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THE INFLUENCE OF SALINITY OF FLY ASH MIXTURES ON ENERGY LOOSES DURING FLOW IN PIPELINES*

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In Polish mining for backfilling the fly ash mixtures are used. Last time for fly ash mixtures preparation the saline water from mine have been used, to thanks to that the saline water missing the surface waters. Usage of saline water for fly ash mixture preparation causes the changes in energy looses during the flow in pipelines. The paper presents the results of energy looses measurement in laboratory pipeline installation with diameter D = 50 mm. The measurements have been performed for different fly ash – saline water proportions. Tested fly-ash from Siersza power plant has typical properties (grain size distribution curve, density) for ashes used for backfilling mixtures preparation. Increase of fluid (water) salinity modifies fluid viscosity. Brine in comparison with pure water retains as liquid with increased viscosity. Increased viscosity can influence on the mixture ash-brine properties for example causing flocculation effect. Also changeable salinity has an influence on proper determination of resistance (frictional) coefficient λ during mixtures flow in pipelines because it depends on Reynolds number which depends on liquid viscosity. Increase of fly-ash concentrations in fly-ash – brine mixtures cause increase of energy losses.

***Key words*:** hydrotransport, pipeline installation, saline water- fly ash mixtures

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Introduction. Exploitation of the natural raw material sources cause the creation of the after exploitation underground voids of large capacities. These empty voids left without filling can constitute the real risk for objects located on the earth surface and cause unfavourable changes in natural environment. For example the typical changes in natural environment in mining zone occurs as disruption in ground water conditions, surface deformation etc. From the other side, the exploitation of natural raw material sources, processing and end-usage cause creation of a significant waste amounts. Mining processes cause two types wastes creation: wastes from mining (gangue etc), wastes from process.

Second, significant group constitute wastes from power industry (from power and heat and power plants) where hard or brown coal is heated. The basic kinds of wastes in this group are: fly ashes, slag.

These wastes must be stored somewhere, the basic way to solve this problem is to store these wastes on the earth surface in dumps. Disadvantage of this storing way is intending bigger and bigger earth areas for that aim. Great dimension of these storage (dumps) causes changes in landscape and natural environment. The physical and chemical properties of the materials stored in dumps cause specific difficulty in their reclamation [1-5]. These storage areas without right protection systems which gives possibility of control the pollution migration are dangerous for natural environment resources (ground and surface waters, air, soil etc.) and indirectly or directly to the human. Wastes created in mining processes have not only the solid form, they can also have a liquid form. 1n natural resources exploitation the other natural resources are used as for example water. The physical or chemical properties of water after passing through the technological cycle are changed, for example it becomes strongly saline. For the sake of content of different chemical substances and toxins, these waters can not be directly released to the surface waters and can not be subjected to natural biodegradation process. To save clear natural environment there is a necessity to look for a new environmental friendly storage ways.

1n mining materials as fly ashes slag etc. as materials for empty void backfilling can be used. This way of waste development is not a pure storage because some of these materials properties for efficiency and mining safety improvement are used. Some characteristic properties of fly ashes for self-setting backfilling can be used.

Backfilling mixture. Most often a mixture for backfilling consist of specific proportions of fly ash, saline water, gypsum etc. Hydraulic filling is transported to the build in place in pipeline

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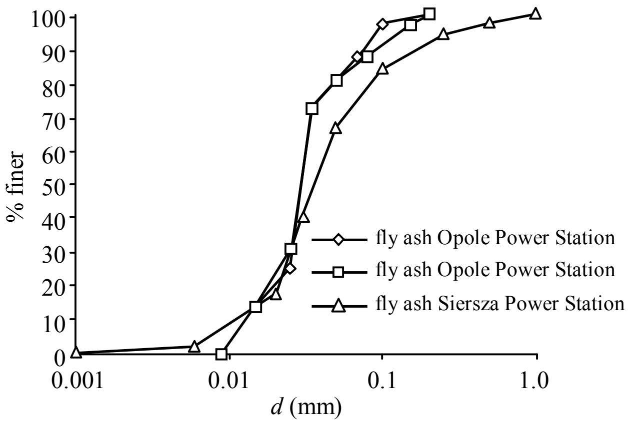

Fig.1. Grain size distribution curves for fly ashes from two Polish stations (Siersza and Opole)

