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The influence of organic polymer on properties of mineral concentrates

Part I

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ABSTRACT

The property is evaluated when acceptance for loading of solid bulk cargoes is judged prior to shipment. The liquefaction can be prevented by means of limiting the moisture content of the cargo by introducing the safety margin, regardless of the condition of stresses. It is rational to limit the moisture content of cargoes, which may liquefy, because liquefaction is not liable to occur when the degree of saturation is low, even if the permeability of the material is low. To prevent sliding and shifting of ore concentrates in storage biodegradable thermoplastic materials were added to the ore. The polymer absorbs water from the particle pore in mineral concentrates and its moisture content goes down. In consequence, polymer prevents: drainage of water from the particle pore, sliding and shifting of ore concentrates in storage.

Keywords: polymer, mineral, water, cargo

INTRODUCTION

Liquefaction is a phase transition of initially solid, but water–saturated, loosely packed granular material into a liquid. The coupled processes which take place in fluid–saturated granular material lead to liquefaction.

The following chain of events can describe the liquefaction process. When the cyclic load is applied to such material, particles of the material may move in microscopic scale. The deformation of the mineral concentrates leads to a change in the pore space. During liquefaction the pore space generally decreases. The reduction of the pore space leads to an increased pore pressure. If the fluid cannot migrate the increase in the pore pressure follows from the pore fluid compression due to reduction of the pore volume. However, the fluid migration associated with drainage reduces in general the maximum values of the pore pressure. The increased pore pressure reduces shear stress the grains can support, and leads to a reduction of their elastic shear strength [1, 2].

Shear strength of granular materials is maintained by friction force between particles and by cohesion. Friction force is a product of effective compressive force between particles and friction coefficient. When pressure of water in void becomes high then effective compressive force between particles becomes small. In such cases, if the cohesion is negligible, shear strength of the granular material becomes very low and the material flows.

Many factors influence liquefaction of solid bulk cargoes under dynamic sea loading. One of them is the property of the cargo which contains moisture.

The moisture content which allows for passing the bulk cargoes from solid into liquid state, is called critical. One of its possible measures is the *Flow Moisture Point –FMP.*

Chapter VI of the SOLAS Convention requires that "cargoes which may liquefy shall only be accepted for loading when the actual moisture content of the cargo is less then its *Transportable Moisture Content*" [3].

Large group of organic polymers is used in mineral industry to fulfil specific functions such as depressants, dispersants or flocculent [4]. Organic polymers can be used in a wide range. These polymers can be used as absorbers of water from mineral concentrates before their transportation by sea. Particularly attractive are the new materials based on natural renewable resources, which prevent from further impact on the environment.

In this work the results of investigation on possible using new biodegradable thermoplastic materials, are presented. To prevent the sliding and shifting of ore concentrates in storage, biodegradable thermoplastic materials are added to the ore. The used materials are based on starch. Y Class polymer is composed of starch and natural cellulose. Starch can be destructurized and compatibilized with different synthetic polymers such as polycaprolactone (Z Class polymer) [5]. The polymers are hydrophilic, tend to absorb moisture and prevent drainage of water from the ore particle pores. Cellulose is one of those polymers which has been used in many applications. Starch is an inexpensive abundant product available annually from corn and other crops. It is totally biodegradable in many environments and makes development of totally degradable products possible.

EXPERIMENTAL TESTS

Material

A sedimentary lead concentrate was used for the tests in question.

The main component of the concentrate was the mineral galena (PbS). The sedimentary galena is a product of gravimetric separation, of large mineral particles. The lead content in sedimentary galena amounts to about 80 %. The water content in sedimentary concentrate is equal to 1-2 % The sedimentary galena is a fine material described as that " which may liquefy if shipped above the TML".

The following material was tested:
- Y Class polymer – made - by Novamont S.P.A.- of thermoplastic starch and cellulose derivatives from natural origin
- Z Class polymer–made - by the same company - of starch and polycaprolactone

The sample of polymer was in a granular form.

Testing methods

The influence of the adding of polymer to the ores on their parameters determining ability for safe shipment by sea, was assessed on the basis of determination of the following parameters:

Grain size content

For liquefaction to occur, the concentrate should have a permeability low enough that excess pore pressures cannot drop before sliding occurs.

From the viewpoint of grain size distribution, criteria of the grain size were introduced based on the effective size of D10 which is derived from the grain size accumulation curve and represents permeability. The materials other than coals can be regarded as non-liquefaction ones in the case when D10 is bigger than 1 mm. Here D10 constitutes such value provided the maximum grain size of the material is not greater than 9.5 mm.

