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STUDY OF REGIONAL FACTORS AND BASIC PROPERTIES OF RAW MATERIALS FOR THE BIOCONCRETE FILLER SELECTION

Abstract. *The article analyzes the possibility of using various organic aggregates for bioconcrete and the latest publicly available statistics on the cultivation of the main types of agricultural crops in Ukraine, as well as the amount of production waste during their processing. The world experience in the use of bio-concrete in residential and public construction is studied and summarized. The optimal forms of structural elements and technological features of the use of concrete mixtures with organic aggregate are determined. The main tasks of theoretical and experimental tests are declared. The two most optimal types of mixtures for insulation were selected by preliminary analytical comparison. A program was developed and the main methods and materials for laboratory tests were selected. The key physical, mechanical, and chemical characteristics of some components of bioconcrete were studied, and the dependence of the level of hygroscopicity of raw materials on time and humidity was experimentally determined. Three main compositions of concrete mixtures and bituminous aggregates were experimentally selected. Taking into account the experience of using woodworking industry waste as a filler to prevent fungal damage to the organic component of biobased concrete, phenols were used, which proved to be much more effective in interaction with the proposed composition. The research revealed the peculiarities of the use of bitumen in biobeton with the subsequent need to study the optimal temperature range of the components during further mixing.*

Key words: *bioconcrete, organic filler, physical and mechanical characteristics, hygroscopicity.*

Горб Олександр, Шевченко Олександра, Бідна Надія. ДОСЛІДЖЕННЯ РЕГІОНАЛЬНИХ ЧИННИКІВ ТА ОСНОВНИХ ВЛАСТИВОСТЕЙ СИРОВИНИ ПІД ЧАС ВИБОРУ ЗАПОВНЮВАЧА ДЛЯ БІОБЕТОНУ

Анотація. *Стаття містить аналіз можливості застосування різноманітних органічних наповнювачів для біобетонів та останніх наявних у відкритому доступі статистичних показників вирощування основних видів сільськогосподарських культур на території України, а також кількість виробничих відходів під час їх переробки. Вивчено й узагальнено світовий досвід шляхів використання біобетонів у житловому та громадському будівництві. Визначено оптимальні форми конструктивних елементів і техноло-*

гічні особливості застосування бетонних сумішей з органічним наповнювачем. Задекларовані головні задачі теоретичних та експериментальних випробувань. Шляхом попереднього аналітичного зіставлення обрано два найбільш оптимальні типи сумішей для влаштування утеплення. Розроблено програму й обрано основні методи та матеріали для лабораторних випробувань. Досліджено ключові фізико-механічні й хімічні характеристика деяких компонентів біобетонів, експериментально визначено залежності рівня гігроскопічності сировини від часу й вологості. Експериментально обрано по три основні склади бетонних сумішей і бітумних наповнювачів. З огляду на досвід використання як наповнювача відходів деревообробної промисловості для запобігання грибковим ураженням органічного складника біобетону, використано феноли, які виявили себе значно ефективніше під час взаємодії із запропонованим складом. Дослідження виявили особливості застосування бітумів у біобетоні з подальшою необхідністю вивчення оптимального діапазону температур складників під час подальшого змішування.

Ключові слова: *біобетон, органічний наповнювач, фізико-механічні характеристики, гігроскопічність.*

Introduction. In a world grappling with the consequences of climate change, the construction industry has begun to seek innovative solutions that are both environmentally friendly and resource-efficient. One promising development in this realm is the emergence of lightweight bioconcrete blocks made from plant materials. This article explores the composition, benefits, manufacturing processes, and potential applications of these revolutionary construction materials, as well as the challenges that lie ahead.

Bioconcrete, at its core, is a type of concrete [1–5] that incorporates living organisms that enhance its properties and allow it to adapt and react to environmental conditions. This innovative approach not only improves the structural integrity of concrete but also offers a sustainable alternative to conventional mixtures that heavily rely on cement.

