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ALTERNATIVE IMPLEMENTATION OF ELEVATING DIKE SYSTEM OF DESLUDGING SITES

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1. Introduction

The safe operation of desludging site depends mostly on reliable and problem-free functioning of its dike system. Gradual development of industrial facilities towards environmental compatibility brings technological changes to industrial production process as well as changes to method of waste processing and deposition [3]. Hydraulic transportation and subsequent waste deposition-floating process is currently subject to modifications at many desludging sites. Besides the economic and environmental factors – significant losses of return water and changes to technological production process – the reasons also include production of new types of waste. Due to their emission cut programs, thermal power station has been forced to start capturing of fly ashes and their subsequent deposition.

Currently, wastes are transported and deposited at Slovak desludging sites using the following methods [3]:

- hydraulic – floating;
- combined – using hydraulic method and sealed meanders built at desludging site, post-sedimentation exploitation and export of the sediment into the accumulation space of the desludging site;
- mechanical – using truck transportation.

The method of construction of safe dike system at desludging site depends on transportation method to the desludging site and type and properties of the waste. Based on these waste-related factors, elevating dikes of desludging sites are made of [3]:

- earths − mostly exploited from borrow pits at desludging site area or its immediate surroundings;
- waste − delivered through hydraulic transport, sedimented and exploited from accumulation area of the desludging site;
- waste − technologically unprocessed, delivered by trucks from its place of origin;
- waste − technologically processed, delivered by trucks from its place of origin.

Examples show implementation of elevating dikes at desludging sites by waste technologically unprocessed and technologically processed, delivered by trucks from its place of origin.

2. Elevation of desludging site using technologically unprocessed waste

The desludging site is located near Nováky, on the right bank of Nitra river (aerial view in Fig. 1a,b) [1]. Between 1970 and 2001, it served for sedimentation of carbide lime and mechanical treatment of waste waters from an industrial facility. The desludging site is of flat type, during its operation it was divided into deposition cassettes. Peripheral earth dikes are 10,0~14,0 m tall and made of local earth through stepwise elevation. Slopes of the dike system range from 1:2 to 1:3. Schematic profile of the dike system is shown in the Fig. 2. Total area of the desludging site bordered by the foot of the primary dike slope is ~14 ha.

Fig.1a, b. Aerial view of thedesludging site

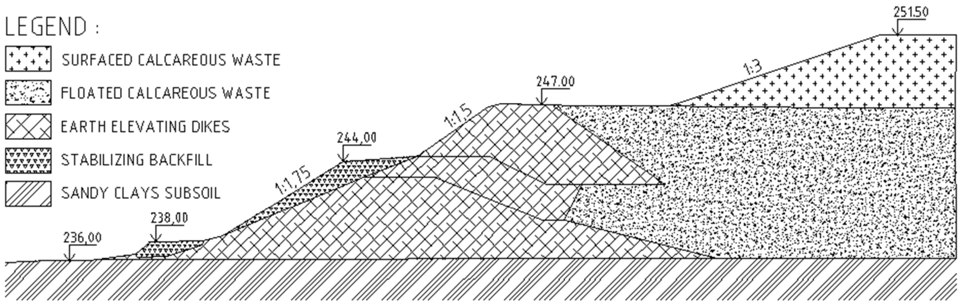

Fig.2. Schematic cross-section of the desludging site's dike system.

Deposition of calcareous waste is permanent. Floating of material was terminated at an elevation 246,0 – 247,0 m above the mean sea level. From this elevation, the desludging site has been elevated by surfacing sedimented waste (condensed calcareous suspension with cca 50 % water content) exploited from sedimentation reservoirs at the premises of the facility. Gradient of slopes for surfacing sedimented waste was set to 1:3 using control stability calculations. Survey works at the desludging site focused on comparison of properties of floated and mechanically deposited calcareous waste. Effect of sludge deposition method (floating replaced by surfacing) was apparent in all observed parameters.

So far, changes in geotechnical properties of calcareous sludge may be characterized as follows:

- values of dry unit weight γ_d [kN.m^{-3}] and unit weight in natural bedding γ_n [kN.m^{-3}] of the surfaced sludge range within the maximum values of floated sludge;

- water content values w [%] and porosity n [%] of surfaced sludge range within the minimum values of floated sludge;
- values of shear stability parameters (angle of internal friction φ_{ef} [°] and cohesion c_{ef} [kPa]) of surfaced sludge range within the maximum values of floated sludge;
- values of oedometric modules E_{oed} [MPa] of the surfaced sludge are significantly higher than those of floated sludge.