In soil mechanics literature the requirement is usually expressed as $0.006 \text{ mm} < D_{10} < 0,3 \text{ mm}$ for liquefaction to be likely, where D_{10} represents the particle size for which only 10% of the material mass is finer [6].

The grain size distribution was measured for both samples of concentrates: i.e. those without polymers and for mixtures with the polymers Y and Z (polymer content in mixture : 0.5%, 1.0%, 1.5% and 2%).

Estimation of FMP

The evaluation of TML was performed with the use of the Proctor Fagerberg Method according to the recommendations given in the Code of Safe Practise for Solid Bulk Cargoes [7].

Water absorption of polymers added to the concentrates

The polymers Y and Z were added to the concentrates in wet state (water content corresponding to the TML of sedimentary galena). Then the samples were tested for estimation of moisture content at several time intervals [8].

RESULTS AND DISCUSSION

Grain size content

In the sedimentary lead concentrate the amount of particles smaller than 0.3 mm is as low as 45 % and content of particles greater than 1mm exceeds 20 %. This is the reason why the lead concentrates may liquefy.

The results of grain size analysis are presented in Fig. 1 through 8 in the form of the grain size distribution curves.

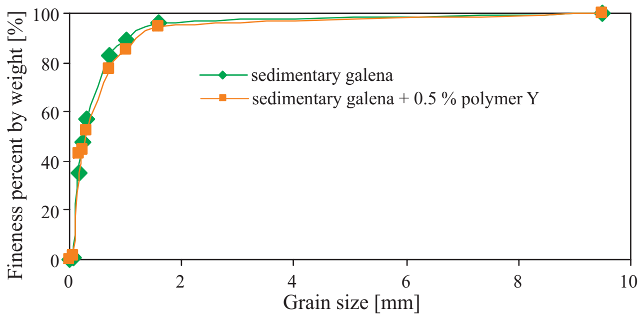

Fig. 1. *The grain size distribution in sedimentary galena + 0.5 % of polymer Y*

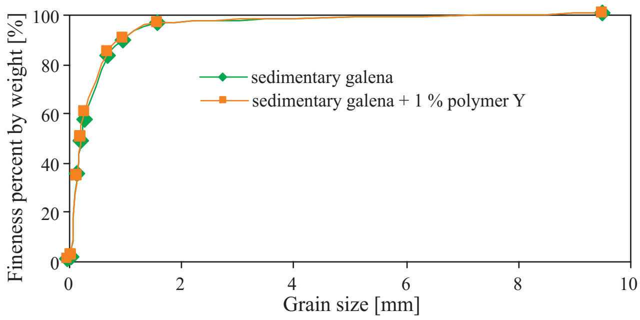

Fig. 2. *The grain size distribution in sedimentary galena + 1 % of polymer Y*

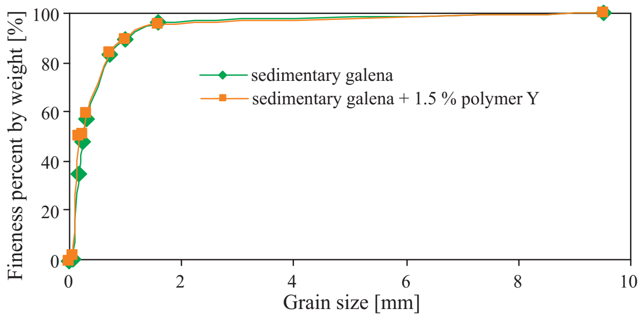

Fig. 3. *The grain size distribution in sedimentary galena + 1.5 % of polymer Y*

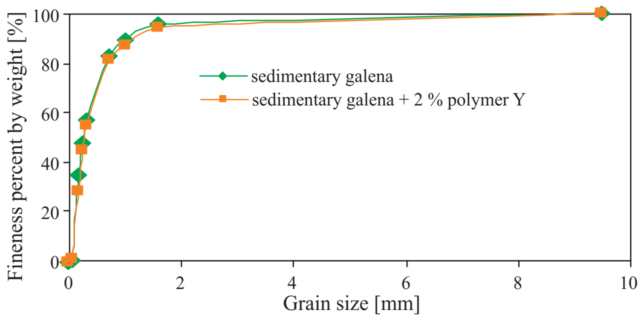

Fig. 4. *The grain size distribution in sedimentary galena + 2 % of polymer Y*

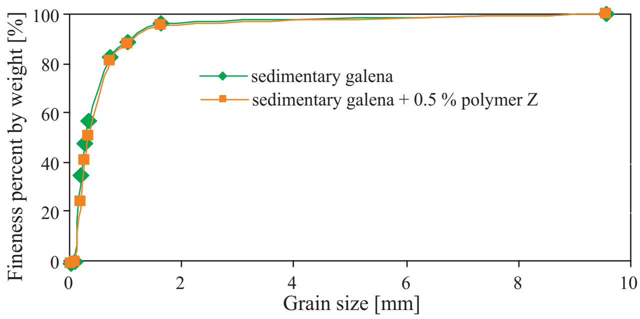

Fig. 5. *The grain size distribution in sedimentary galena +0.5% of polymer Z*

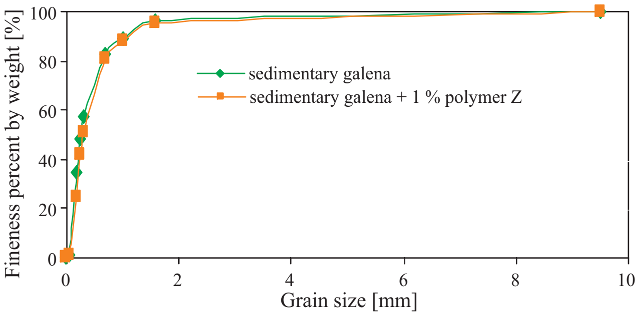

Fig. 6. *The grain size distribution in sedimentary galena +1% of polymer Z*

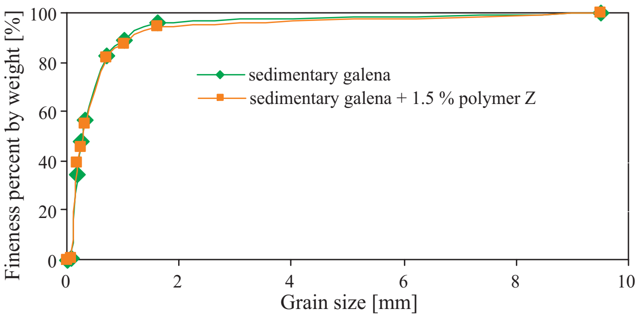