Traditionally, concrete production is responsible for approximately 8% of global carbon emissions, primarily due to cement manufacturing. Bioconcrete can offer a solution by using alternative materials that minimize environmental impact. Lightweight bioconcrete blocks take this concept a step further by incorporating plant materials that provide insulation and reduce the overall weight of the blocks, making them a compelling option for both residential and industrial applications (Fig. 1).

The production of thermal insulation materials in Ukraine is extremely insufficient, and in most regions, due to the lack of raw materials, production has been stopped altogether.

At the same time, there are raw materials available everywhere in Ukraine that do not require complex operations to produce thermal insulation materials.

These include biological waste from agricultural production, in particular, corn cob cores, which, when crushed, are of interest as an effective aggregate for lightweight concrete and thermal insulation materials.

In each region, feed mills produce tens or hundreds of thousands of tons of corn cob rods and sell them mainly as fuel. However, the issue of using corn cobs as a raw material for the production of building materials has remained poorly studied so far.

The main goal of this work was to produce materials for thermal insulation of the enclosing structures of rural buildings based on feed mill waste.

The research objectives were to:

1) Establish the possibility of using corn cob rods as aggregate in lightweight concrete and as a material for backfill;

2) Determine the optimal compositions of lightweight concrete based on corn cob rods;

3) To study some physical, mechanical and thermal properties of the obtained materials;

4) To outline the areas of application of materials based on corn cob rods for rural and urban construction.

The study of two types of thermal insulation materials in rural construction and economic considerations for the use of biofillers based on the results of field studies were carried out.

Vegetable waste from industry and agriculture has long attracted attention as a cheap raw material suitable for the production of lightweight concrete, various thermal insulation materials, plywood, wood-based panels, and other building materials and products.

These types of raw materials include: flax, hemp, rope and kenaf bark, reed waste, large

