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SULFUR CONCRETE AS A CONSTRUCTION MATERIAL

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This article highlights the experience of the usage of sulfur concrete, its advantages and disadvantages (compared to traditional concrete, based on Portland cement), particular manufacturing technologies of the sulfur concrete, its applications in construction.

Introduction. Concrete is one of the most popular building materials in the world. It is used in almost all civil and industrial construction sites. Traditional concrete, consisting of a binder (e. g. Portland cement), large and small aggregates, different additives and water, is usually made using technologies, which allow to achieve the high quality of finished products. However, the construction industry is growing and there are new ways to improve the quality of construction materials.

Sulfur as a binder for the production of concrete. Several investigations, aimed at creating new construction and building materials, based on the previously idle connections and including elemental sulfur are conducted in many countries of the world. Nowadays, in the world industry, and particularly in oil-refining industry of Belarus, there is a problem of sulfur waste, produced during the purification of gasoline and diesel. The situation with sulfur determines the need of looking for new directions for its use, including the usage of sulfur as a binder in the production of sulfur concrete and sulfur-based products.

Sulfur concrete is a composite material which includes sulfur binder, inert aggregates and extenders. The presence of sulfur binder is a sulfur concrete difference from traditional (based on Portland cement) concrete, so it is necessary to know about the properties of sulfur to produce sulfur concrete.

Sulfur is able to compound with almost all chemical elements, it is one of the most common non-metallic elements in nature, its compounds can occur in all aggregate states (solid, liquid, gas). Based on the physical characteristics, sulfur is a crystalline solid, stable in two modifications: orthorhombic (density 2.07 g/cc) and monoclinic (density 1.97 g/cc). The melting point of the sulfur is about 118 °C, the boiling point is 445 °C. In the sulfur market there often appear its lump, granular or liquid forms.

The binding properties of sulfur are known from the 17^{th} century. At first, it was used for connections of the metal and stone elements in the production of ship anchors. Sulfur has been actively explored for its usage in the construction, firstly in the US, and later in the Soviet Union.

Sulfur concrete was actively investigated in North America in the 70-s of the 20^{th} century, when it has been proved that sulfur is safe to environment. Initially sulfur concrete was investigated as a two-component compound (sulfur and a filler). There are some advantages that have been identified in relation to traditional concrete: low water absorption, high corrosion resistance, fast curing and the preservation of high strength. But the disadvantages of the sulfur concrete, produced in that period of time, were also present (low resistance to high temperatures, low fire resistance). In addition, when large amounts of sulfur concrete harden, shrinkage occurs to considerable number of cracks. The other disadvantage of sulfur concrete is the need to maintain the temperature of 140 °C during its production, as well as the high requirements for the precision production technology compliance [1].

With the development of technology and improvement of sulfur concrete, it became known that under the influence of changing in temperature, solar radiation and other effects, the sulfur structure can be changed by changing its molecules from one allotropic state to another, which leads to the emergence of dangerous internal stresses which can destroy the integrity of the material, thereby reducing the durability of the material. In addition to adversely affecting the sulfur concrete weather, particular attention was paid to the fragility of sulfur, which led to higher brittleness of sulfur concrete (compared to the cement concrete). Many of the shortcomings could be eliminated by improving the material and technology, however, many are preserved to this day.

To reduce the impact of the above-mentioned shortcomings in the quality of the sulfur concrete, researchers have proposed to add in the sulfur binder various plasticizing and structuring additives – modifiers. This modifies are divided into four groups: plasticizers, stabilizers, flame retardants and antiseptics. Plasticizing agents are added into the sulfur binder to reduce the brittleness and increase the strength of the sulfur, to slow crystallization upon cooling. These plasticizing agents include: naphthalene, paraffin, dicyclopentadiene, polystyrene, coumarone resin, carbon black, graphite. Stabilizing additives are intended to change the structure of sulfur and to increase its resistance to atmospheric conditions. These include: dicyclopentadiene, thiokol, iodine, phosphorus, selenium, arsenic, antimony trichloride, bitumen, carbon black, naphthalene. Flame retardants are used to reduce the flammability of the sulfur compositions. Antiseptics are used to increase the biological stability of the sulfur concrete. There are positive and negative qualities of sulfur concrete, made of modified sulfur [6].

Moisture resistance of sulfur concrete is better up to 20%, compared with traditional concrete, acid resistance – up to 3,5 times, frost resistance – up to 6 times, abrasion resistance – up to 6 times, compression strength – up to 3 times, bend strength – up to 2 times, tension strength – up to 2 times, curing speed – up to 80 times [2, 3].

