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Adhesion of Mineral Binders with Organic Aggregates

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Abstract**:** ***The article presents the results of studies of the adhesion properties of organic aggregates such as rice husks, cotton stalks, kenaf core and pine shavings with mineral binders Portland cement, gypsum and alkaline activated binder. It was shown that adhesion between the organic aggregate and mineral binders depends not only on the type of binder, but also on the type of organic aggregate and its surface structure***

Keywords**:** ***Cotton stalks, rice husk, kenaf core, adhesion, mineral binder, alkaline activated binder, Portland cement.***

I. INTRODUCTION

Wastes of plant origin in the form of fibers, particles or threads have great potential for use as a filler, reinforcing substance or filler in composite materials based on mineral binders [1-5]. Such composite materials have many advantages compared to other traditional materials, for example, based on wood, better insulation and fire resistance, better resistance to water, better bactericidal properties, etc. [1], [6].

Plant waste consists of three main components: cellulose, hemicellulose and lignin. The relative fraction of these components may vary depending on the type and plant source [7].

Organic aggregates of plant origin are chemically active compared to mineral aggregates. When preparing an organic-mineral mixture, due to the alkaline environment of the mineral binder, organic aggregate - water-soluble substances (WSS) (the simplest sugars: sucrose, glucose, fructose, as well as starch, tannins and resins) are released from the organic filler into the dough [1], [8], [9]. It is well known that the presence of sugars slows the setting and hardening of cement stone. However, the low strength of organic-mineral compositions cannot be explained only by the presence of WSS in the organic cellulose aggregate, since even when all the WSS have been completely removed from the wood chips, for example, the strength of arbolite obtained on this aggregate does not increase significantly, but at the same time it does not provide obtaining its stable properties [1].

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Although high-strength materials are used in the production of organic-mineral compositions, the problem of obtaining a material with good construction and technical properties still remains. The incomplete use of the strength of the components that make up such compositions is also explained by the fact that the destruction of conglomerate from high-strength materials (binder, organic aggregate) is caused by the disruption of adhesion between them. Thus, the low strength at a significant binder consumption can be explained to some extent by the weak adhesion of the organic aggregate with the mineral binder, since the mineral binder and the organic aggregate are antagonistic in nature.

In addition, the variability in the properties of organic aggregates, in general, depends on the growing environment (temperature, humidity, soil composition, air and age), but also depends on how the plants are collected and processed. Thus, the physical and mechanical properties of organic-mineral composites are highly dependent on the aggregate rock used in the production, as well as on their content, particle size, and particle processing.

The adhesion of a mineral binder to an organic aggregate is largely determined by the bonding of these materials, which occurs as a result of chemical and physico-chemical processes that occur between them.

At present, there is also no generally accepted theory of the nature of adhesion, therefore, it is difficult to identify the nature of adhesion of materials of a complex composition such as mineral binder and organic filler of plant origin. In this regard, the objective of our research is to develop a methodology for determining the adhesion of mineral binders to various organic fillers of plant origin and to find ways to increase the adhesion of mineral binders to organic filler of plant origin. The organic aggregates used in the research (cotton stalks, kenaf core, rice husk) differ from each other, primarily in fractional composition. For example, rice husk has maximum particles (<7mm) that do not allow adhesion to be determined by existing standard methods. In addition, to date, there is no generally accepted methodology for determining the adhesion of organic aggregates with a mineral binder. Existing methods for studying adhesion do not allow determination of the adhesion forces of these aggregates due to the small particle sizes with mineral binders.

II. CHARACTERISTICS OF MATERIALS

A. Organic aggregates

As an organic filler, kenaf core, cotton stalks, rice husks and wood shavings were used in the studies.

Kenaf core - a waste of the primary processing of kenaf stems. The stems of kenaf, before processing to separate the fiber of the bast from the wood, are subjected to special processing.
A necessary stage of such preparation is the soaking of kenaf for 20-30 days in natural reservoirs or pits filled with water, or in special pools with hot water.
During this treatment, water-soluble sugars, organic acids and mineral salts are leached from the fire. In the dumps of the bonfire kenaf comes in crushed form.
The stalks of cotton compared with wood are more flexible and ductile, but less durable. This is due to the fact that cotton is an annual shrub, a significant part of the bast fibers of which does not have time to wood.
Rice husk - a waste of the rice processing industry - is an ellipsoid flake from light yellow to yellow 6-8 mm long, 3-4 mm wide and 0.3-0.5 mm thick. The main components of rice husk as a plant material are cellulose, polysaccharides, hexosans.
Comparative characteristics of organic aggregates are shown in table I.