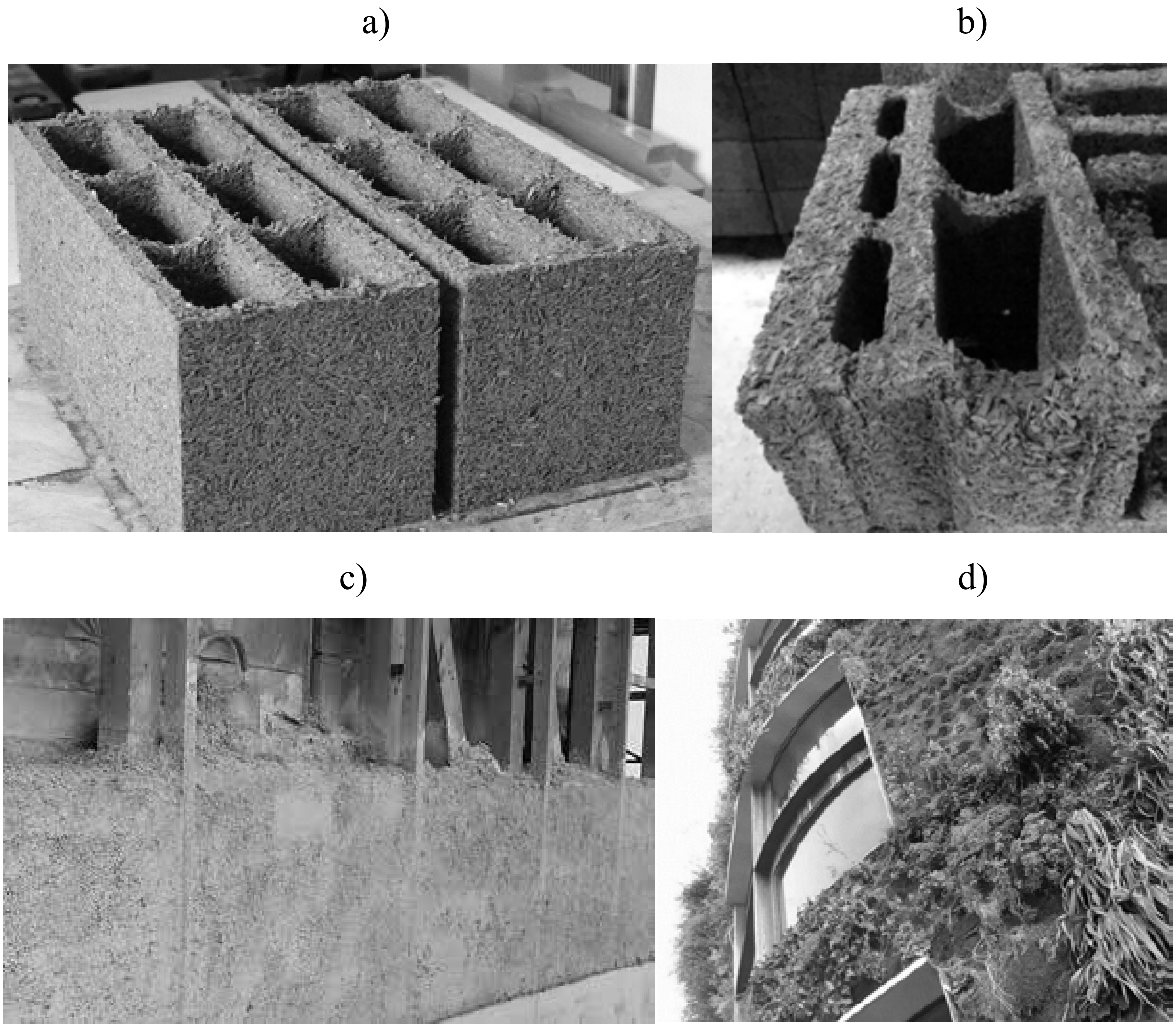

Fig. 1. Examples of bioconcrete application: a) symmetrical blocks; b) asymmetrical blocks; c) insulation; d) eco-building

and small woodworking waste, straw, sunflower husk, sunflower stalk, and corn cob rods.

Materials and methods. The works of researchers from different countries highlight the use of certain types of plant material as aggregates for lightweight concrete, develop their compositions, suggest methods of their manufacture, and establish some of their physical and mechanical properties.

The issue of using agricultural waste such as sunflower husks and stalks, corn cobs as raw materials for building materials is not sufficiently covered in the current literature, especially the use of such waste as organic aggregates in lightweight concrete.

The use of corn cob stalks as the most poorly studied raw material for the manufacture of building materials is currently worthy of attention among agricultural waste.

Over the past half century, the area under corn has increased 1.6 times, yields have increased 3 times, and gross grain harvest has increased 4.8 times. According to statistics, the area under corn in 2018 amounted to 189 million hectares globally and 4.58 million hectares in Ukraine (8.3%). With such a sown area, Ukraine is capable of growing about 25 million tons of corn grain. In particular, in 2021, the corn planted area in Ukraine amounted to 5.3 mln ha, and in the world – about 192 million ha.

Grain warehouses and feed mills accumulate a huge amount of secondary raw materials when grain is threshed.

Only a small part of the waste is used to make furfural. For the most part, corn cobs are used by the local population as fuel and sometimes simply dumped in landfills.

It should be acknowledged that the use of corn stover as fuel is far from rational given its effectiveness as a raw material for building insulation materials. In Ukraine alone, more than 2 million tons of corn cobs will remain after threshing for grain, which, after grinding, will amount to about 10 million m^3 of lightweight pellets.

Almost all regions of Ukraine will have sufficient quantities of this raw material for the production of thermal insulation materials.

The hydrolysis industry and furfural production are expected to use about 500 000 tons of corn cob stalks, including some stalks that were proposed to be used for cattle feed in the form of flour, which allegedly contains nutrients.

But turning the cobs into flour is a very labor-intensive process and hardly profitable for business. In practice, it is known that even mechanized feed mills refuse to process corn cobs into flour because of their elastic rubber-like structure.

There is almost no data on the use of corn cobs for construction purposes. It would make more sense to use a significant portion of the cobs for the production of heat-insulating building materials, providing the population with fuel instead.

In Ukraine, the main areas with the largest corn crops, and thus areas of possible concentration of raw materials, are Dnipropetrovsk, Odesa, Poltava, Kharkiv, and Kirovohrad regions. However, not all of the cobs concentrated in these regions can serve as a raw material base for industrial processing.