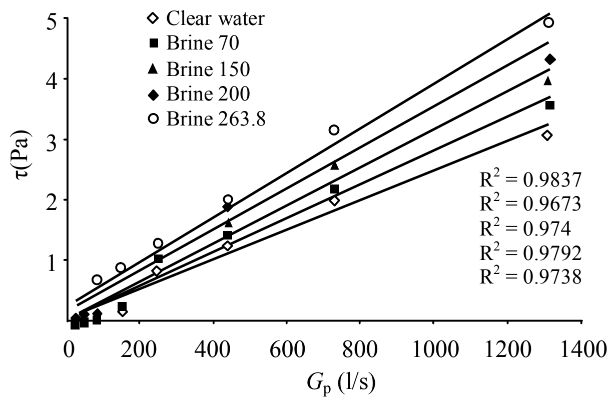

Fig.2. Pseudo-flow curves for pure water and different brines

installations. For proper hydrotransport pipeline installation design and work the knowledge of mixture parameters (viscosity, concentration, density), energy looses is very important. Mixture properties have big influence on pressure looses and flow conditions [6-9]. During mixture flow the pressure looses are higher in comparison with the clear water flow. Mixture properties depend on solid particles concentration, fluid viscosity etc. Properties of flowing mixture change with increasing of fine particles content. For low mixture concentration the Newtonian properties are characteristic, but if concentration increasing above the specific limit concentration the properties change and mixture becomes non- Newtonian. Mixtures for backfilling must have specific features: good transportation properties in pipeline installation, good migration parameters, adequate sedimentation and consolidation time, compressive strength, load capacity, high a wash out resistance in contact with tailwaters.

In Polish mining for self-binding filling the following materials are used: flu-ash, gypsum, Portland cement 35 and saline water with salt concentration between 0-70 g/dm^3. Content of free calcium oxide and gypsum cause that the ashes have hydraulic binding properties (pozzolana) and in contact with water they create ash-concrete with high compressive strength (1.9-6.8 MPa). Physical, chemical and mechanical ash properties depend on kind of coal that has been burned. The fly ashes density ρ_s changing in a range 1.8-2.6 Mg/m^3. Specific for these materials is that they have characteristic grain size distribution curves, practically all fractions are smaller than 1 mm. Typical grain size distribution curves for fly ashes from two Polish power plants are shown in Fig.l. One can observed that these ashes have significant fractions content with diameter $d < 0.2$ mm and the percent fractions bigger than 0,2 mm is rather small (up to 15 % in extreme case).

Brine Viscosity Meaurements. Rheological characteristics (pseudo-flow curves $\tau = f(G_p)$ for pure water and brine have been measured with internal rotated cylinder viscometer Rheotest 2. All rheological characteristics for pure water and brine have been performed with measuring system N – especially designed for low viscosity fluids measurement. Pseudo-flow curves obtained for clear water can be treated as comparative characteristics to show the influence of salt content on increasing liquid viscosity [10-13]. The rheological measurements have been performed for clear water and different brines. The characteristics of tested brines is shown in Table 1.

Measured pseudo-flow curves for different evaporated salt concentration are show in Fig.2.

Investigations for brine – fly ash mixture flow. For the sake of increasing usage of saline water in hydraulic filling mixtures preparation, author performed laboratory tests on influence of saline water on mixture parameters and energy looses during flow in experimental pipeline installation with diameter $D = 50$ mm. The experimental set up has been built in the Hydraulic Laboratory of Institute of Environmental Engineering of Agricultural University of Wroclaw and its scheme is shown in Figure 3. Measurements have been performed accordingly to the methodology described in.

Table 1

The characteristics of tested brines

Name of brine	NaCl content
Brine 70	70 g NaCl/dcm^3
Brine 150	150 g NaCl/dcm^3
Brine 200	200 g NaCl/dcm^3
Brine 264	264 g NaCl/dcm^3

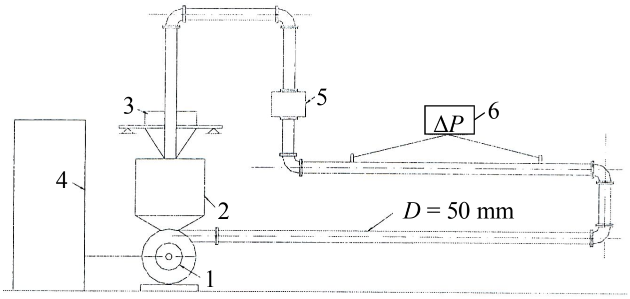

Fig.3. Scheme of the laboratory pipeline installstion D = 50 mm for hydrotransport parameters measurement

