Impact of sulfuric waste on the properties of concrete composites

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ABSTRACT:
The article presents the results of tests on compressive strength, bending tensile strength and frost resistance for concrete with a content of 24% to 36% of sulfur polymers derived from the purification process of copper and other non-ferrous metals. The obtained results of the research allowed to indicate areas of application of this type of concrete. In addition, the article presents the technology and method of making sulfur concrete, focused on the basic physical and mechanical characteristics of this type of concrete. The problem of industrial waste recycling was discussed and sulfur concrete was indicated as one of the ways to reuse waste sulfur.

KEYWORDS:
concrete composites; sulfur waste recycling

1. Introduction

Sulfur concrete is a type of structural concrete. Typical composition of this type of concrete is: sand, gravel or glass (55-80% by weight) and sulfur polymer which is added to the mixture at high temperature. The sulfur binder combined with a properly selected aggregate creates concrete with satisfactory strength and a relatively long service life. During the binding of sulfur concrete, no chemical reaction occurs. The concrete mix is built into the building and left to cure as a result of a slow temperature drop [1, 2].

As a result of the slow cooling of the sulfur concrete mix, changes occur in the sulfur crystallographic system, which results in the concrete obtaining strength. Sulfur concrete is characterized by resistance to acids and salts, low permeability and thermoplasticity comparable to some asphalt concretes. In the temperature range from 130 to 140°C, the sulfur concrete mix changes its consistency from solid to liquid or plastic. Sulfur concrete is a material similar to typical concrete, however, it differs faster in setting the mix, greater early compressive strength, acid resistance, water resistance, oil resistance, resistance to aggressive environment. No water is used in the production of sulfur concrete [3, 4].

Sulfur concrete is mainly used in the construction of tanks for toxic materials, pipelines, underwater constructions, strengthening of sea shores. This type of concrete is also often used to build road surfaces loaded with traffic and industrial floors exposed to an aggressive environment. Sulfur concrete can be made of recycling materials such as polymers from modified waste sulfur, then with the addition of suitable sulfur concrete fillers can be used in the production of road curbs, paving stones, drainage troughs, road foundations or sewage pipes. Conducting the production of sulfur concrete using sulfur polymers which are post-production waste, reduces production costs. The use of environmentally harmful waste materials as a substitute for aggregate reduces the negative environmental impact of landfilled waste [5-8].
2. The method of producing sulfur concrete

The production of sulfur concrete is a demanding process. For the production of sulfur concrete it is necessary to create an appropriate environment that guarantees the workability of all components of the sulfur-concrete mix. The main problem in the production of this type of concrete is obtaining a temperature of sulfur concrete in the range of 130 to 140°C [2-4].

The materials used in the study to produce sulfur concrete were sulfur polymer, quartz aggregate and quartz powder. The sulfur binder derived from the purification process of copper and other non-ferrous metals modified with styrene in the amount of 5% by weight was used as the sulfur polymer in the study. The polymer under the influence of temperature in the range from 130 to 140°C changes the solid form into a liquid form and turns dark brown. The polymer used in the test is flammable at temperatures higher than 168°C, therefore special attention was paid in order not to exceed this temperature. The polymer used in the research also has a characteristic sulfur smell. The study also used quartz gravel with aggregate grain size 2-8 mm and quartz flour with a grain thickness of 0.065 mm and a density of 2.2-2.5 kg/dm³ in white.

3. Own research

The main purpose of our own research consisting in producing a sulfur concrete mix was to investigate the impact of sulfur-based waste on the properties of concrete composites.

In the conducted research it was decided to make samples of sulfur concrete with sulfur polymer content and other components of the sulfur concrete mix as shown in Table 1.

Table 1
Percentages of each component of the sulfur concrete mixes tested

| Concrete series | The content of ingredients [%] |   |   |
|-----------------|--------------------------------|---|---|
|                 | Polymer of sulfur | Quartz aggregate | Quartz powder |
| A               | 24                | 64             | 12            |
| B               | 26                | 62             | 12            |
| C               | 28                | 60             | 12            |
| D               | 30                | 58             | 12            |
| E               | 32                | 56             | 12            |
| F               | 34                | 54             | 12            |
| G               | 36                | 52             | 12            |

