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USE OF TAILINGS ASHES IN ROAD EMBANKMENT STRUCTURES

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ABSTRACT

Road embankments requires processing of a large amounts of materials, therefore there is currently an effort to find a suitable replacement for traditionally used materials. One option is using some solid combustion products from coal (ashes), which production and subsequent disposal in the impoundments continues to grow [1].

Keywords: Ash, Embankment, Settlement

I. INTRODUCTION

The largest amounts of waste material are in our region produced by energy production (thermal plants and heating plants). It is a waste of mineral origin – cinder, ash from coal and coke, fly ash and dust. In our region are mostly incinerated less valuable solid fuels (lignit and brown coal dust with heat value of about 2500kcal/kg). Compared to more valuable black coal dust (with heat value of 5800kcal/kg) is the amount of fuel required for produce a unit of electricity in our country about double. This even results in greater waste production. With continuous growing production of waste products increase problems with their landfilling [2]. In connection with growing production of waste deposited on tailings impoundments would be beneficial to use these materials secondarily.

Figure 1: Deposition meander of ash impoundment in Zemianske Kostoľany

The resulting mixture of ash deposited on tailings impoundment consists of [2]:

- cinder, which is after the falling down from the hoppers of boiler installations milled - milled particles are mostly of larger dimensions,
- fly ash, which falls down from the separators.

Ashes thus can be divided into coarse-grained with dominant sand particles and fine-grained ashes with dominant silty particles. Size distribution of ashes is documented on Fig. 2.

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a) dry samples b) wet samples

Figure 2: Coarse-grained and fine-grained samples of ashes [3]

II. PROPERTIES OF ASHES DEPOSITED ON THE IMPOUNDMENT IN CONNECTION WITH THEIR USE IN EMBANKMENTS OF TRAFFIC ENGINEERING

Alternative materials must show the same or better geomechanical properties than traditional, in order to road structure pursuance of the all the prescribed requirements. Assessment of suitability of using ashes in embankments of road constructions was carried out according to the criteria in Slovak (or Czech) technical standards and technical and qualitative terms (further just TKP) of the Ministry of transport, construction and regional development of Slovak republic (further just MDVRR).

2.1 Requirements (criteria) of suitability using ashes in road embankments constructions

A) TKP MDVRR part 2 Earthworks for embankments from ashes states following [4]:

„Ash used in embankments cannot contain more than 3% particles like wood, organic waste atc., or more than 5% of organic components. For the construction of the embankment body can be used dry fly and ash taken from power plants and impoundments, but must be mined over the water level. The proposal is effective especially in case of embankment foundation on weak subsoil (less weight of embankment).

B) According to Slovak technical standard STN 73 6133 are soils suitable for the soil embankments if [5]:

1) have a continuous grading curve and are well grained,
2) have missing or stable clay and silty particles (recommended fine-grained content of f_{max}=50%),
3) are with small amount of compaction work well compactable to high unit weights (ρ_{dmax}=1500kg.m^{-3}),
4) are not frost susceptible,
5) have very good permeability.

2.2 Assessment of suitability using ashes in road embankments constructions

To assess the suitability, the representative grading curves of coarse-grained (blue grading curve) and fine-grained (green grading curve) ash indicated on Fig. 3 were used. The red line shows the boundary between fine-grained and coarse-grained ash. Classification of fine-grained ash to class F5-F8 is only based on grain size distribution. Determination of consistency limits for these materials are not feasible.

