Features of building composites designing for their exploitation in extreme conditions

V Lesovik¹, R Fediuk², E Glagolev¹, I Lashina¹, A Mochalov² and R Timokhin²

¹ Belgorod State Technological University named after V.G. Shukhov, 46, Kostyukova St., Belgorod, Russia
² Far Eastern Federal University, 8, Sukhanova St., Vladivostok, Russia
fedyuk.rs@dvfu.ru

Abstract. The types of natural and technogenic impacts to protective structures are systematized. It was revealed that the protective structures research on the effect of the damaging factors complex of weapons modern types was not carried out. The results of a study on the rice husk ash use as a component of a composite binder are presented. To achieve the purpose of the work, an organomineral nanomodifier was developed with the following composition: 32% of cement, 31% of ash, 17% of quartz flour, 14% of crushed limestone, 6% of hyperplasticizer. The modifier was ground to a specific surface area of 500–900 m²/kg. It was added to cement in the amount of 1, 3, 5, 7, 10%. Water was added in the amount necessary to ensure the same mobility. Cement stone was studied at the age of 1, 3, 7, 28 days. Curves of strength were constructed. It was found that rice husk ash (amorphous and porous) obtained at a burning temperature of 600 to 700°C (using the appropriate combustion method) has the potential for use in structural concrete due to the pozzolanic properties of such rice husk ash.

1. Introduction
Modern political realities, as well as the more frequent natural and man-made disasters (Figure 1) require reliable protective and other special structures.

Systemic design of building composites for special structures requires a comprehensive account of all impacts that can, both strengthen and weaken each other. Accordingly, the abundance and heterogeneity of impacts causes difficulties in their adequate joint accounting.

The radiation protection of various structures is studied in great detail. A number of concretes are developed on various heavy fillers (serpentinite, magnetite, hematite, limonite, etc.).

Protection of fire and high temperature was researched by V.M. Kretova and T.A. Hezhev [1], Feng Wang [2], Izotov V.S [3]. Increase in strength and impermeability of structures was researched by V.I. Loganina [4], R.S. Fediuk [5–7], as well as V.S. Lesovik's School of Science [8–9]. It is proved that the creation of high-density and high-strength composites is possible only due to the synergistic action of organic and mineral additives, and also by controlling the structure formation at nano-, micro- and macrolevels.

At the same time, the protective structures study for the effect of a damaging factors complex of modern weapons was not carried out. The main characteristics required for the enclosing structures’ materials of protective structures are compressive strength, impact endurance, protection against
radiation, gas permeability. Obviously, to ensure the protective properties of shelters against modern weapons, it is necessary to develop fundamentally new composites.

In fact, the contribution of the cement industry to the global emission of greenhouse gases, especially CO₂, is 8-10% and with the addition of the third most energy-intensive industry cause serious environmental concern in the industrial environment. Replacement of a cement part with various additives (including waste products) allows reducing the emission of greenhouse gases to the atmosphere.

The use of finely ground multicomponent cements and binders of low water demand of various compositions allows the composites creation with predetermined mechanical and operational properties. However, it is necessary to carefully select the binders’ composition, as well as the choice of technology for modifying and manufacturing binders.

As a raw material for the production of mineral additives, raw materials of both natural and technogenic origin can be effectively used, in particular by-products of energy manufacturing (fly ash and slag waste); of ferrous and non-ferrous metallurgy (molding sands, slag, secondary dross); waste of crystalline silicon production, etc.

It should be noted that non-crystalline (amorphous) silica is chemically more active than crystalline silica. Silica in amorphous form in our country is made from natural (perlite, obsidian, diatomite, kieselguhr, nepheline, trepel) and man-made silicate raw materials, quartz sand in the main form of “white soot” and pyrogenic silica (aerosil).

In addition, sources for the production of amorphous silica may include geothermal waters (for example, in the Kamchatka Krai), as well as siliceous plants: oats, horsetail, larch needles, and diatoms.

2. Results and Discussion
The use of crop waste as mineral additives is of particular interest in recent years. There are 200 kg of husk out of a grains rice ton, after combustion, 40 kg of ash is formed, which consists of 80–85% of silica.

The structure of rice husk ash (RHA) is affected by the combustion conditions. Initially, rice husks contain about 50% of cellulose, 25–30% of lignin and 15–20% of silicon dioxide. After burning,
cellulose and lignin are removed, leaving quartz ash behind. Based on the temperature range and the duration of the husks burning, crystalline and amorphous forms of silica are obtained (Table 1).

