Applied Mechanics and Materials
ISSN: 1662-7482, Vols. 725-726, pp 208-213
doi:10.4028/www.scientific.net/AMM.725-726.208

Submitted: 2014-10-13
Revised: 2014-11-03
Accepted: 2014-11-03
Online: 2015-01-29

Effectiveness of Soil Reinforcement Based on Complex Ash-Cement Bonder

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Keywords: complex ash and slag binding, unfortified ash and slag mixture, polymer-mineral composition, redispersible polymer powders, mineral fillers, stabilization and strengthening soil.

Abstract. This article is about strengthening soil in application of the problem with utilization of ash-and-slag wastes from coal thermal power-stations to reduce the cost of construction of road, to get sufficiently strong of road bases with reinforcing soils, to provide a higher rate of acquisition of durability and higher durability and frost resistance.

Introduction

Progressive tendency in resource-demanding sectors is transformation of industrial wastes in raw material for industrial use [1,2].

In the world practice there were developed many different compositions and technologies of composite and mixed bonders (including cement) based on ashes of thermal power-stations and other waste mineral resources (WMR), but its qualitative, ecological and economical indicators, and also the power-intensity of the production does not satisfy modern requirements. It is known that this case does not let to use actively the dry ash for organization of bases and covering of topping of road from reinforced soils, where it is used as active hydraulic additive that is active component of mixed bonder in combination with cement or lime.

It causes the need of creation of new compositions and technologies from these materials with indicators which are not only are not worse, but even better than traditional.

Review

Decrease in power-intensity and in construction cost of motor roads can be reached with the use of reinforced local soils in road constructions. In areas which are not supplied with standard stone materials, the use of reinforced soils has no alternatives. But the area of application in road constructions of such material is limited by considerable time of its setting, high fragility and abradability.

At the same time, as number of researches accent [3-24] that with increase in resistance of the model with high percentage of cement, the modulus of elasticity also increases (refer with: Fig. 1), material becomes fragile and destroys almost instantly after reaching the limiting state.

In order to improve the properties of soils reinforced with cement in combination with ash-slag in recent years more and more builders use different organic and polymer additives which provide higher setting rate and higher resistance and frost resistance of cement soil.

Such additives include special polymer-mineral composition based on redispersible polymer powders and mineral fillers [1,2].

From the survey information of application of wastes from combustion of thermal power-stations' rigid fuel we can make a conclusion that with the basic criterion which defines the ability of ash and slag to show bonding properties, which means presence of calcium in free or bonded type, following criteria are used (refer with: Eq. 1, Eq. 2, Eq. 3) [2]:

- base module (hydro silicate module) Mo, which represents ratio of sum of basic oxides to sum of acid oxides:

$M_o = (CaO + MgO + K_2O + Na_2O): (SiO_2 + A1_2O_3)$ (1)

- silicate (silica) module Mc, representing ratio of silicon oxide, which reacts with other oxides, to the total content of aluminum oxide and iron:

$M_c = SiO_2: (A1_2O_3 + Fe_2O_3)$ (2)

- quality coefficient K, representing ratio of oxides, which increase hydraulic activity to oxides, to the ones, which decrease it:

$К = (CaO + A1_2O_3 + MgO): (SiO_2 + TiO_2)$ (3)