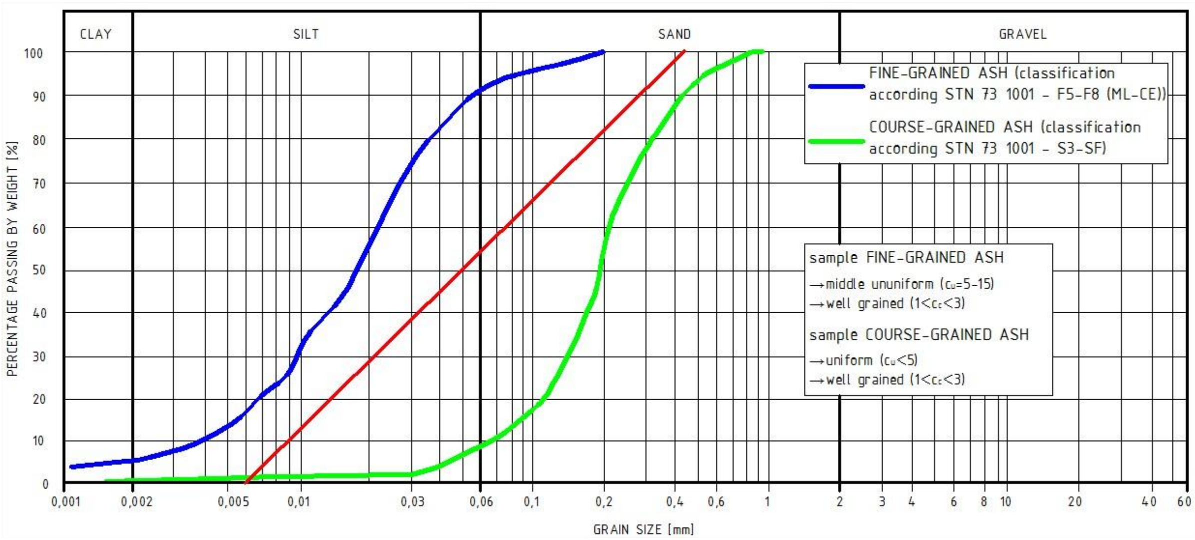

Figure 3: Grain size distributions of representative samples of fine and coarse-grained ash [3]

1) Criterion of continuous grading curve and good grain is satisfied in both types of representative samples of ashes: **fine-grained ash is ok, coarse-grained ash is not**.
2) Ratio of fine particles is in case of coarse-grained ash f = 10 %, in case of fine-grained ash f = 90 %: **fine-grained ash is not satisfactory, coarse-grained ash is ok.**
3) Compactability parameters expressed by dry unit weight and optimal moisture can be found in Fig. 4 and Fig. 5.

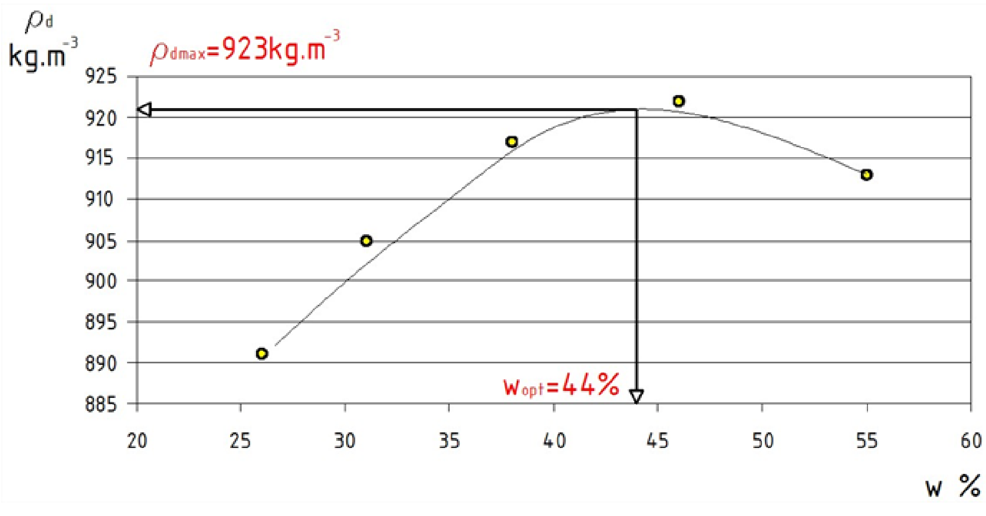

Figure 4: Compactability parameters of fine-grained ash [3]