### Table 1. Influence of the combustion temperature to the RHA structure.

| Temperature, °C | RHA structure | Specific surface area, m²/g |
|----------------|---------------|-----------------------------|
| less than 500  | Particles are spherical with a porous structure | 0.5 – 2.1 |
| 500 – 600      | Porous crystalline grains less than 1 mm, possibly exhibiting a transformation between amorphous and crystalline state | 76 – 122 |
| 600 – 700      | Amorphous particles and pore diameters are the highest | 100 – 150 when the temperature decreases |
| 700 – 800      | Partially crystalline formation of coral crystals | 6 – 10 |
| 800 – 900      | Crystalline | less than 5 |
| 900 – 1000     | The formation of coral-like crystals increased and gradually became smaller and melted | - |

Based on the works’ analysis of the world's leading scientific schools [10–14], the following conclusions are drawn:

1. Only rice husk ash (amorphous and porous) obtained at a combustion temperature of 600 to 700°C (using the appropriate combustion method) has the potential for use in structural concrete due to the pozzolanic properties of such an RHA.
2. The chemical composition of the RHA shows a high content of silicon dioxide and, in addition, the chemical composition is not affected by the geographical location of the rice fields.
3. Mixtures containing RHA require more water to achieve a standard consistency compared to samples without RHA, and the water demand increases with the replacement of the cement to RHA. Accordingly, it is necessary to use plasticizers.
4. The density of concrete containing RHA is can be used for general construction works within the range for conventional concrete.
5. The compressive strength of concrete containing RHA depends on the water-cement ratio, but at least up to 10% of the RHA cement replacement will lead to strength comparable to the no-additive samples.
6. An impermeable RHA-concrete microstructure to a degradation agent, for example, sulfate attacks, chloride penetration, etc., and also due to good shrinkage properties, makes it possible to use concrete as durable during its operation.

At the same time, there was no purposeful research of using RHA possibility for self-compacting concretes with predetermined properties necessary for protective structures.

One of the main protective structures characteristics is shock endurance. There are several technological ways to solve this problem. One of them is to increase the static strength of concrete, and this way is practiced in a number of foreign countries. It is based on the use of high-quality cements, fractionated aggregates, and superplasticizers. Another direction is the modifying the structure technology of concrete by introducing into the concrete mixture some porous dispersed components (damping additives). This method’s studies of the concretes’ shock endurance increasing are devoted in works of P.G. Komokhov [15], R A Ibragimov [16–17], etc. However, these concrete provide a relatively moderate increase in shock endurance - up to 2–4 times, which is not sufficient for protective structures in the conditions of destruction’s modern means, which create high dynamic loads on enclosing structures.
Perspective is the use of fiber-reinforced concrete in the production of protective structures’ enclosing ones (G. Kakali [18], V.S. Lesovik [19], R.S. Fediuk [20–21]), which has high impact resistance. Dispersed reinforcement allows to significantly increase the whole set of physical and mechanical characteristics of concrete, such as static strength, crack resistance, impact resistance.

Thus, it is expedient to develop dispersed-reinforced concrete on composite binder using production waste.

To achieve the work purpose, an organ mineral nanomodifier was developed with the following composition: 32% of cement, 31% of ash, 17% of quartz flour, 14% of crushed limestone, 6% of hyperplasticizer. The modifier was ground to a specific surface area of 500–900 m²/kg. It was added to cement in the amount of 1, 3, 5, 7, 10%. Water was added in the amount necessary to ensure the same mobility. Cement stone was studied at the age of 1, 3, 7, 28 days. Curves of strength were constructed.

In order to determine the maximum effectiveness of the RHA action to cement stone, two-factor variation was made: the first factor is the optimal dosage (0–12%), the second factor - the fineness of grinding (500–900 m²/kg). As a control sample, a pure cement stone of fine-grained cement was used.

The analysis of the obtained results showed that the maximum increase in strength of about 30% in comparison with pure Portland cement is achieved with the introduction of RHA in 14% amount. Further increase in the content of the additive in the system leads to a drop in strength (Figure 2), which is due to the system dilution, as well as an increase in the water demand of the mixture.

![Figure 2. Compressive strength dependence of cement stone on the introduced RHA amount.](image)

Further, an almost linear dependence of the required grinding time of organ mineral nanomodifier was found for achieve a different specific surface in the range from 280 to 900 m² / kg (Figure 3, a). Obviously, the required grinding time can be predicted to reach a certain surface area with these data. The modifier was injected into the cement, water was added, and the compressive strength was measured after 28 days after grinding the organ mineral nanomodifier components together with 6% by weight of Pantarhit PC 160 and measuring the surface area. The results are shown in Figure 3, b.
Figure 3. Dependence of the compressive strength of cement stone on the grinding time of an organomineral nanomodifier.

It can be seen that the maximum compressive strength was obtained at a surface area of 550 to 600 m$^2$/kg. The increase in the surface area does not lead to a further increase in strength, and even to a decrease. This is due to the excess of fine particles, because the superplasticizer limit was reached, that we had investigated earlier [22–23]. This behavior was also observed in the change in the viscosity of the mixture when the surface area of the particles was above 600 m$^2$/kg. It is expected that an increase in the amount of superplasticizer will lead to the creation of concrete with an even greater compressive strength.

3. Conclusion
It was revealed that the use of crop waste as a component of the organ mineral nanomodifier helps to reduce the viscosity and improve the structure formation of their basis water-binding systems. This leads to improved formability of self-compacting fibrous concrete, while the developed surface and the presence of nanoscale particles predetermine the growth of the contacts and mechanical adhesion number between the particles during compaction, providing high rates of raw strength and, as a consequence, the possibility of using concrete mixtures for constructing of important complex configuration structures.

Thus, designing and creating materials for special structures is a very difficult task, which requires the unification of scientists’ scores. The only way to solve this problem is transdisciplinarity, a way of expanding the scientific world view, which consists in considering a particular phenomenon outside the framework of any scientific discipline.

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