Table I. Comparative characteristics of organic aggregates [10]

Aggregate	Kenaf core	Pine Crusher	Cotton stalks	Rice husk
The content of water-soluble substances, mg/l	520	900	More 100	Near 800
Humidity%	15	20	14	20
Acidity of water extract, H_{cp}	6,6	7	6,5	6,3
Water absorption in 1.5 hours, %	550	100	300	210
Average bulk density, kg / m^3	60	150	100	105
Density in a dense body, g/cm^3	0,170	0,510	-	-
Sealed aggregate mass, kg/m^3	120	230	180	150
Compaction ratio	2	1,5	1,8	1,5
Volume increase during water absorption after 6 hours,%	0	1	1%	0

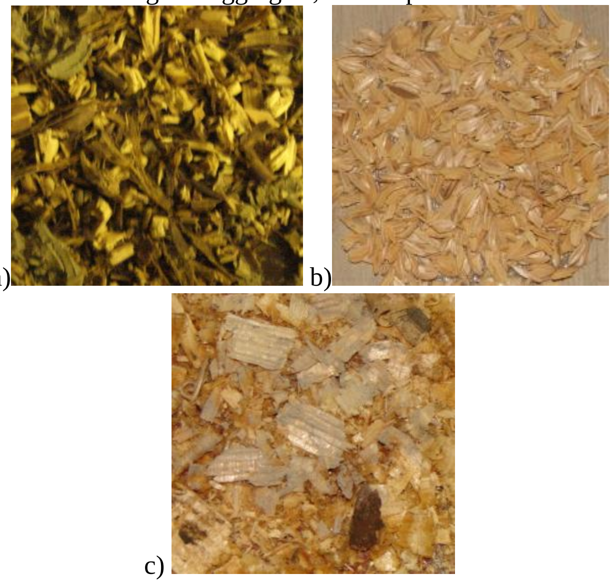
B. Mineral binders

Portland cement (PC), AAB and gypsum were used as mineral binders.
Portland cement ПЦ 400-D20 JSC "Akhangarantsement".
Setting time:
- start of setting - 2 hours 35 minutes,
- end - 3 hours 50 minutes

The normal density of the cement paste is 25.5%.
The AAB consisted of ground Electrotemophosphoric slag and an aqueous solution of sodium disilicate. The normal density of the binder test is 25%.
Gypsum was used brand G4.

III. TESTING METHODOLOGY

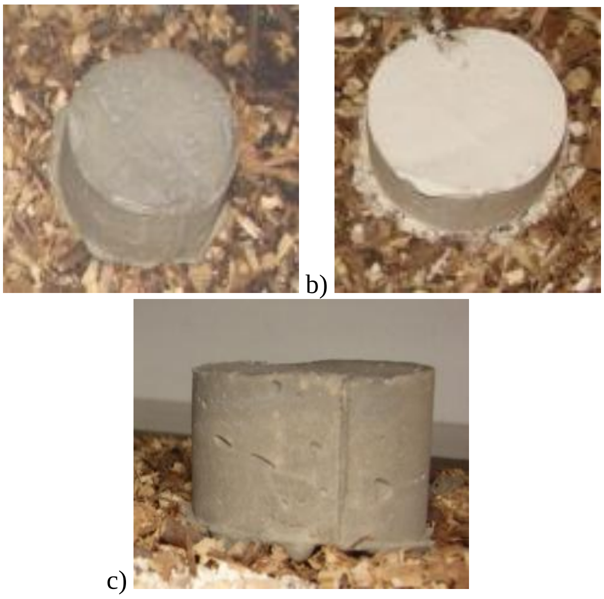
The adhesion of organic aggregates was determined by our developed method. To compare the adhesion between organic aggregates and mineral binders, aggregates were crushed to the size of rice husk particles. The prepared organic aggregates were glued with epoxy glue onto a thick plywood substrate and left until the epoxy glue completely cured (Fig. 1). Therefore, we proposed a methodology for studying the adhesion of organic aggregates. The method is based on determining the strength of separation from the surface of the glued material. To determine the adhesion value for each type of binder and organic aggregate, six samples were made.



a) b) c)

Fig. 1. Glued samples of organic aggregate on the substrate with epoxy glue: a - crushed cotton stalks; b - rice husk; c – pine