To obtain clear image of the effect of changing the deposition method of calcareous sludge on their mechanical properties, mean values of shear strength parameters and oedometric modules of floated and surfaced sludge were derived from the experimental measurements. Comparing mean values of mechanical characteristics of the two sludge types, the following can be declared:

- mean values of shear strength parameters of surfaced calcareous sludge are higher (φ_{ef} by 3,2^{o} and c_{ef} by 9,4 kPa) than those of floated sludge (Fig. 3);
- meanvlues of oedometric modules E_{oed} of surfaced calcareous sludge are approximately 1,5 – 2,0 times higher than those of floated sludge (Fig.3).

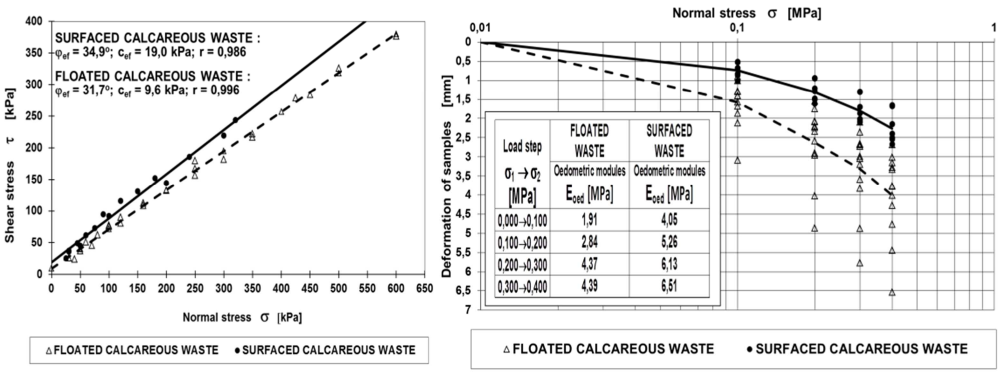

Fig. 3. Comparison of shear strength and compressibility of calcareous waste.

Calcareous waste shows effect of transport and construction machinery, which is used for distribution and spreading of the waste, on shear strength and compressibility compared to floated calcareous sediment. In case of calcareous desludging site, which is to be further elevated, including the dike system, through mechanical surfacing of waste, increased shear strength and decrease in compressibility of calcareous waste has positive effect on its overall stability.

3. Elevation of desludging site using technologically processed waste

Technologically processed wastes, which are currently deposited at desludging sites or used for elevating dike systems, include stabilized mixture, produced by technological processing of ash and its deposition at landfills. An example of such deposition of stabilized mixture is desludging site at the right bank of Nitra river in the district of Prievidza [2]. The desludging site is approximately 2 km long with maximum width of cca 600 m. An aerial view of the desludging site is shown in the Fig. 4a,b.

From 1965 to 1990, ashes from the power station were transported by hydraulic mechanism and floated to the desludging site. Deposited layer is 30,0÷ 35,0 m high and occupies the area between the river and the foot of steep mountain range. Primary dikes are filled partly from earths and partly from ash. Elevating dikes are made of ash. General gradient of the dike system's air slope is ~ 1:4. A schematic cross-section of the dike system is shown in Fig. 5.

Fig. 4. Aerial view of the desludging site.

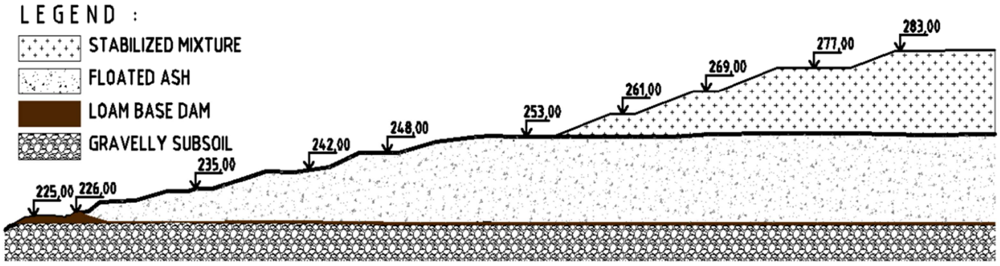

Fig. 5. Cross-section of the desludging site's dike system in district of Prievidza.

Traditional floating of ash was terminated at the altitude of ~ 253,0 m above the mean sea level. After termination of floating and partial recultivation, so-called stabilized mixture has been deposited at the desludging site since 1998. The mixture is technologically modified ash defined as inert waste. It is deposited in rolled layers onto the ash sediment in a prescribed way.

