STUDY OF AN ORGANIC COMPOUND WITH SULFUR AS A MODIFIER FOR INNOVATIVE CONCRETE

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Abstract. *The article investigated the kinetics of modified sulfur samples using thermogravimetric analysis methods. New innovative concrete, modified with organic compounds, and its physicochemical properties were studied. This innovative concrete was produced using a sulfur-modifier modification and a number of components. Thermogravimetric analysis (TG) of the modifier was carried out to study its response to heat treatment. TG analysis was performed using Thermo Scientific GC1310 in combination with Tsq 9000_TA Instruments STD 650 (USA). The temperature range of analysis was set within 100-1000°C. Thermal expansion coefficient of the studied sulfur-containing concrete. The results also confirmed that the coefficient of thermal expansion for concrete modified with sulfur modifier was 14.8×10 -6/0 C. The average deformation of the analyzed concrete was 0.0026-0.0051, which indicates excellent deformation characteristics compared to conventional concrete*
The sulfur-modifier modification experiences a one-stage thermal mass loss, and the mass loss phenomena are endothermic in nature.
Keywords: *sulfur concrete, coefficient of thermal expansion, modifier, analysis, sulfur.*

Introduction: Sulfur concrete is an innovative and environmentally friendly building material that has attracted significant attention in recent years. Developed as an alternative to traditional cement-based concrete, sulfur concrete offers unique properties and benefits that make it suitable for a variety of construction applications [1-3].

In sulfur concrete, sulfur primarily acts as a binder. The composition also includes other components such as rock fragments, sand, ash and stabilizers. Due to its low porosity and high mix density, sulfur concrete has superior strength compared to traditional cement concrete. The unique matrix structure of sulfur concrete can be attributed to the combination of sulfur and incorporated aggregates [4].

Sulfur concrete is primarily composed of sulfur, which acts as a binder, as well as aggregates such as rock fragments, sand, fly ash and stabilizing materials. Sulfur, a byproduct of the oil and gas industry, is abundant and inexpensive, making it an attractive choice for use in building materials. This type of concrete has the following advantages[5].

Improved Strength: Sulfur concrete exhibits superior strength compared to traditional cement concrete due to its low porosity and high mix density. The result is a stronger and more durable building material [6].

Faster Curing Time: Unlike cement-based concrete, which can take several weeks to cure, sulfur concrete cures quickly, reducing construction time and labor costs [7-9].

Although sulfur concrete offers a number of benefits, it also has some problems and limitations. For example, the high melting point of sulfur can make the production process more energy intensive. Additionally, the long-term performance of sulfur concrete under extreme temperature fluctuations is still being studied. As the demand for environmentally friendly and efficient building materials continues to grow, the potential of sulfur concrete in the construction industry is promising. With ongoing research and development, sulfur concrete has the potential to become a more widespread solution, contributing to a greener, more sustainable built environment [10].

Sulfur concrete has been primarily used in offshore structures, dams, and underground utility systems due to its high strength, density, and low porosity. In the construction industry, Portland cement concrete is the most common material. However, it has a number of disadvantages, such as increased porosity, which affects frost resistance, leading to deterioration in the quality of concrete in winter or in conditions of high humidity. In addition, Portland cement concrete has poor chemical and corrosion resistance, high water absorption properties and unsatisfactory physical and mechanical properties, including durability, modulus of elasticity and coefficient of thermal expansion. In contrast, sulfur concrete exhibits superior performance compared to Portland cement concrete [11].

Objects and methods of research

Orthorhombic sulfur, also known as alpha sulfur or orthorhombic sulfur, is one of the various allotropes of elemental sulfur. It is characterized by its unique crystal structure, which exhibits orthorhombic symmetry, a crystal system defined by three unequal axes intersecting at right angles. This special structure distinguishes orthorhombic sulfur from other sulfur allotropes such as monoclinic sulfur (beta sulfur) and amorphous sulfur. At room temperature and atmospheric pressure, rhombic sulfur is the most stable allotrope of sulfur, making it the most common form found in nature. It is a yellow, brittle, odorless and tasteless solid. Due to its stability, rhombic sulfur plays a critical role in various industrial applications and chemical processes.

In this research work, rhombic sulfur and nitrogen-containing organic compounds were used for sulfur concrete.