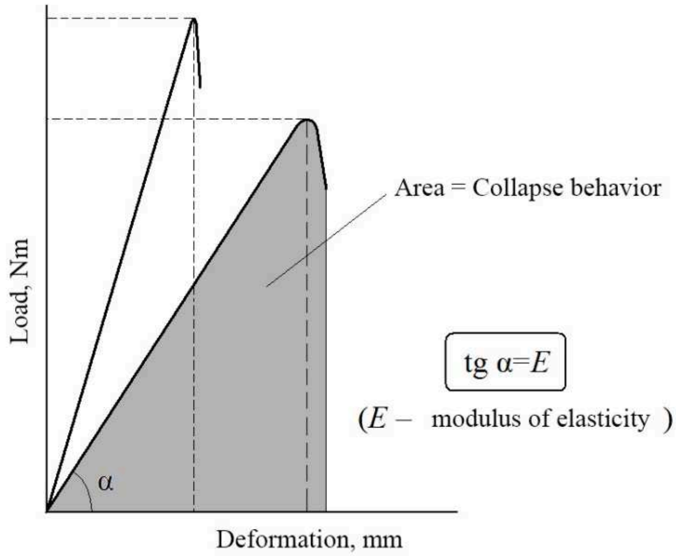

Figure 1. Dependence of the deformation of materials on the loading efficiency

Application of polymer-mineral composition

The developed composition is a mixture of activated silica and polymers based on lignin. Polymers are redispersible and powdered. Polymer-mineral composition also contains calcium salts, sodium salts and formaldehyde. Activated silica (Al_2O_3) possesses high porosity (200-800 m^3/g) whereby granules of silica absorb molecules of water with its activation and cement.

In process of compression of mixture of soil, ash-slag and polymer-mineral composition Van-der-Vaal's mechanism of intermolecular interaction begins and accelerated formation of crystal bonds occurs.

Crystal structure of cement stone is formed along energetic flow of polymer chains, needle-form microcrystals are formed and micro reinforcement of cement stone happens (Fig. 2, Fig. 3). By this way increase in energetic balance of the whole system of the reinforced soil is reached which leads to considerable decrease of setting time of the mixture.

Researches showed that application of polymer-mineral composition makes it possible to increase effectiveness of reinforcement of soils with cement and dry ash [1,3,5,6,15]. Also possibility of reinforcing of unconditioned soils with big amount of powder admixtures is reached.

Ultimate compression strength with the use of dry ash and polymer-mineral composition is increased in 1.2-1.4 times, ultimate tensile strength in bending – in 1.5-1.8 times. Period of setting to the designed strength is decreased by 5-7 days.

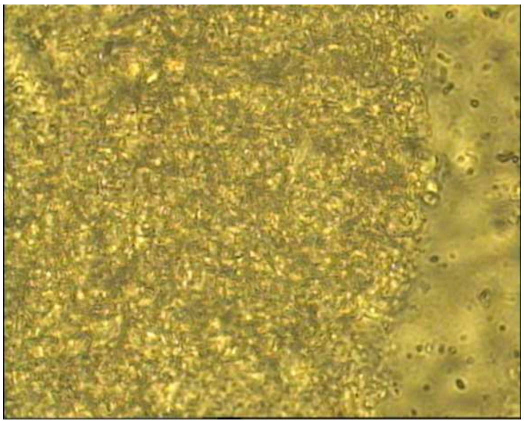

Figure 2. Cement stone crystals while reinforcing sand clay soil (magnified 300 times)

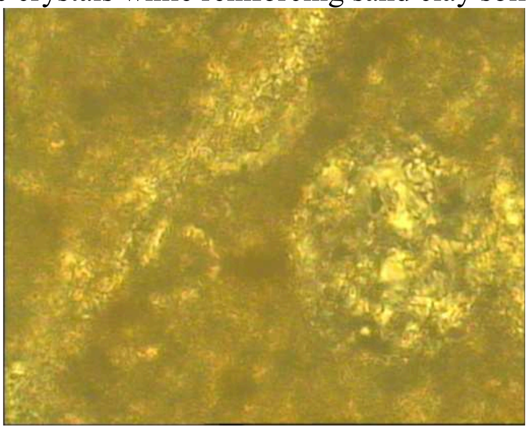

Figure 3. Cement stone crystals while reinforcing loamy soil with addition of polymer-mineral composition (magnified 300 times)

Dry ashes, which are used for reinforcing of soils as independent bonder or active component of mixed bonder, should be from dry selection directly from electrofilters or cyclones of thermal power-stations which are found after combustion in boiler room of thermal power-stations of brown and black coal, peat and pyroschist. Such dry ashes should satisfy following requirements (Tab. 1) [1,4,15].