Inert waste - stabilized mixture is anthropogenic geomaterial produced according to a prescribed formulation and subject to regular inspections. Analysis of properties of the stabilized mixture has been performed since it has been deposited in 1998 until now. In the Tab. 1, the results are compared with values of properties measured on samples collected 6, 8 and 10 years after deposition. The analysis of test results listed in the Tab. 1 shows that time has no significant effect on properties of the stabilized mixture. Differences in index characteristics are only minor. Permeability coefficient of stabilized mixture samples is relatively constant. Strength parameters of the stabilized mixture are determined with respect to its nature using methodology of rock mechanics (compressive strength, transversal tension, bending tension) and soil mechanics (shear strength). Increased strength of stabilized mixture with time was not observed when subjecting samples to rock mechanics testing.

Our previous research papers on inert waste properties concluded that the least favorable physical state is its complete disintegration (crushing). Use of direct shear test results of crushed stabilized mixture as input for stability calculations can therefore be considered as absolutely correct. Fig. 6 shows evaluation of all tests carried out so far, i.e.

measurements between 2001 and 2011 (φ_{ef}= 33,8^o; c_{ef} =2,5kPa, number of shear tests n = 204). However, it must be noted that cohesion value is not acceptable for any geotechnical calculations. In the interval of low normal stress values (σ from 0,0 to 12,0 kPa), it is only mathematical representation of strength line (simplified shape of the curve).

Verification of shear strength of crushed stabilized mixture included the effect of water (flushing the sample with water during test) on shear strength parameters. Comparison of shear strength values for dry and water-flushed samples is shown in the Fig. 7. When comparing the results of dry and watered samples of stabilized mixture, evaluation of tested groups 3 to 5 yields the difference between the average values of angle of internal friction φ_{ef} of dry and watered stabilized mixture (grains smaller than 2,0 mm) ranging from 4 to 6 %. Due to low number of tests evaluated, the results cannot be generalized.

Table 1. Geotechnical properties of the stabilized mixture.

<table>
<tr><td colspan="7">Mean values of stabilized mixture properties
(elaborated by H.E.E. Consult, s.r.o., Trenčín,
INGEOENVILAB, s.r.o. , Žilina, STU SvF Bratislava)</td></tr>
<tr><td colspan="2">parameter
unit</td><td>90 days deposited</td><td>180 days deposited</td><td>6 years deposited</td><td>8 years deposited</td><td>10 years deposited</td></tr>
<tr><td colspan="7">i n d e x   p r o p e r t i e s</td></tr>
<tr><td colspan="2">w[%]</td><td>39,45</td><td>42,57</td><td>51,55</td><td>45,56</td><td>44,61</td></tr>
<tr><td colspan="2">γ_n[kNm^{-3}]</td><td>15,22</td><td>15,33</td><td>15,02</td><td>15,70</td><td>15,30</td></tr>
<tr><td colspan="2">γ_d[kNm^{-3}]</td><td>11,05</td><td>10,93</td><td>9,94</td><td>10,80</td><td>10,60</td></tr>
<tr><td colspan="2">ρ_s[gcm^{-3}]</td><td>2,647</td><td>2,639</td><td>2,632</td><td>2,636</td><td>2,619</td></tr>
<tr><td colspan="2">absorption capacity [%]</td><td>45,78</td><td>47,69</td><td>55,06</td><td>50,86</td><td>53,72</td></tr>
<tr><td colspan="2">compactness [%]</td><td>41,71</td><td>41,38</td><td>37,75</td><td>40,97</td><td>40,47</td></tr>
<tr><td colspan="2">porosity [%]</td><td>58,30</td><td>58,58</td><td>62,25</td><td>59,03</td><td>59,53</td></tr>
<tr><td colspan="2">S_r[%]</td><td>74,13</td><td>78,52</td><td>81,75</td><td>83,36</td><td>79,47</td></tr>
<tr><td colspan="2">number of samples</td><td>131</td><td>119</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td colspan="7">s t r e n g t h   p r o p e r t i e s</td></tr>
<tr><td rowspan="2">compression strength [MPa]</td><td>instantaneous</td><td>8,88 (121)</td><td>9,96 (116)</td><td>6,64 (5)</td><td>9,03 (5)</td><td>5,07 (5)</td></tr>
<tr><td>saturated</td><td>8,56 (82)</td><td>8,88 (83)</td><td>6,27 (5)</td><td>6,50 (5)</td><td>4,45 (5)</td></tr>
<tr><td rowspan="2">transversal tension [MPa]</td><td>instantaneous</td><td>1,03 (104)</td><td>1,14 (106)</td><td>0,67 (5)</td><td>1,17 (5)</td><td>0,90 (5)</td></tr>
<tr><td>saturated</td><td>1,11 (66)</td><td>1,16 (73)</td><td>0,72 (5)</td><td>0,91 (5)</td><td>0,78 (5)</td></tr>
<tr><td colspan="2">bending tension [MPa]</td><td>2,47 (115)</td><td>2,27 (104)</td><td>1,98 (5)</td><td>1,05 (5)</td><td>0,81 (5)</td></tr>
<tr><td rowspan="3">shear strength</td><td>period</td><td colspan="2">years 2001 – 2010
46 tests, n=184</td><td>-</td><td colspan="2">year 2010
5 tests, n=20</td></tr>
<tr><td>φ_{ef}[^{0}]</td><td colspan="2">33,80</td><td>-</td><td colspan="2">34,80</td></tr>
<tr><td>c_{ef}[kPa]</td><td colspan="2">2,70</td><td>-</td><td colspan="2">2,70</td></tr>
<tr><td colspan="7">p e r m e a b i l i t y</td></tr>
<tr><td colspan="2">k_f[m.s^{-1}]</td><td>1,12x10^{-8}</td><td>1,25x10^{-8}</td><td>3,67x10^{-9}</td><td>1,31x10^{-8}</td><td>2,29x10^{-8}</td></tr>
<tr><td colspan="2">number of samples</td><td>123</td><td>119</td><td>5</td><td>5</td><td>5</td></tr>
</table>