The main advantages of sulfur concrete over traditional one are its higher strength properties (compressive and flexural), the ability of this material to work under the tension loads (depending on the modifier, this index is increased), high chemical (corrosion) resistance, lower rates of water absorption and water permeability, high frost resistance, fast curing, the possibility of winter concreting. In addition, products, made of sulfur concrete can be subjected to repeated heating and re-processing of molding designs, eliminating the waste and scrap. It is worth noting another important advantage of the concrete made using the sulfur binder – is the lack of water in the manufacturing process, which allows for operation at low temperatures. Sulfur concrete absolutely hydrophobic and does not absorb water, so is ideal for the manufacture of deep foundations in the grounds of a high water table. Depending on the characteristics defined for the manufactured building material, every manufacturer and patent holder of technology defines its requirements for raw materials [5].

The first patent relating to the properties of sulfur concrete and its production technology has been registered in the United States. In this document it was mentioned such a thing as a sulfur modifier for the production of higher-quality sulfur concrete for the first time. However, the trade production of the sulfur concrete (and products based on it) was firstly established by Canadian company StarCrete (previously it was called Sulfurcrete) in 1975. His company, together with Cera Innovations Ltd, has developed a technology for the production of concrete on the basis of the modified sulfur. According to this technology, molten sulfur and the modifier is applied to the concrete preparation place, where it is mixed with a pre-warmed aggregates and fillers, forming sulfur concrete mixture. Currently, products under the brand name StarCrete widely used for the manufacturing of corrosion-resistant structures for the protection and repair of concrete floor coatings in chemical and food industries and others [1].

Later, the technology, alternative to that was introduced on Sulfurcrete enterprise, was mastered. The main difference – modifiers are entered directly while stirring the melt with warm sulfur aggregates. In 1991, the US Patent about the preparation of granulated sulfur concrete technology was published. Its appearance was due to the need for the manufacture of construction materials anytime, anywhere (before this technology it was necessary to maintain a certain temperature of the solute, that add additional place and time limits). In principle, the technology of producing sulfur concrete granules were differed from the others in the disposition of the ready mixture in a unit, where the concrete is exposed to the effects of gas (high-pressure) or water, and that contributed to the formation of granules. This allowed to transport it in a packaged form or in bulk over long distances and produce products directly on the construction site. For further use it was needed to reheat the pellets to the melting temperature about 140–150 °C.

Another country, that has actively explored sulfur for its possible use in construction, was the Soviet Union, in which the first application of sulfur concrete was carried out in 70-s of 20th century. Nowadays in Russia there is not any large-scale production of sulfur concrete. JV LLC "Inter-S" (Astrakhan region) has a manufacturing technology of such material, developed jointly with "Astrakhangazprom", NIIZhB and the Ministry of Construction of the Russian Federation, but actually it is producing only a modified sulfur (sulfur cement) for the production of sulfur concrete. However, the production of sulfur cement has no foreign analogues in Russia.

Traditionally, the sulfur polymer cement is produced in a circular manner in a batch reactor equipped with a stirrer, using expensive chemical modifiers. The process for this reaction, to afford the final product, takes up to several hours. The technology, offered by LLC "Astrakhangazprom", is different from usual in that the process takes place in a continuous technology, using low-cost and environmentally safe chemical modifier. "Gazprom Sera" (Astrakhan) is actively engaged in a large-scale production of sulfur concrete, but it is not possible nowadays. The lack of opportunities is occurring due to the lack of precision equipment, capable of regulating the heating of the mixture in the range of ±1 °C. Upon heating the mixture above 150 °C, it is released hydrogen sulfide and sulfur dioxide - gases which have nerve activity and pose a threat to humans. Therefore, it is especially important to the establish industries that can produce large quantities of sulfur concrete with the strict compliance with technological standards.

Another country actively engaged in the production of sulfur concrete is Kazakhstan. The company "Serobeton Story" has received the money grand and has developed the sulfur concrete waste-free production process. Innovative technology provides up to 100% replacement of Portland cement products for certain sectors of construction and solves environmental problems of oil producing regions of Kazakhstan through the use of technogenic waste (lump sulfur) [4].

Several European countries, such as Poland, Germany, France and other are using sulfur concrete not only for the production of structural materials (replacing traditional concrete), but also in road construction (for road paving).

With regard to our region (Belarus), sulfur is not used as a binder in the concrete production at present time. But it is investigated for the reason of practical application and further development of a large volume

scale. The scientific interest to the subject of sulfur concrete use is due to not only to the its unique properties, but also due to the problem of recycling of the technical sulfur. The stocks of it are increasing due to ever-increasing volumes of recycling of sulfur-containing hydrocarbon feedstock (natural gas, oil) and a deeper cleaning of sulfur refined products.

Conclusion. According to the properties of the sulfur concrete, the usage of sulfur in the construction industry of the Republic of Belarus can be a cost-effective direction. It could be because of the number of advantages of the products, made of sulfur concrete, comparing with traditional concrete (better performance and physical and mechanical properties for some sectors of construction, increased durability). Based on this, we can make a conclusion about the curracy of investigating the properties of sulfur concrete, as well as the technology of its production.

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