If at least 0.5 million tons of corn cob stalks are used rationally for construction in Ukraine, this amount could produce about 2.5 million m^3 or 30 million m^2 of local efficient heat and soundproofing building materials.

The most readily available and widespread aggregate for bioconcrete is corn cob stalks, which are a waste product of corn production. They make up 22–25% of the cob weight. Fresh cobs have a moisture content of 10–18% and a bulk density of about 200 kg/m^3.

The rods have the shape of a cut cone 30–150 mm long and 25–40 mm in diameter. This is a wood-like material with a bulk density of 350-400 kg/m^3 in a “dense body”. The outer surface of the rod is covered with a layer resembling a honeycomb, which significantly reduces their bulk weight.

Disscussion. Cobs have a heterogeneous structure. They consist of a honeycomb with scales, a trunk, and a core. The outer layer and the trunk make up about 98% of the total weight of the cobs. The core is only 2% of the total weight. It is a highly porous, hygroscopic, lightweight white substance that is well wetted by cold water (Fig. 2).

The shaft of the rod is tree-like, elastic, and the densest and strongest. The outer “honeycomb” part has a very developed and rough surface.

The rods contain a lot of soluble and hydrolyzed carbohydrates and hemicellulose. Hemicellulose, which is part of the cell wall membranes, belongs to the group of polysaccharides in terms of its chemical composition and is a substance close to cellulose. Unlike cellulose, it has less chemical resistance and is easily hydrolyzed by dilute acids and alkalis, turning into simple sugars, such as rentoses and hexoses.

The extractable substances in the rods are some soluble monosaccharides, organic acids, mineral salts and acids, volatile oils, fatty and resinous acids, etc. During extraction with water, sugary substances, organic and mineral salts and acids are extracted from the rods. The influence of extraction time in cold and hot water and in a 1% NaOH solution of crushed corn cob rods one month after harvesting was investigated. The studies show that the amount of extractives that have passed into the solution increases with increasing temperature and alkalinity of the medium, as well as the degree of grinding of the extracted particles of the rods. In 15 minutes, 4 times less extractive substances are transferred to the aqueous solution from the 10–20 mm fraction than from particles smaller than 3 mm.

With an increase in extraction time to 3 days, this ratio decreases to two. The amount of extracts from the coarse fraction of the rods passes into the alkali solution is half that of the fine fraction at any extraction time.

Rods can be treated to localize extractives on the binder by physical or chemical means, as well as by a combination of both. The physical effect can be carried out by oxygen /oxidation/, sunlight, heat and water.

