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LABORATORY SEISMIC WAVE INVESTIGATIONS ON IMPROVED LOESS SOILS AS ENGINEERED BARRIERS IN THE RADIOACTIVE WASTE REPOSITORY CASE

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ABSTRACT

In connection with the operation of the Kozloduy Nuclear Power Plant and the eventual start of the Belene NPP biulding, a construction of a National radioactive waste repository is forthcoming. The loess terrain in the Kozloduy region is among the areas considered as a prospective medium for the disposal facility. In the world radioactive waste management practice, the "multibarrier approach" for similar kind of facilities is widely spread. One of the loess soil advantages is its easy stabilization with hydraulic binders. The paper deals with the laboratory seismic waves investigations on mixtures made on the base of loess with a zeolite and bentonite additives, strengthened by ordinary Portland cement as engineered barriers against radionuclide migration. The values of the primary (Vp) and secondary (Vs) waves of loess zeolite and loess bentonite samples are compared with the Vp and Vs values of a natural loess and the loess cement mixtures without any additives. There is an increase of the seismic wave velocities of the loess-cement-additive mixtures up to 1000 % in comparison with those of the natural loess and up to 55% to those of only loess-cement mixtures. SEM photographs allowed observing dense texture of the samples.

INTRODUCTION

As a result of the whole period of operation of the Kozloduy Nuclear Power Plant, the closing of its first two reactors and the eventual start of the Belene NPP, it is expected that the low and intermediate level radioactive waste (LILW) volume in the conditioned state will amount to about 100 000 m^3. These wastes are stored at present in temporary storages on the plant territory and it is envisaged to be constructed a permanent repository. The investigations carried out so far both in the country and abroad - Hungary and Romania, proved that some loess areas could be considered as a prospective medium for LILW disposal. The loess terrain in the Kozloduy region is among these areas as it offers advantages from the viewpoint of the local population reaction, the hazards related to radioactive waste transport and the natural conditions. It can be easily stabilized with hydraulic binders and can be transformed in impermeable and strong material. On such material were founded all the Kozloduy NPP facilities. The up-to-date NPP practice has confirmed the foundation properties of the loess-cement screen. From the viewpoint of the problem it would be of significant importance to improve the water and geochemical impermeability capacity of the loess-cement mixtures by the addition of some natural materials and to provide the base for further sorption and retardation property studies.

In the world radioactive waste management practice, the "multibarrier approach" has been applied for avoiding of radionuclide release in the environment and assuring the long time repository stability, i.e. the combination of geological and engineered (artificial) barriers. There are studies in the Bulgarian nuclear practice and in the world radioactive waste disposal researches considering the use of natural materials with great sorption potential such as zeolite and bentonite as artificial barriers for radionuclide isolation.

For the physical reliability of the mixtures, the time-proved strength of the new prepared samples has to be investigated. As indication for more dense structure and more strength interparticle bonds is used the measurement of the seismic waves V_p and V_s. The paper deals with the laboratory seismic waves investigations on mixtures made on the base of loess with a zeolite and bentonite additives, strengthened by ordinary Portland cement as engineered barriers against radionuclide migration. The values of the primary (V_p) and secondary (V_s) waves of loess zeolite and loess bentonite samples are compared with the V_p and V_s values of a natural loess and the loess cement mixtures without any additives. SEM photographs have been made for evaluation of the samples texture. The results shown that both compositions – with zeolite and bentonite additives are prospective as an additional barrier for a low and intermediate level radioactive waste repository.

METHODOLOGY

Materials origin and preparation

Two types of loess have been investigated, both from the Kozloduy NPP region - the eventual area of the radioactive waste repository. The first one according to one Bulgarian classification (Minkov, 1968) is sandy loess and the second one – clayey loess. As a hydraulic binder a standard Ordinary Portland Cement (OPC) was used, with an unconfined compressive strength index of 35 MPa. Two kinds of high-sorption additives were used: Na^+ activated bentonite from the BENTONITE Ltd. Plat and zeolite (with a clinoptilolite content of about 70%) from the Beli Plast quarry. The samples were prepared as a mixture of disturbed loess, percentage of cement and percentage of additive, all compacted at the optimum moisture content W_{opt} till attainment of standard bulk density ρ_{ds}. The cylindrical samples, with dimensions of h/d - 5/5 cm, aged 28 days before the laboratory measurements in glass tanks with 100% relative moisture inside, at 20^0C. The exact values of the weight percents of the composites are listed in Table 1.

Table 1. Investigated mixtures, aged 28 days

Soil	Ordinary Portland Cement, [%]	Zeolite, [%]	Bentonite, [%]
Sandy loess	7	10	-
"	12	-	10
"	7	20	-
"	12	-	20
Clayey loess	7	10	-
"	12	-	10

Apparatus

For the laboratory seismic wave investigations an ultrasonic apparatus "OYO-Model 5217 – new Sonic" is used. The following equations are used to be estimated the Poison`s ratio $\nu$, Young`s E_d and shear G_d moduli (by Lomtadze, 1974):

$$\nu = (V_p^2 - 2V_s^2)/2(V_p^2 - V_s^2),\ [-] \quad (1)$$

$$E_d = V_s^2\rho_n 2(1+\nu),\ [MPa] \quad (2)$$

$$G_d = V_s^2\rho_n,\ [MPa],\ where \quad (3)$$

ρ_n is the bulk density of the sample in 10^3 kg/m^3

A scanning electronic microscope "JEOL JSM – T300" is used for the investigation of the microstructure of the samples.