After achieving strong adhesion of the particles of organic aggregates with epoxy glue (after 1 day), their surface using formwork with a diameter of 4.5 cm was poured with a test of the studied binder of normal density (Fig. 2). After the binders reached the brand strength after 28 days (for gypsum after 2 hours) hardening, the nozzle of the device for determining adhesion was glued to the surface of the binder using adhesive on a polyurethane basis.



a) b) c)

Fig. 2. Fragments of samples of binders on the surface of the organic aggregate: a - PC, b - gypsum, c - AAB

Adhesion strength was determined using a DYNA proseq Haftprüfer Pull-off Tester tear-off machine from Form + Test Prüfsisteme after 28 days of binder hardening.

The general view of the device, the test process, and the surface of organic aggregates are shown in Fig. 3-4.

Studies were conducted on a test of normal density. Physicomechanical properties of binders were investigated in accordance with current standards and methods.

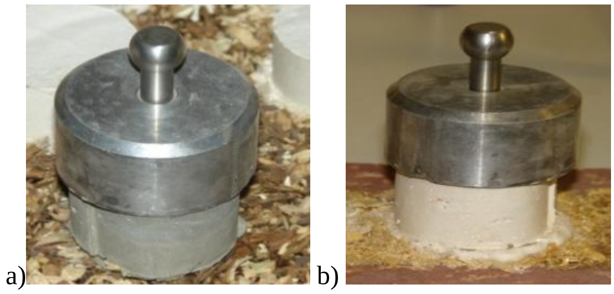


Fig. 3. Gluing the nozzle of the device on the surface of binders: a - AAB; b - gypsum

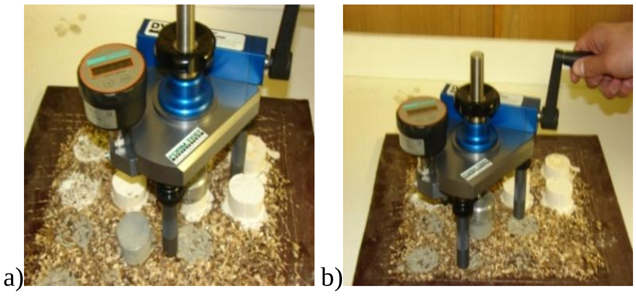


Fig. 4. Fragments of the test of adhesion of binders to organic aggregates: a - AAB; b - the same, PC

IV. RESULTS AND DISCUSSION

The results of the study of adhesion of kenaf core with mineral binders (Fig. 5) showed that the highest adhesion to kenaf core is AAB - 0.087 MPa. Gypsum stone with kenaf core has an adhesion strength of 0.079 MPa. Of the six prepared samples of the PC test, only one sample had a bond strength of 0.0246 MPa, and the remaining five peeled off when the device was installed.

On visual inspection of the surface of the kenaf core, faint traces of the PC are visible, but traces of the AAB and gypsum are visible with the naked eye.

Kenaf core is a waste product that involves the separation of kenaf fibers from the core by soaking in water pools or pits. In the literature, data are provided that when using bast waste in the production of organic mineral composites, there is no need for pre-treatment of organic aggregate, since due to technological operations of separating the fibers from the core, all the available WSS are washed out.

If it is believed that the contained WSS is washed out of the kenaf core, then the adhesion strength of mineral binders to the kenaf core should be the highest. However, the obtained results indicate that the adhesion strength of the PC with the kenaf core turned out to be the lowest in comparison with other aggregates (Fig. 6-8).

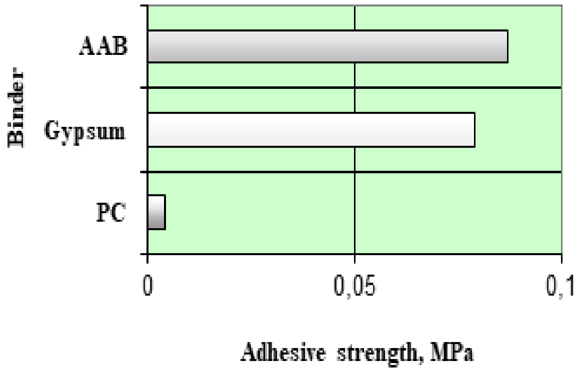


Fig. 5. Adhesion of kenaf core with binders

The data obtained once again confirm the idea that the effect on the strength of organic mineral compositions is exerted not only by the amount of WSS contained in the organic aggregate.