During all series of concrete, quartz aggregate was preheated, which was added to the container gradually in several equal portions. The aggregate temperature before the test was about 25°C, the heating time was on average 2 hours and 40 minutes, the temperature of the aggregate at the time of feeding the mixture of sulfur binder and quartz flour was about 145°C. The mixture of sulfur binder and quartz flour was made in a separate container, the temperature of the mixture when added to the quartz aggregate was about 25°C. At the time of combining the three components, no change in the consistency of the mixture was observed. The first mixing time was about 4 minutes, during which time, according to the visual assessment, the sulfur polymer, quartz flour and quartz aggregate formed an evenly distributed mixture. Subsequent mixing was repeated cyclically every 2 minutes and the mixing time was 30 seconds. After 10 minutes, a change in consistency from solid to liquid was observed. After 30 minutes, the mixture reached a consistency enabling it to be placed in steel molds. The temperature of the mixture at the time of pouring it into the molds was around 143°C. After placing the mixture in steel molds, it was immediately compacted. The average time taken to make samples was about 3 hours 15 minutes. Samples were demoulded after 24 hours.
For each type of concrete, 6 cubic samples with dimensions 150x150x150 mm and 12 cubic samples with dimensions 100x100x100 mm and 6 cuboid samples with dimensions 150x150x600 mm were made. Cubic samples were subjected to compressive strength tests after 2 and 28 days and frost resistance tests, while cuboid samples were subjected to compressive strength and flexural tensile tests after 2 days and after 28 days. The compressive strength test was carried out in accordance with [9], the concrete frost resistance test was carried out in accordance with [10], while the bending tensile strength test was carried out in accordance with [11-13].

Figure 1 shows the results of the compressive strength tests of cubic samples with dimensions 150x150x150 mm, while Figure 2 shows the results of tensile strength tests when bending cubic samples with dimensions 150x150x600 mm.

The tests obtained high early compressive strength, the largest increase in compressive strength tested after 28 days, occurred for the C and D series samples and amounted to 13%. The smallest increase in compressive strength occurred in series A. In flexural tensile strength tests, low early strength and a slight increase in strength after 28 days were obtained, for all samples ranging from 4 to 10%.

Table 2 summarizes the results of frost resistance tests.
Table 2
Frost resistance test results

| Concrete series | Compressive strength after freezing and thawing cycles [MPa] | number of freezing and thawing cycles |
|-----------------|------------------------------------------------------------|--------------------------------------|
|                 | control sample | sample tested | decrease in strength [%] |                             |
| A               | 36.89          | 29.91         | 18.9                   | 100                         |
| B               | 43.56          | 35.33         | 18.9                   | 100                         |
| C               | 40.78          | 33.15         | 18.7                   | 100                         |
| D               | 40.14          | 32.43         | 19.2                   | 100                         |
| E               | 38.35          | 31.29         | 18.4                   | 100                         |
| F               | 36.56          | 29.61         | 19.0                   | 100                         |
| G               | 35.19          | 28.43         | 19.2                   | 100                         |

The decrease in compressive strength in the frost resistance tests for all samples ranged from 18.4 to 19.2%. The smallest decrease in strength was obtained by the C series samples, while the largest D and G series samples.

Conclusions

The research confirmed the possibility of using industrial sulfur waste from the purification process of copper and other non-ferrous metals to produce concrete composites. As the amount of sulfur polymer added increased, the compressive strength of the samples did not increase. The best compressive strength results were obtained for the B series, where 26% sulfur polymer was used in the composition.

The results of bending tensile strength tests confirm the possibility of using this type of concrete in structures or structural elements exposed to relatively high compressive forces and low bending forces. As with the compressive strength tests, the best bending tensile strength results were obtained for the B series.

In the frost resistance tests, no visible cracks or scratches were found in any of the tested series, in addition, the mass of defects of the tested concrete for each series did not exceed 5% of the sample mass before the test. For each series of sulfur concrete tested, there was no decrease in strength greater than 20%, but it should be emphasized that the results were close to this limit.

The average setting time of the tested series of sulfur concrete, which was about 41 seconds and the high early compressive strength, allows the use of this type of concrete not only in road construction, but also in any structural repair works on construction of buildings.

References

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STRESZCZENIE:

W artykule zaprezentowano wyniki badań wytrzymałości na ściskanie, rozciąganie przy zginaniu oraz mrozoodporności dla betonów z zawartością od 24% do 36% polimerów siarkowych pochodzących z procesu oczyszczania miedzi i innych metali nieżelaznych. Uzyskane wyniki badań umożliwiły wskazanie obszarów stosowania tego typu betonów. Ponadto w artykule przedstawiono technologię oraz sposób wykonania betonów siarkowych, zwrócono uwagę na podstawowe cechy fizyczne oraz mechaniczne tego typu betonów. Omówiono problem recyklingu odpadów przemysłowych oraz wskazano betonu siarkowe jako jeden ze sposobów ponownego wykorzystania siarki odpadowej.

SŁOWA KLUCZOWE:
kompozyty betonowe; recykling odpadów siarkowych