Thermogravimetric analysis

The purpose of thermogravimetric analysis (TG) of the modifier was to study its response to heat treatment. TG analysis was performed using Thermo Scientific GC1310 in combination with Tsq 9000_TA Instruments STD 650 (USA). The temperature range of analysis was set within 100-1000°C.

Estimation of the coefficient of thermal expansion

The coefficient of thermal expansion is a valuable indicator of the performance of concrete under different temperature conditions. The coefficient for sulfur modified concrete was measured and compared with traditional concretes such as Portland cement concrete. In this analysis, concrete samples were initially immersed in water for two days at different temperature ranges from 10°C to 50°C. After immersion, the length of the concrete was measured. At the final stage, changes in the length of concrete at different temperatures were assessed using a differential converter. Linear expansion of the samples was recorded at a rate of 0.2°C/min.

Preparation of sulfur modifiers

In a 100 ml heat-resistant beaker equipped with a mechanical stirrer, an oil bath and an electric stove, 10 g of sulfur was heated with constant stirring to a temperature of 185 ° C for 30 minutes, forming a transparent viscous tangerine mass. colored liquid sulfur. Next, 0.6 g of modifier was added to the liquid sulfur solution with continuous stirring, maintaining the temperature at 185-190°C for 1 hour. As a result of the reaction, a slight decrease in viscosity and the formation of brown sulfur and comonomers based on a nitrogen-containing modifier were observed (Fig. 1).

Upon completion of the reaction process, the resulting product was transferred from the beaker to a special container using a spatula and allowed to cool to room temperature. The resulting sulfur copolymer was then heated to 180-190°C in a stainless-steel reactor equipped with a mechanical stirrer and a temperature-controlled oil bath until a liquid phase formed. As a result of the modification of sulfur with nitrogen-containing compounds, it was obtained.

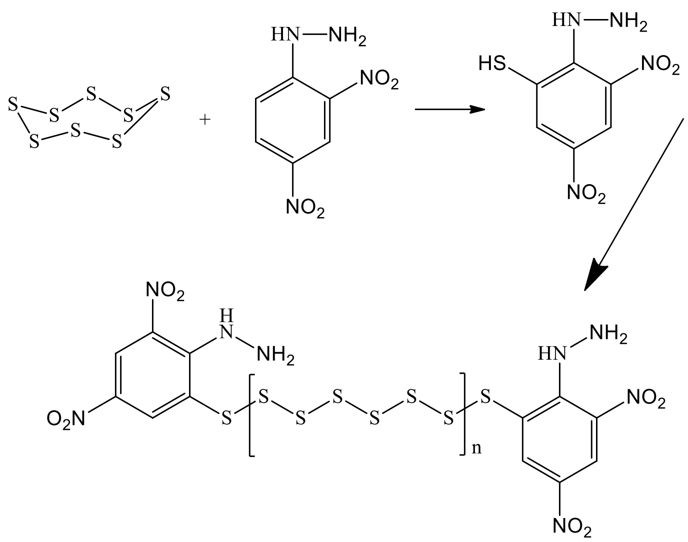

Figure 1. Sulfur modifier preparation procedures.

Preparation of sulfur concrete based on nitrogen-containing organic compounds

At the beginning of the preparation of sulfur-2,4-dinitrophenylhydrazine-modified concrete, the necessary components (crushed stone, sand and fly ash) were collected and heated at 180°C for 6 hours. Next, the liquid modifier sulfur-2,4-dinitrophenylhydrazine was combined with the prepared ingredients (crushed stone, sand and ash) in a volume ratio of 1:2.5. The resulting mixture was then heated at 140-160°C for 30 minutes. In the final step, the heated mixture was allowed to cool to room temperature, yielding the desired sulfur-2,4-dinitrophenylhydrazine-modified concrete. After this, its mechanical and physical properties were assessed

Results and discussion:

Thermogravimetric analysis (TGA)

Thermogravimetric analysis (TGA) has proven to be an important tool for understanding the thermal stability and compositional changes of sulfur-2,4-dinitrophenylhydrazine concrete. This method allows researchers and industry professionals to evaluate the effects of adding sulfur modifiers to concrete, which results in improved performance and durability of the material. Sulfur modified concrete has received considerable attention due to its improved properties such as increased chemical resistance, increased strength and shorter setting times. However, understanding the thermal behavior of these modifications is critical to optimizing concrete performance and ensuring its durability. The TGA process involves monitoring changes in the mass of a sample as it is exposed to a controlled temperature program. In the case of sulfur-modified concrete, TGA helps identify the stages of thermal decomposition of the sulfur modifier, as well as the interaction between sulfur and the cementitious components in the mixture. By analyzing the obtained thermogravimetric data, researchers can determine the optimal amount of sulfur modifier to use and the ideal concrete curing conditions.