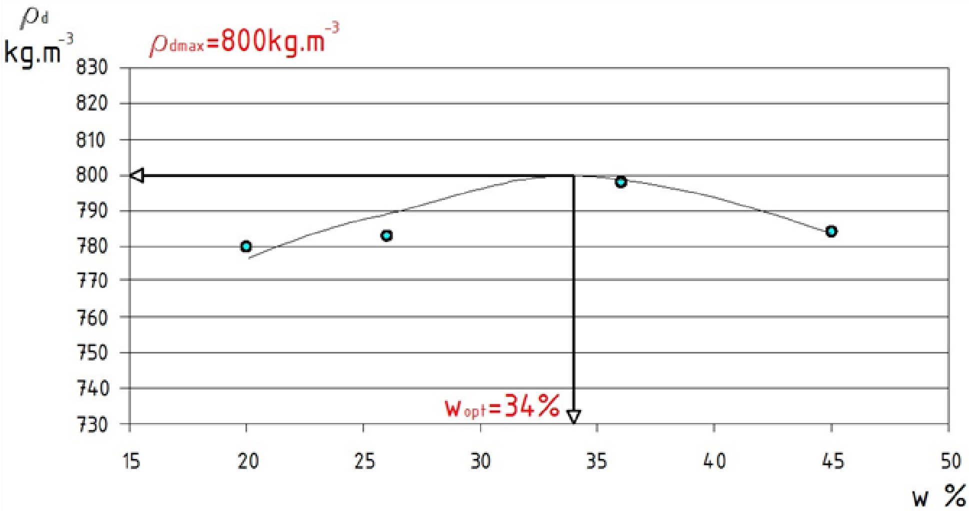

Figure 5: Compactability parameters of coarse-grained ash [3]

Criterion of maximum dry unit weight at compaction ($\rho_{dmax} > 1500 kg.m^{-3}$) is established for soils where density is much higher than the density of ashes (soils - 2,5-2,7$g.cm^{-3}$, ashes - 1,8-2,1$g.cm^{-3}$). Assessment of suitability ashes into embankments according this criterion would therefore be pointless. The low density of these materials can be use for embankment foundation on weak subsoil.

4) Assessment of frost susceptibility was carried out according to the modified Scheibl criterion [5] – Fig. 6. The grading curve of fine-grained ash falls into a danger frost zone. Coarse-grained ash can be classified according this criteria as mild frost soil. **Fine-grained ash is not satisfactory, coarse-grained ash is ok.**

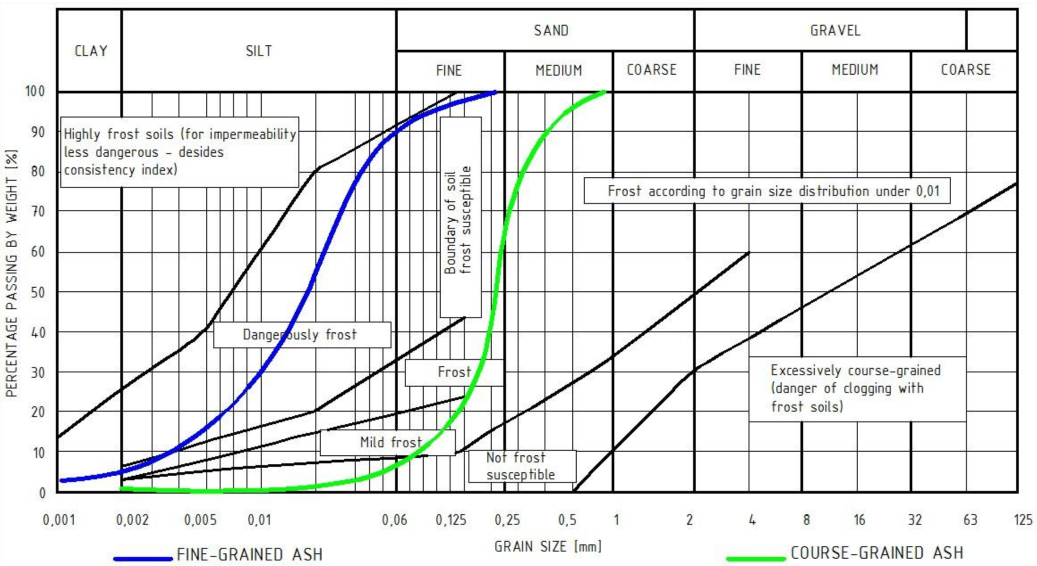

Figure 6: Frost susceptibility criterion for soils according grading (modified Scheibl criterion) [5]

5) Permeability of floated ashes are as follows:

- fine-grained ash → $k_f = 4,5.10^{-7} m.s^{-1}$,
- coarse-grained ash → $k_f = 2,05.10^{-5} m.s^{-1}$.

To the requirement of very good permeability is closer coarse-grained ash.

3.3 Summary

Based on the assessment of two types of ashes deposited into the tailings impoundments (coarse and fine-grained ash) appears to be a preferable alternative to use coarse ash into the embankments. It results mainly from the grain size distribution which is in case of coarse-grained ash preferable, particularly in terms of low proportion of fine-grain fraction, less frost susceptibility, high permeability. Silty fraction of fine-grained ashes has the ability to bind water, what is inappropriate especially in terms of frost susceptibility.