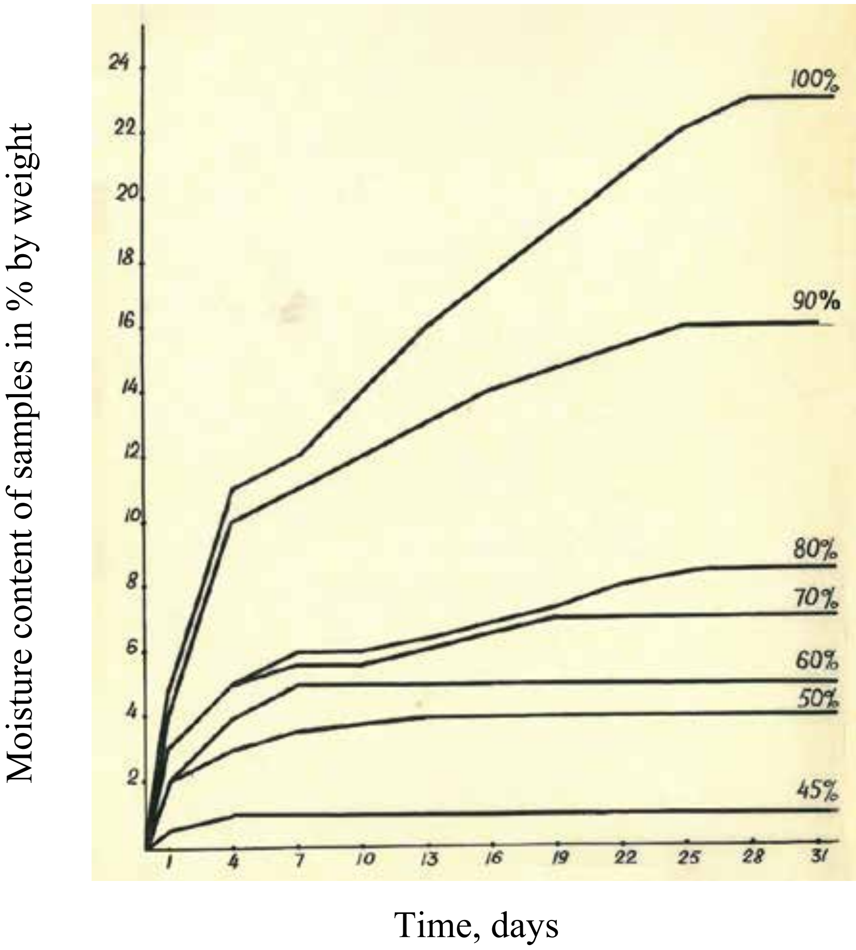

Fig. 2. Dependence of hygroscopicity of raw materials on time and humidity

Chemical localization is achieved by treating the rods with special substances to convert plant sugars into insoluble or harmless compounds for cement, as well as to create impermeable films on the surface of wood particles.

Water-soluble sugars are attacked by various bacteria, fermented and partially oxidized, and vitrified during drying or crystallized, becoming less soluble than the sugars in fresh cobs.

As the crushed corn cobs are kept in the air, the amount of water-soluble substances in them decreases at the age of three months compared to one month by 15–20% in cobs with a particle size of less than 3 mm and by 20–30% in cobs with a particle size of 10–20 mm; in the case of longer keeping in the air (up to b months), the amount of water-soluble substances decreases, but slightly.

Based on the research, it can be concluded that corn cob stalks are much more resistant to fungi than wood. It can be assumed that the fungal resistance of the cores depends on the presence of extractive substances that are toxic to fungi, which can be tannins and phenols. Phenol has fairly good antiseptic properties. In addition, according to Terek Sylvester, corn cobs do not contain mannan, which, according to Nikitin, is easily decomposed by various bacteria and fungi.

The properties of cements and butums used in the work are given in Tab. 1–2.

Petrolatum

A mixture of solid paraffin wax and high-viscosity mineral oil. The softening point is about 55°. It is used for some lubricants, for high-speed drying of wood, etc.

Cookersil

This is a dark-colored liquid with a specific gravity of 0.92. The raw material for its production is heavy shale resin. Cookersil has thermal activity and high heat resistance (up to 200°).

Results. On the basis of crushed corn cob rods and bituminous binders, it is possible

Table 1

Cements

№	Type and activity of cement	Normal density of cement dough in %	Curing times		Compressive strength, MPa	Volume weight, kg/m³	Uniformity of volume change
			Start time	End time			
1	Portland with an activity of 50.6 MPa	24.3	3–15	6–00	50.6	1057	Y
2	Portland with an activity of 59.0 MPa	21.4	0–18	3-30	59.0	1053	Y
3	Portland with an activity of 45.6 MPa	24.5	4–00	9-00	45.6	1022	Y

Table 2

Petroleum bitumen

Main properties of petroleum bitumen	Bitumen types		
	PB-III	PB-IV	PB-III – 60%, PB-IV – 40%
Bitumen hardness /penetration/ in degrees	56	21	40
Extensibility /ductility/ see at t = 25°C	42	4	18
Softening point on the "Ring and ball" device in degrees	52	80	63

to obtain tile materials with a bulk weight of 340–400 kg/m³ and a compressive strength of 0.3–0.6 MPa, which can be used for thermal insulation of buildings with high humidity. It is better to produce tile insulation with pure bitumen and hot bitumen mastic by dipping, and with cold pastes by mixing. The best slab insulation in terms of strength, bulk weight and transportability is insulation based on pure PB-IV bitumen, as well as on a mixture of PB-III and PB-IV bitumen, respectively, 60 and 40% by weight.

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