1 – pump, 2 – mixture tank, 3 – measuring tank, 4 – pump speed governor, 5 – inductive flow-meter, 6 – pressure difference transducer

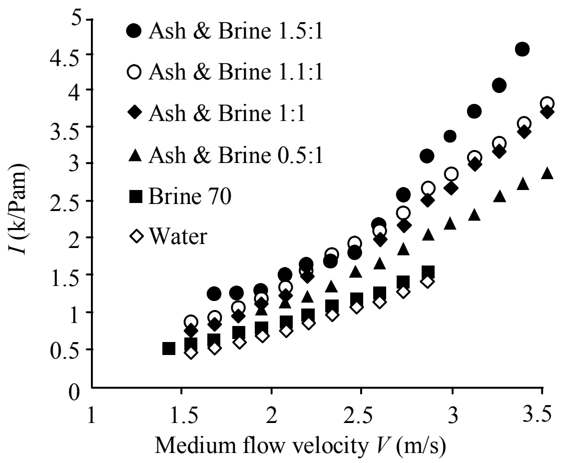

Fig.4. Measured losses I for different medium flow velocities

Results. For dry fly-ash the typical physical and geotechnical parameters as grain size distribution curve, density ρ_s (kg/m3) have been determined. Grain size distribution curve obtained form sieve analysis is shown in Fig.1. Density has been determined with pycnometer method.

Grain size distribution curve shows that fly-ash from power station Siersza have characteristic diameter $d_{50} \approx 0.036$ mm. Sand fraction content ($0.05 \leq d \leq 2.0$ mm) constitute about 32 % of total sample mass, however dust content ($0.002 \leq d \leq$ ≤ 0.05 mm) reaches 68 %. Ash from Siersza power plant contains less than 2.5 % particles with diameter smaller than 0.006 mm. Maximal grain size diameter is d = 1.0 mm. Accordingly to Polish standards (PN-74/B-02480) grain size distribution for investigated fly-ash correspond to grain size distribution characteristic for sand dust. Density of this ash is equal p5 = 2367.5 kg/m^3.

As it can be seen from Fig.2 brine viscosity increase with salt concentration. Brine retains as liquid with increased viscosity.

For energy losses measurements with described above installation (D = 50 mm) the 70 gNaCl/dm^3 brine and fly-ash have been used. Energy losses have been measured in following sequence:

• characteristics $I = f(v)$ measurement during clear tap water flow in pipeline installation. This characteristics constitute comparable – control characteristics for checking

• correct work of measuring installation and calibration formulas,

• energy losses measurement for brine 70 flowing in installation,

• energy losses measurements for different mass ratios fly-ash and Brine 70 mixtures, for following different mass fly-ash – brine ratios: 0.5:1, 1:1, 1.1:1 and 1.5:1.

Measured characteristics of energy losses $I = f(v)$ are shown in Fig.4.

From obtained characteristics it can be seen energy loses have increasing tendency during increasing both flow velocity and fly-ash content in mixture. Simultaneously to energy losses measurement the following basic mixture parameters have been measured: mixture density ρ_m, mixture temperature T(°C).

Table 2

Obtained and calculated investigation result

Parameters	Kind of mixture					
	Pure water	Brine	Ash-brine	Ash-brine	Ash-brine	Ash-brine
Weight ratio fly-ash-brine	–	70 g NaCl/dcm^3	0.5:1	1:1	1.1:1	1,5:1
T(°C)	16	16*-17.5**	21-21.5	25-26	27-27.5	28.5
ρ_m(kg/m^3)	1000	1021.2	1253.7	1420.0	1433.0	1501.5
γ_m (kN/m^3)	9.81	10.02	12.30	13.96	14.06	14.73
c_v	–	0.018	0.185	0.307	0.317	0.366

* the test beginning, ** end of test

On the basis of measured parameters the mixture density and volume concentration have been calculated (see Table 2). The data for mixture density and calculation from placed container method have been obtained. Density has been calculated from formula:

$$\rho_m = \frac{m_0 - m}{V_m}$$

where ρ_m – mixture density, m_0 – container with mixture, m – container weight, V_m – mixture volume.

Mixture volume concentration has been from equation:

$$c_v = \frac{\rho_m - \rho_w}{\rho_s - \rho_w}$$

where ρ_w – water density, ρ_s – fly-ash density.