When studying the adhesion strength of crushed cotton stalks with mineral binders, the following results were obtained: the adhesion strength of the AAB was 0.218 MPa, which was the highest compared to other binders, while the PC binder showed a bond strength of crushed cotton stems of 0.055 MPa, and gypsum - 0. 0325 MPa. After separation on the surface of crushed cotton stalks, residues of adhering binders are noticeable (Fig. 6).

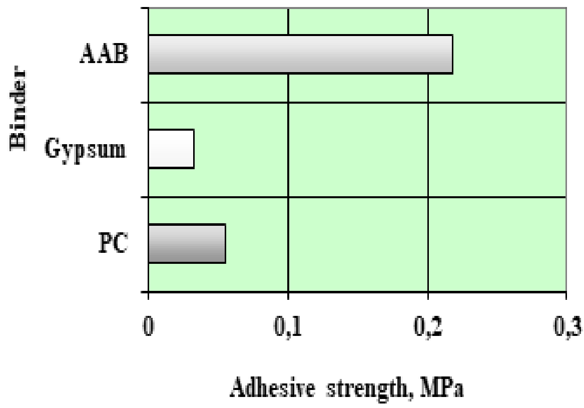


Fig. 6. Adhesion of cotton stalks with binders

The results obtained found that the adhesion strength between raw rice husk and PC is 0,115 MPa (Fig,7). This can be explained by the fact that rice husk has a hard surface compared to other organic aggregates.

The highest strength properties with pine sawdust were also shown by the AAB, which was almost two times higher than the adhesion strength of the PC and was equal to 0.078 MPa, while the PC dough showed a bond strength of 0.022 MPa. The gypsum binder had an adhesion strength of 0.05 MPa. On the surface of pine sawdust after the separation of binders, traces of AAB are strongly visible. The smallest trace is seen when applying the PC (Fig. 8)

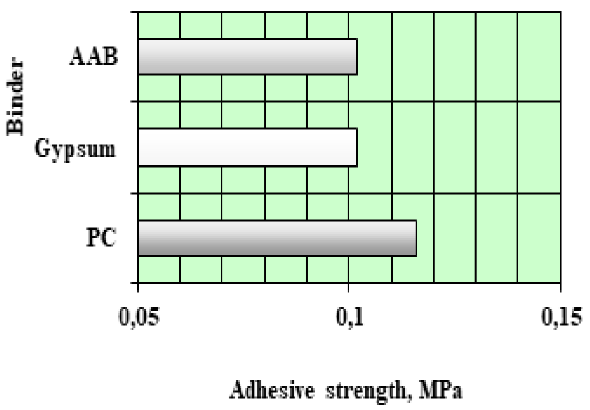


Fig. 7. Adhesion of rice husks with binders

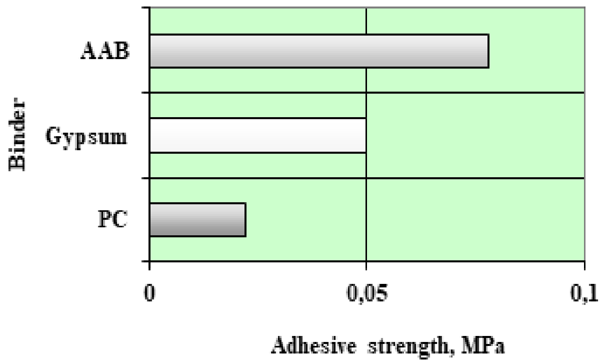


Fig. 8. Adhesion of pine sawdust with binders

PC has the lowest adhesion strength to the kenaf core, which is 0.0041 MPa.

Based on the results obtained, it was found that with organic aggregates the highest adhesion strength was achieved with AAB, with kenaf bonfire - 0.087 MPa, crushed cotton stalks - 0.218 MPa and pine sawdust - 0.078 MPa.

V. CONCLUSIONS

From the results obtained, the following conclusions can be drawn:

1. In our opinion, AAB has a high bond strength with organic aggregates, which makes it possible to obtain an organic-mineral composite material with good technical characteristics.

2. PC had the highest adhesion with rice husk, which was equal to 0.115 MPa.

3. The adhesion between the organic aggregate depends on the chemical morphology of the binder and the organic aggregate, and also depends not only on the type of organic aggregate but also on the structure of the latter.

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