Note: *(121) – figure in parentheses represents number of tests*

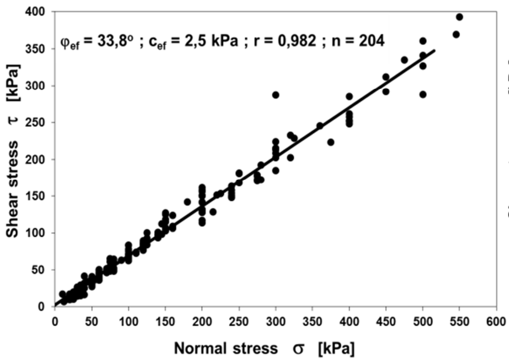

Fig.6. Shear strength of stabilized mixture

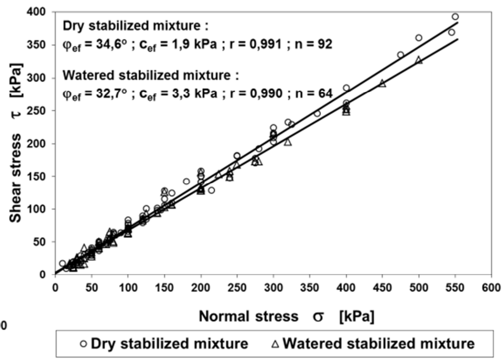

Fig.7. Shear strength of dry and watered stabilized mixture

4. Conclusion

Mandatory regular monitoring of desludging sites is regulated by Slovak law. Regular, systematic, long-term and standardized monitoring of geotechnical properties of all geomaterials forming body and bedrock of desludging site represents an indispensable part of such monitoring. One of the essential elements of the monitoring process is updating and expansion of their databases reflecting changes in technological processes of constructing and operating desludging sites. Actual results of stability and deformation analyses of desludging sites can only be based on using continually updated and verified databases holding data on properties of geomaterials from desludging sites.

References

[1] Klúz, M., Masarovičová, M., Slávik, I., Breznický, J. : NCHZ Nováky – verifying the actual material properties desludgingNováky, Expertise review, Slovak University of Technology in Bratislava, Faculty of Civil Engineering, 2011, 46 p. (in Slovak)
[2] Masarovičová, M., Slávik, I., Dvořáková, S. : Provisional impoundment, SE a.s., ENO, ZemianskeKostoľany – update information for geotechnical stability analysis of desludging site, Expertise review, Slovak University of Technology in Bratislava, Faculty of Civil Engineering, 2010, 49 p. (in Slovak)
[3] Slávik, I. : Monitoring of the geotechnical properties of geomaterials of the impoundments, Habilitation thesis, Slovak University of Technology in Bratislava, Faculty of Civil Engineering, 2012, 173 p. (in Slovak)

ALTERNATÍVNE SPÔSOBY NADVÝŠENIA HRÁDZOVÉHO SYSTÉMU ODKALÍSK

Anotácia

V príspevku sú prezentované alternatívne spôsoby intenzifikácie odkalísk – dva príklady realizácie nadvyšovacích hrádzí odkalísk z odpadov navezených technologicky neupravených a z odpadov nevezených a technologicky upravených. Pre materiály zabudované do nadvyšovacích hrádzí sú porovnané niektoré dôležité geotechnické vlastnosti v pôvodnom uložení s vlastnosťami ovplyvnenými spôsobom zabudovania.