III. PROPOSAL OF REINFORCED EMBANKMENT OF HIGHWAY R2 ZVOLEN EAST – PSTRUŠA USING ASHES

3.1 Engineering solution and boundary conditions of geotechnical calculations

Proposal of reinforced embankment of highway R2 Zvolen East-Pstruša was carried out in km 7,369 70 – Fig. 7. Cross section of the embankment in km 7,369 70 reaches a height of 13m. Shape of the embankment is in the Fig. 8. The evaluation of geotechnical conditions of subsoil was based on results from exploration wells JP-62 and DPS-24, which were situated in a km 7,369 70 [6]. Type and thickness of subsoil layers are in the Fig. 9.

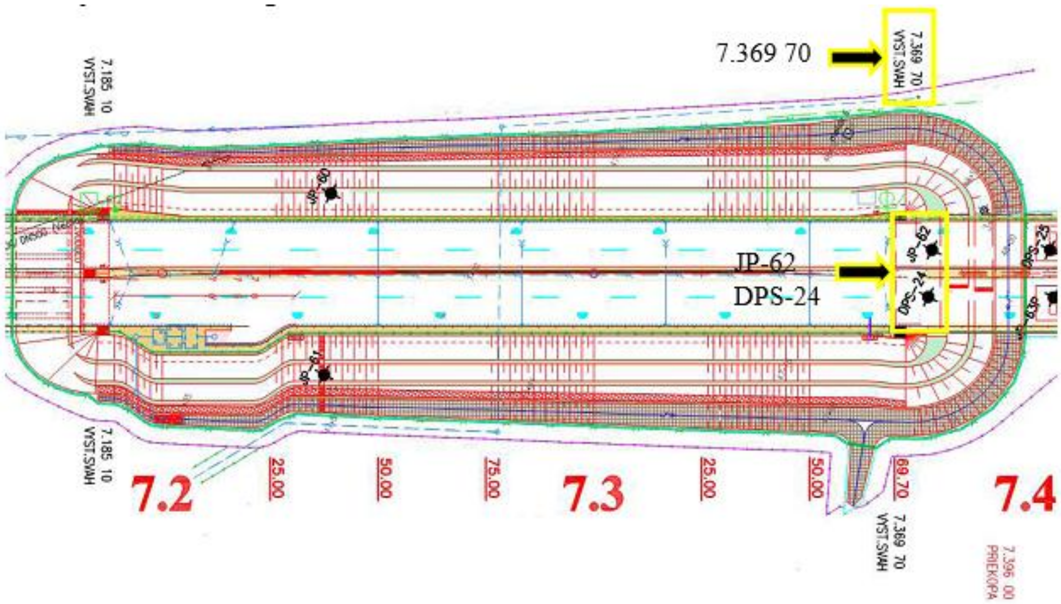

Figure 7: Situation of highway R2 Zvolen East – Pstruša (km 7,185 10 – 7,369 70) [6]

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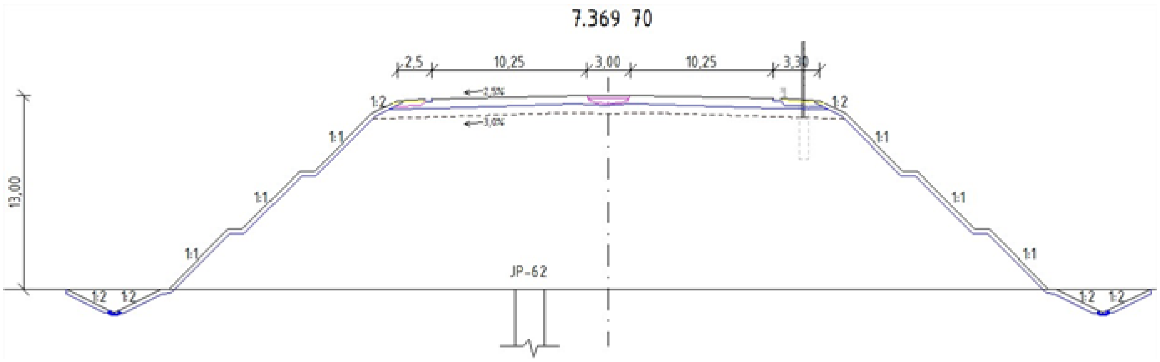

Figure 8: Shape of embankment in km 7,369 70 [6]

Geotechnical properties of subsoil and materials used in embankment are shown in Table 1, and the shear strength line of compacted coarse-grained ash is in Fig. 10. Load from transport has been in [6] determined using two load models. The first load model taken from the STN EN 1991-2 considered into account the following parameters: location of loading lane, type of road, number and width of loading lanes. The second load model took into account the gravity of ground dimensions of the actual vehicles. The result is an uniform continuous load q [kN.m^{-2}]. The most adverse combination of load states from two load models was determined the combination during construction of the road (weight of land vibratory roller - 18kN.m^{-3}).