Table 1. Requirements for fly ash

Control indicators	Requirements for dry ash		
	Dry ash as independent slow hardening bonder	Dry ash as active component of mixed bonder	
		In combination with cement	In combination with lime
Content of free oxide of calcium [%]	Not less than 8	Not more than 4	—
Specific surface [cm2/g]	Not less than 3000	Not less than 3000	Not less than 3000
Content of sulfur and sulphate compounds (calculated in SO3) [%]	Not more than 6	Not more than 3	—
Loss in calcination [%]	Not more than 5	Not more than 10	Not more than 10

As a result of approbation there was developed an optimal composition of complex ash-cement bonder (CAB):

Portland cement M400 - 70%, dry ash - 25%, polymer-mineral composition - 5%.

Production receipt of reinforced soil: soil - 100%, CAB - 6-10% (from weight of reinforcing soil), water - until reaching the optimal soil moisture [2,16].

Mixture of soil with CAB can be got by method of mixing in any mixing equipment (pit soil mixing installation, concrete mixer RBU and etc.), moved out and laid by asphalt-spreading machine. Compression is carried out by brigade of road rollers until reaching the coefficient of compression not lower than 0.98.

By experiments it was shown that in designing soil bed with CAB there can be used solutions accordingly to recommendations [1,2] or individual solutions according to SP 34.13330.2012 Automobile roads (the updated edition of SNIP 2.05.02-85*) (Fig. 4).

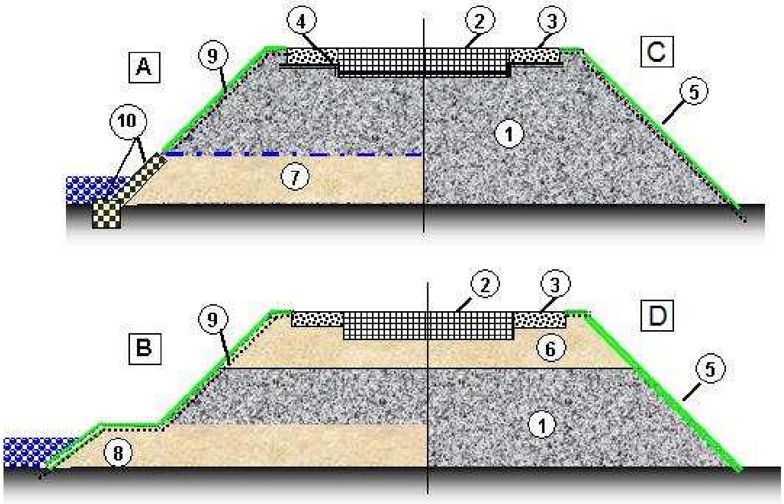

Figure 4. Approximate schemes of cross-section of soil bed with CAB
A,B – for II, III types of terrain with humidification; C,D – on dry areas; 1 – CAB; 2 – road base (with border lane); 3 – reinforced roadside; 4 – plain combined geogrid; 5 – topsoil or cohesive soil with sowing; 6 – non-distending or low-distending soil; 7 – draining or cohesive soil; 8 – berm from clay soil; 9 – volumetric geomat with geotextile; 10 – mattress reno and gabion with geotextile

Summary

Carried out researches showed that application in road construction of ash-cement bonder is not only effective solution to the problem of utilization ash-slag wastes of coal thermal power-stations, but also it is a factor of considerable decrease of costs for construction of motor roads, which lets to construct durable enough road bases from reinforced soils.

The main problems of implementation and active practical application of these recommendations contain:

- in formation of scientific and technical politics based on economical approaches which are based on the highest effectiveness of technical and constructive solutions with whole complex of expenses and benefits;
- in creation of economical mechanisms which provide mutual interest of all participants of process of implementation economical materials and constructions;
- in reorientation of politics of technical regulation in ecological interests;
- in formation of unified technical requirements to different construction materials;
- in accounting of regional features for carrying out of technical politics, creation of conditions for development of creative initiative of road engineers of all levels;
- in revision of basic principles and approaches to technical regulation and typical designing based on united economical and ecological approaches;
- in creation of effective corresponding to the proposed materials system of quality control of materials and works.

Solutions of those actual problems and recommendations will let us go to the innovative way of development of road sector based on search and accumulation of theoretical knowledge in different adjacent areas of science and technics, practical application of that knowledge for using cheap, but high efficient materials, technologies, instruments, technique and equipment.

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