RESULTS AND DISCUSSIONS

In the design stage of a surface repository seismic behaviour of the soil base has to be estimated by evaluation of the dynamic characteristics of the medium, including the new-prepared loess-cement-additive samples. For that purpose a lot of data for the seismic wave laboratory V_p and V_s measurements of natural loess in the region of Kozloduy NPP have been analysed. Simultaneously with the mixtures, samples only of loess-cement have been laboratory measured as base values for the estimation of the impact of the additives. The measurements were done according to the same above-described procedure. The following values of the laboratory received seismic waves and calculated dynamic moduli are given only for a preliminary assessment of the gained strength of the mixtures and investigation of the role of the additives on the structure of the samples. The results from the investigations and their comparison with natural loess and loess-cement mixtures are listed in Table 2, 3 and 4.

Table 2. Average values of natural loess samples (by Gogov, 1978)

Soil	Primary wave (avr. value/number of tests)	Secondary wave (avr. value/number of tests)	Poison`s ration	Young`s modulus
	V_p [m/s]	V_s [m/s]	ν [-]	E_d, [MPa]
Sandy loess	290 – 1160 (680/37)	140 – 580 (315/37)	0.36	487
Typical loess	1200 – 1970 (1690/7)	550-990 (810/7)	0.35	3368

For the observe investigation and comparison of the structure of the samples SEM photographs have been taken. The first one (Fig. 1) presents natural undisturbed sandy loess sample. The structure is "light" i.e. with a lot of pores of different size, even macro-pores. The SEM photographs taken on the loess-cement-bentonite (Fig. 2) and loess-cemet-zeolite (Fig. 3) samples show one much more dense structure with well-spread compact mass covering the grains and almost completely fulfill the pore space.

Fig. 1. Natural loess. Magnified x 100.

Table 3. Seismic characteristics of loess-cement samples

Soil	Cement percent	Primary seismic wave	Secondary seismic wave	Poison`s ratio	Young`s modulus	Shear modulus
	q [%]	V_p [MPa]	V_s [MPa]	ν [-]	E_d [MPa]	G_d [MPa]
Sandy loess	7	1570	928	0.23	4 100	1665
"	10	1729	971	0.26	4622	1820
"	12	1913	1051	0.28	5479	2134
Clayey loess	7	2004	1043	0.31	6147	2338
"	10	2125	1128	0.30	7133	2735
"	12	2241	1161	0.32	7630	2898

Table 4. Seismic characteristics of loess-cement-additive samples

Soil	Cement percent	Additives [%]		Primary seismic wave	Secondary seismic wave	Poison`s ratio	Young`s modulus	Shear modulus
	q [%]	zeolite	bentonite	V_p [MPa]	V_s [MPa]	ν [-]	E_d [MPa]	G_d [MPa]
Sandy loess	7	10	-	2206	1122	0.32	6349	2395
"	12	10	-	2475	1159	0.35	6941	2552
"	7	20	-	2245	1113	0.33	6228	2329
	12	20	-	2475	1089	0.37	6161	2232
	7	-	10	2073	897	0.38	4397	1588
	12	-	10	2318	1108	0.35	6513	2409
	7	-	20	1881	900	0.35	4165	1541
	12	-	20	2148	925	0.38	4484	1617
Clayey loess	7	10	-	2300	1252	0.29	8327	3229
"	12	10	-	2466	1133	0.37	7225	2644
"	7	-	10	1977	944	0.35	4916	1817
"	12	-	10	2100	1024	0.34	5750	2139

Fig. 2. Loess with 12% cement and 20% bentonite. Magnified x 200.

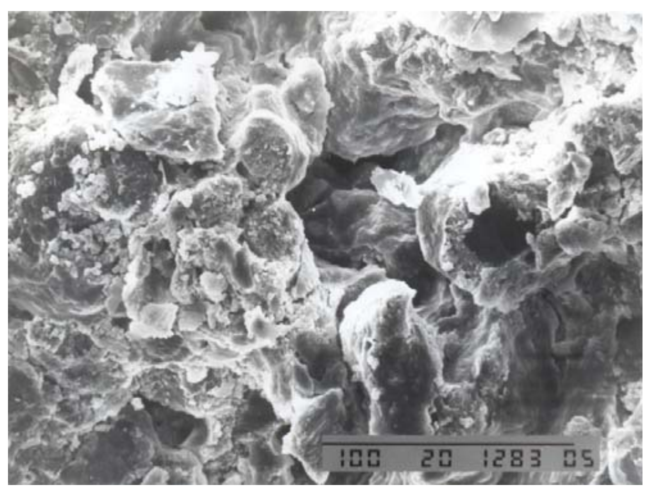

Fig. 3. Loess with 12% cement and 20% zeolite. Magnified x 500.

CONCLUSIONS

On the base of the received results and analysis the following highlight and conclusions could be drawn. There is an increase of the seismic wave velocities of the loess-cement-additive mixtures up to 1000 % in comparison with those of the natural loess and up to 55% to those of only loess-cement mixtures. The more dense structure of the loess-cement-additive mixtures is shown on the SEM photographs. So, the loess-cement-additive mixtures are perspective for future investigation for radioactive waste disposal system. The laboratory seismic wave measurements except for the dynamic characterization give additional information for the strength behavior of the samples and are a secondary sign of showing the increase or decrease of the strength properties.

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