On the basis of known mixture density ρ_m according to described in methodology the energy losses in meter of mixture column have been calculated from formula:

$$I_m = I_w \frac{\rho_w}{\rho_m},$$

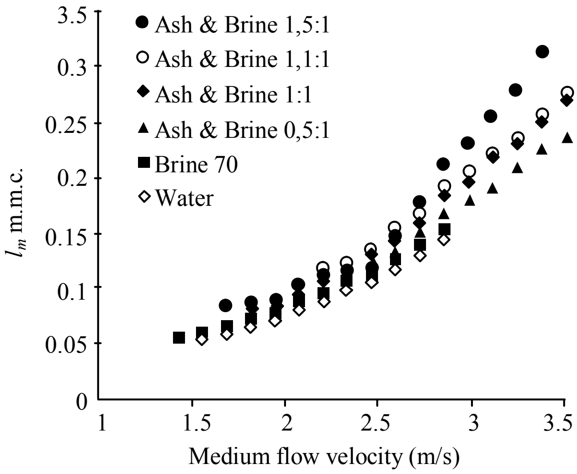

Fig.5. Measured energy losses in meter of mixture colump

where I_m – energy losses in meter of mixture column, I_w – energy losses in meter of water column.

Study results are presented in Fig.5. Results of energy losses measurements show that the energy losses magnitude increase with mixture flow velocity increasing and with increasing of ash content (mixture concentration).

Concluding remarks. Tested fly-ash from Siersza power plant has typical properties (grain size distribution curve, density) for ashes used for backfllling mixtures preparation. Increase of fluid (water) salinity modifies fluid viscosity. Brine in comparison with pure water retains as liquid with increased viscosity. Increased viscosity can influence on the mixture ash-brine properties for example causing flocculation effect. Also changeable salinity has an influence on proper determination of resistance (frictional) coefficient λ during mixtures flow in pipelines because it depends on Reynolds number which depends on liquid viscosity. Increase of fly-ash concentrations in fly-ash – brine mixtures cause increase of energy losses.

REFERENCES

1. Boddu S. Behaviour of eccentrically and obliquely loaded footing on reinforced flyash. M.Tech. Thesis. IIT. Roorkee, 2002.
2. British standard code of practice for Strengthened / reinforced soils and other fills. BS: 8006-1997.
3. Chaney R.C., Dengler L.A., Fang H.Y. Pulverized coal ash as structural fill. *Journal of Geotechnical Engineering*. ASCE. 1982, p. 1356-1359.
4. Das Arghya, Ch.Jayashree, B.V.S.Viswanadham. Effect of Randomly Distributed Geofibers on the Piping Behaviour of Embankments Constructed With Fly Ash as a Fill Material. *Geotextiles and Geomembranes*. 2009. N 27, p. 341-349.
5. Desai M.D. Experience in shear testing for problems of earth dam foundations & embankment materials. Pre-conference Symposia on Pore Pressure & Shear Resistance of Soils. INS of SMFE, New Delhi, 1967.
6. Desai N.H. Experimental Investigation for use of Flyash as a Major Constituent with Clay for Construction of Embankment. M.Tech Thesis. D.D.University. Nadiad, 2007.
7. Venkatappa Rao G., Banerjee P.K., Shahu J.T., Ramana G.V. Geosynthetics – new horizons. New Delhi: M/s Asian Books Pvt. Ltd, 2005, p. 24.
8. Geotechnical Software Suite GEO5- User's Guide Manual. Version 12. Fine Ltd, 2011.
9. Gupta K.K. Bearing capacity and settlement characteristics of reinforced flyash. M.E.Thesis. IITK. Rookee, India, 1995.
10. Ji-Shu Sun, Yuan-Ming Dou, Chun-Feng Yang, Jian-Cheng Sun. Study on the application performances of saponated residue and fly ash mixture as geogrids reinforced earth retaining wall filling material. Geohunan International Conference. ASCE. Geotechnical Special Publication, 2009. N 197, p. 197-201.
11. K.Ramu. An experimental study of fly ash columned bed in expansive soil. Geotechnics in Infrastructures Development. Guntur, India. 2009, p. 77-79.
12. Mc Kittrick D.P. Reinforced earth: application of theory of research to practice. Keynote Address. Symposium on Soil Reinforcing & Stabilizing Techniques in Engg. Practice, Sydney, Australia, 1978.
13. Pal Sujit Kumar, Ghosh Ambarish. Shear strength behaviour of indian fly ashes. Geotechnics in Infrastructures Development. Guntur, India. 2009, p. 18-22.

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