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The 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 article presents that the addition of 28% sulfur polymers to a sulfur concrete mix is optimal. The obtained results of the research allowed the researchers to indicate areas of application of this type of concrete. In addition, the article presents the technology and method of making sulfur concrete, focusing 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 for the construction of road surfaces loaded with traffic and industrial floors exposed to an aggressive environment.

KEYWORDS:
concrete composites; sulfur waste recycling

1. Introduction

Sulfur concrete is a type of structural concrete. Typical composition of the 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 utilized in the building process and left to cure as a result of a slow temperature drop [1, 2].

As a result of gradual cooling, 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 in the fact that the mix sets quicker, has greater early compressive strength, is acid resistance, water resistance, oil resistance and resistance to hazardous environments. 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 and strengthening of sea defences. This type of concrete is also often used to build road surfaces susceptible to high volumes of traffic and industrial floors exposed to hazardous environments. Sulfur concrete can be made of recycled 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. Producing sulfur concrete using sulfur polymers from post-production waste, reduces

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production costs. The use of environmentally harmful waste materials as a substitute for aggregate reduces the negative environmental impact of landfilled waste [5-8]. The purpose of the work and own research was to determine the impact on concrete composites of additives in the range of 24 to 36% of sulphur polymers derived from the purification process of copper and other non ferrous metals.

2. Methods and materials in own research

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 temperatures 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/dm^3 in white.

The main purpose of our own research into the production of 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 [wt. %]		
	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 the concrete series, quartz aggregate was preheated and 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 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].

3. Presentation and discussion of the results

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.

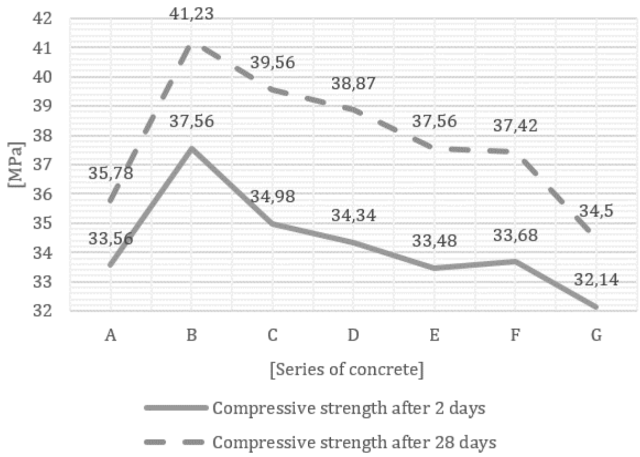

Fig. 1. Compressive strength of the tested concrete series after 2 and 28 days [own study]

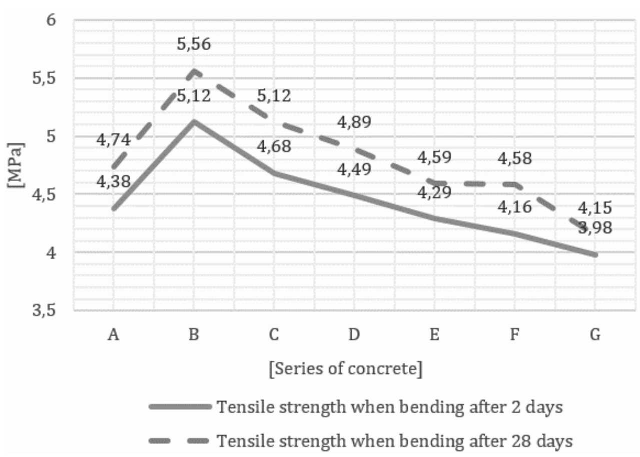

Fig. 2. Tensile strength at bending of tested concrete series after 2 and 28 days [own study]

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]			
	control sample	sample tested	decrease in strength [%]	number of freezing and thawing cycles
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.

4. 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 during the construction of buildings.

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Wpływ odpadów pochodzenia siarkowego na właściwości kompozytów betonowych

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 betony siarkowe jako jeden ze sposobów ponownego wykorzystania siarki odpadowej.

SŁOWA KLUCZOWE:
kompozyty betonowe; recykling odpadów siarkowych