Fig. 7. *The grain size distribution in sedimentary galena + 1.5% of polymer Z*

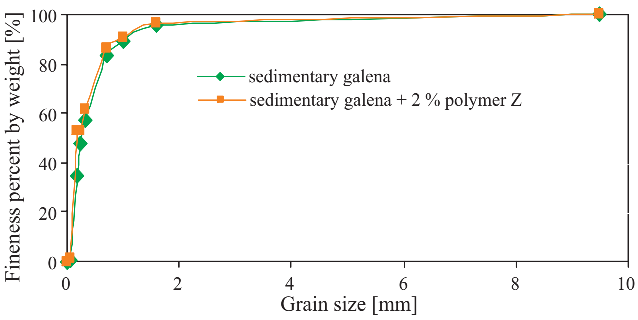

Fig. 8. *The grain size distribution in sedimentary galena + 2 % of polymer Z*

The course of grain size distribution curves indicates that all the tested concentrates are susceptible to liquefaction in sea transportation conditions as in each case the content of grains smaller than 0.3 mm is above 10%.

The percentage values of content of the grains (below 0.3 mm in size) in mixtures of concentrates and polymers are presented in Tab. 1.

Tab.1. *The content of the grains of size below 0.3 mm in concentrates*

Sample type	Content of grains [%]	
	Added polymer Y	Added polymer Z
Sedimentary galena +0.5% content of polymer	52.51	49.03
Sedimentary galena +1.0% content of polymer	58.85	51.04
Sedimentary galena +1.5% content of polymer	59.85	54.88
Sedimentary galena +2.0% content of polymer	54.66	61.72

The above presented results of the grain size analysis indicate that the addition of polymers does not significantly change grain size distribution.

Estimation of TML

Tab. 2. *Transportable Moisture Limit (TML) determined by Proctor C/Fagerberg Method*

Sample type	TML [%]				
	Content of polymer				
	0%	0.5%	1.0%	1.5%	2.0%
Sedimentary galena + added polymer Y	6.20	6.15	6.16	6.22	6.19
Sedimentary galena + added polymer Z	6.20	6.23	6.24	6.19	6.21

Despite the presence of a polymer in tested concentrates the values of estimated TML are similar because liquefaction is tightly related to the grain size content values.

Water absorption of polymers added to the concentrates

The results of estimation of water content in concentrates with added polymers are presented in Fig. 9 through 12.

The water uptake of the blend containing starch and cellulose (polymer Y) was higher than that of the blend containing starch and polycaprolactone (polymer Z).

The mixtures containing 1.5 % of polymers Y and Z absorbed water the most and for them the greatest decreasing content of moisture in tested concentrate was observed.

