basin. Vulnerability reduction of the local communities (thesis)." Faculty of Environmental Sciences - Babes Bolyai University, Cluj-Napoca, Romania, 2010

[3] Costan C, Ozunu A, Mihaiescu R, Gututui A, Petrescu I "Technologic risks and vulnerability reduction in the Aries river basin", Regional IAG/AIG Conference on Geomorphology, Landslides, Floods and Global Environmental Change in Mountain Regions, Brasov, Romania, 2008

[4] Normative P100-1/2006: "Seismic Design Code P100 – Part I: Design provisions for buildings"

[5] Mihăiescu R, Muntean OL, Vescan I, Floca L, Ferencik I "The matrix assessment of environmental risks in the lower basin of the Aries river basin", Environment & Progress, vol. 1, EFES Publishing House, Cluj-Napoca, 2003, pp 325 – 330

[6] Muntean OL, Rus R, Surdeanu V "Anthropic landscape of the mining region Abrud – Rosia Montana", Universitatis Babeş-Bolyai, Geographia 43, 1998, pp 23–27

[7] Stefanescu L, Costan C, Ozunu A "Risks Associated to structural stability of tailing dams in the Arieş middle basin", ProEnvironment 3, 2010, pp 414 - 423