Design of geosynthetic reinforcement was based on the static assessment of the structure, whereby uniaxial polyester geogrids Secugrid® R6 with a characteristic short term tensile strength from 60-200 kN/m were chosen.

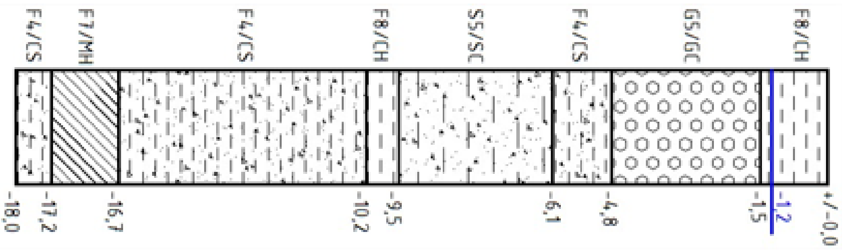

Figure 9: Subsoil layers [6]

Table 1: Geotechnical properties of materials used in geotechnical calculations.

	name of the soil	classif. STN731001	n [-]	g [kN.m^{-3}]	f_{ef} [°]	c_{ef} [kPa]	I_c [-]	E_{oed} [MPa]
subsoil	clayey sand with gravel	S5-SC	0,4	18,5	27,0	8,0	-	29,9
	clayey gravel	G5-GC	0,3	18,5	33,0	2,0	-	93,3
	sandy clay, stiff	F4-CS	0,4	18,5	23,0	11,0	1,0	15,8
	silt with high plasticity, stiff	F7-MH	0,4	18,5	17,0	16,0	1,15	24,6
	clay with high plasticity, stiff	F8-CH	0,4	20,5	17,0	15,0	0,9	12,3
embankment	coarse-grained ash*	S3-SF	0,27	10,7	37,2	0,0	-	20,0
	gravel with admixture of fine-grained soil**	G3-GF	0,25	19,0	31,5	0,0	-	114,0

* geotechnical properties of compacted coarse-grained ash according PS

** soil of embankment originally projected

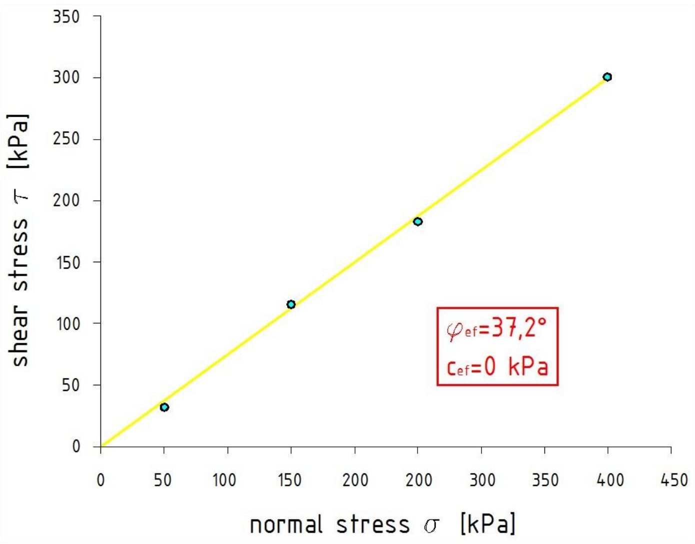

Figure 10: Shear strength line of compacted coarse ash [3]

3.2 Geotechnical calculations

I. LS → Within the geotechnical calculations was firstly performed an assessment of reinforced embankment from compacted coarse ash in the program GEO5 - module *Reinforced embankments*. In module reinforced embankments was the structure assessed to topple and displacement. The vertical load-bearing capacity of subsoil, internal stability (breakage and rip of reinforcement from embankment block) and global stability according to Bishop (Fs > 1,5) was assessed. In module *Slope stability* was subsequently considered external stability of embankment according to Sarma (Fs > 1,5). The results of the assessment are summarized in Table 2 and proposed types (according to short-term tensile strength), number and length of reinforcements are in Fig. 11.