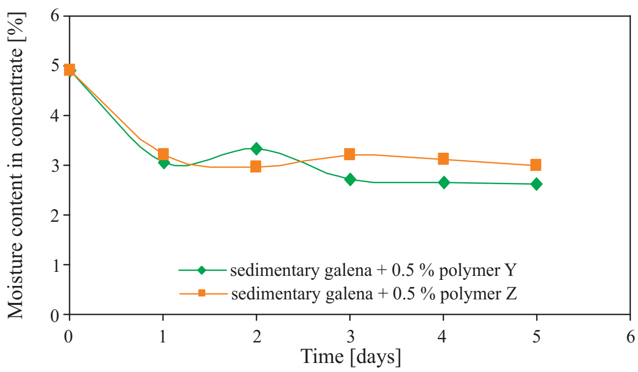

Fig. 9. *The influence of polymer on concentrate moisture content in sedimentary galena + 0.5 % polymer*

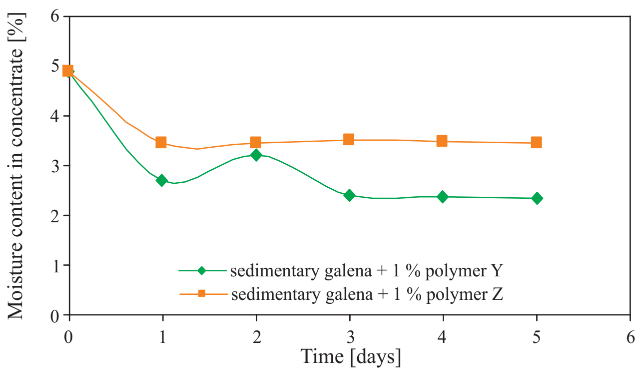

Fig.10. *The influence of polymer on concentrate moisture content in sedimentary galena + 1 % polymer*

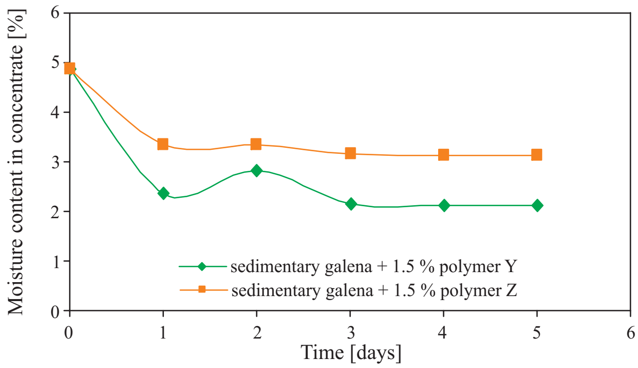

Fig. 11. *The influence of polymer on concentrate moisture content in sedimentary galena + 1.5% polymer*

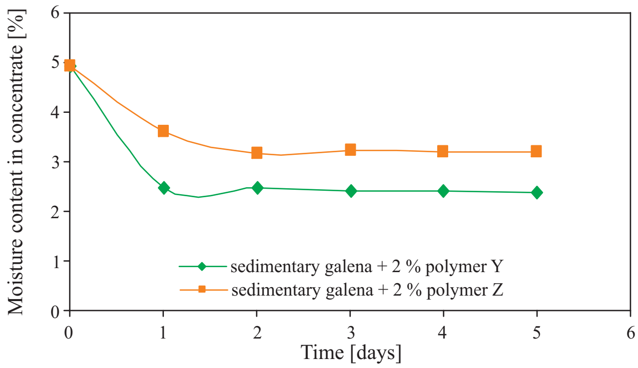

Fig. 12. *The influence of polymer on concentrate moisture content in sedimentary galena + 2% polymer*

The time required for reaching the lower moisture content in ore concentrates (below TML) was very short.

For the first 2 days moisture of ore concentrates decreased significantly and after 4-5 days it became stable reaching 2.4 % content for the tested concentrate.

After two days the slight increasing of moisture content of concentrate (mixture with polymer Y) was observed. It could indicate an insignificant leaching of starch during the experiment. The decreasing of moisture content after next day could be connected with the swalling of cellulose.

CONCLUSIONS

- The grain size analyses indicate that polymers do not significantly change grain size distributions.
- The comparison of the TML values confirms that the correlation between the grain content and TML value occurs.
- As to the results of the performed tests it can be stated that polymers absorb water from the pores between particles of mineral concentrate and its moisture content decreases.
- The type of polymer affects water uptake. In general, the polymer made of starch and cellulose absorbed more water than that made of starch and polycaprolactone. The equilibrium absorption of polymers was reached in 48 hours.
- The new solution of liquefaction problem is very promising because the used polymers are considered to be products of a low environmental impact.

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