Table 2: Results of geotechnical calculations.

assessment		results
topple		M_{res}=17693,52 kNm/m > 561,55 kNm/m = M_{ovr}
displacement		H_{res} = 644,47 kNm/m > 85,45 kNm/m = H_{act}
vertical load-bearing capacity		R_d = 396,38 kPa > 146,25 kPa = σ
internal stability	reinforcement breakage	R_t = 23,74 kN/m > 2,08 kN/m = F_x
	reinforcement rip	T_p = 191,30 kN/m > 1,54 kN/m = F_x
external stability	according to Bishop	F_s = 1,69 > 1,5 = $F_{s, lim}$
	according to Sarma	F_s = 1,55 > 1,5 = $F_{s, lim}$

The reinforced embankment from compacted coarse ash meets all assessments within I. LS.

II. LS → In module *Settlement* was according to the methodology STN 73 1001 calculated the final settlement of subsoil and effective stresses under the proposed embankment from coarse ash. Calculated final subsoil settlements under the embankment from coarse ash were compared with the final subsoil settlements under embankment which would be constructed according to the original project proposal (from soils G3-GF).

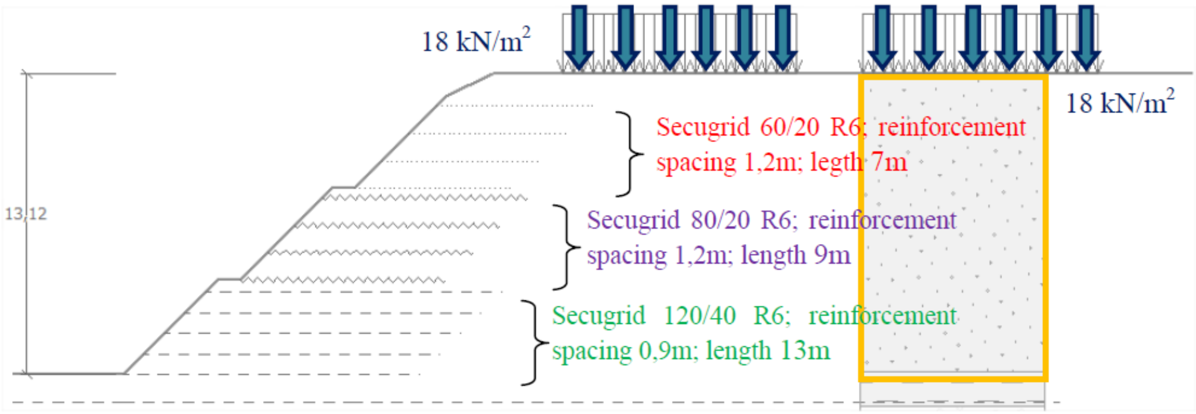

Figure 11: Reinforcing elements placement in the body of embankment from compacted coarse ash

In Fig. 12 are calculated final subsoil settlements under embankment from compacted coarse ash. Subsoil settlements below the center of the embankment reaches up to 150mm, what is despite of low weight of compacted coarse ash relatively high value. In comparison, the final settlements under embankment originally proposed (soil G3-GF) reaches up to 350 mm - Fig. 12.

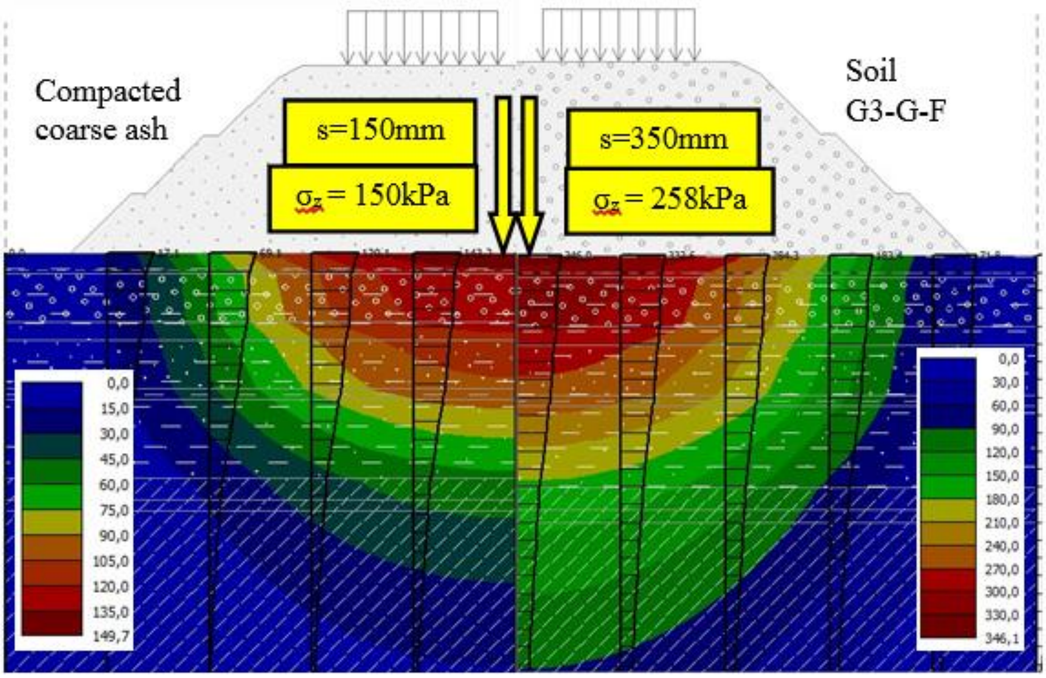

Figure 12: Settlement isosurfaces of embankment from compacted course ash / from soils G3-G-F

IV. CONCLUSION

The low unit weight and a high value φ_{ef} of ashes are very favorable properties with respect to their use in embankments of road constructions. Based on the assessment of suitability of using ashes in embankments coarse ashes appear to be more appropriate than fine-grained ashes, especially in terms of their low frost susceptibility, the low proportion of fine grains and relatively high permeability. Purely fine ashes are in many aspects inconvenient. According to this statement, the separation of coarse ashes from the fine particles would be necessary, what can be ensured by cycloning, or by extraction of coarse ash near the outlets, where is the biggest concentration of the coarse ash.

From comparative calculation of settlement of the subsoil under embankment of "light" compacted coarse ash and of the originally projected soil G3-GF resulted significant differences. The final settlement of subsoil using ash would be approximately half compared to using soil G3-GF into the embankment.

Slovak standards do not specify requirement of assessing suitability using ash in embankments of road construction in terms of ecology i.e. *chemical properties* of the embedding material. Czech standards indicate this requirement. According to the technical requirements, Ministry of Transport, Department of Road Infrastructure (TP 93 - Design and operation of constructions of communications using fly ashes and ashes [7]) specified the maximum amount of leached chemicals (elements). In case of tailings ashes would be useful to assess the arsenic extraction, which is probably in these materials in increased quantities. In this article, the interest was not paid to this assessment.

According to [8] until the 90s of the last century was using of ash in civil engineering limited to only ground backfilling and leveling near by the source. Since the 90s of the 20th century in Czech Republic using ash in civil engineering particularly in embankments of roads highly increased. In some years the processed amount exceeded 100 000 tons per year (e.g. construction D11 Osičky - Hradec Králové in 2009).

REFERENCES

[1] V. Mráz et al., Příklad porušení protipovodňové hráze z vedlejších energetických produktů při povodni, in Role inženýrského geologa v současnosti (2014) 125–172, University of Technology in Liberec, ISBN 978-80-903635-4-0.

[2] I. Slávik, Geotechnické problémy hydraulických skládok priemyselných odpadov, Dissertation Thesis, Bratislava, Slovak University of Technology, Faculty of Civil Engineering, 1997.

[3] Z. Tomašovičová, Zhutniteľnosť hnedouhoľných popolov – vplyv na šmykovú pevnosť, in Sborník studentských prací (2002), Technical University of Ostrava.

[4] Technicko-kvalitatívne podmienky MDVRR časť 2 Zemné práce, http://www.ssc.sk/files/documents/technicke-predpisy/tkp/tkp_2_2011.pdf.

[5] STN 73 6133.

[6] P. Kostovský, Návrh a posúdenie cestného násypu na úseku R2 Zvolen – Kriváň, Diploma Thesis, Bratislava, Slovak University of Technology, Faculty of Civil Engineering, 2015.

[7] Technické podmínky MD TP 93, http://www.pjpk.cz/TP93_def_2011.pdf.

[8] F. Kresta, Secondary materials in highway engineering, Technical University of Ostrava, 2012.