Analysis of the thermal characteristics of the selected modification method was carried out by thermogravimetric (TGA) testing of the sulfur-2,4-dinitrophenylhydrazine modifier. TGA curves of the modifier sulfur-2,4-dinitrophenylhydrazine (Fig. 2) and its thermogravimetric properties (Table 1) were obtained. TGA testing included measurements of energy intake (µV*s/mg), percent weight loss (%) and weight loss (mg) for the modifier sulfur-2,4-dinitrophenylhydrazine at temperatures ranging from 100° to 1000°C.

The results show that the mass loss of the sulfur-2,4-dinitrophenylhydrazine modifier was stable up to 215 °C, as this was the liquefaction temperature of the modifier. The weight loss of the sulfur-2,4-dinitrophenylhydrazine modifier began after 220 0 C and slowly decreased to 230 0 C. Then it sharply decreased to 309.91 0 C, where the weight loss was 82.636% and the remainder was 7.624. mg. The next thermal peak was noted at 393.44 0 C. This confirms that:

1. The concrete modifier remained stable up to 210 ° C.

The modifier sulfur-2,4-dinitrophenylhydrazine showed a one-step thermal mass loss. The mass loss processes of this modifier are endothermic processes, since all peaks are endothermic, indicating that the mass loss of this concrete requires additional energy. Changes in the mass of the derivative d(mass)/dT (%/ 0C) showed that the modifier is sulfur-2 ,4-dinitrophenylhydrazine has one volatilization temperature (peak) at 309.910C. The heat flow fluctuated up to 2600C. , then it suddenly decreased to 309.91 0 C due to volatilization of the modifier sulfur-2,4-dinitrophenylhydrazine. After reaching this temperature, the heat flux quickly increased to 400 °C and showed an approximately stable upward trend.

Thus, the use of thermogravimetric analysis to evaluate sulfur modifiers in concrete provides valuable information about the material's thermal stability, decomposition, and interaction with other components. This knowledge contributes to the development of highly effective, durable and sustainable sulfur modified concrete solutions for the construction industry.

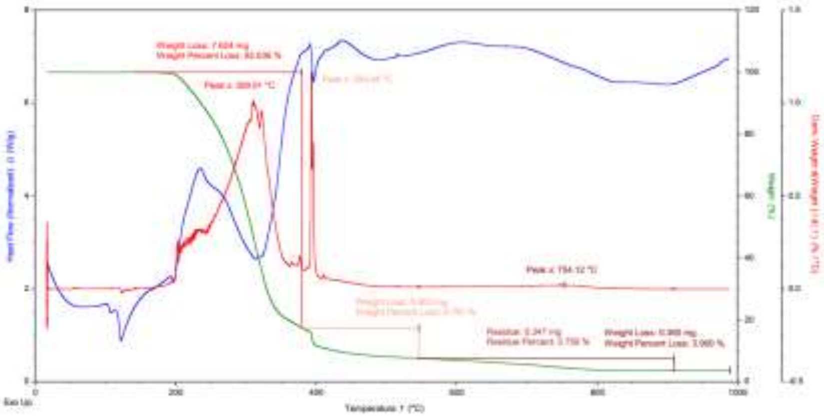

Figure 2. Thermogravimetric curves of the modifier sulfur-2,4-dinitrophenylhydrazine.

Thermal expansion coefficient

The coefficient of thermal expansion is important in the design of structures subject to extreme temperature changes, such as bridges, sidewalks, and buildings in regions with significant seasonal temperature changes. Proper consideration of coefficient of thermal expansion in the design and construction of these structures can minimize the risk of thermal stresses, cracks and other forms of deterioration.

Table 1. Results of thermogravimetry of the modifier sulfur-2,4-dinitrophenylhydrazine.

№	Temperature , ^{0}C	Values in energy consumption, μV	Weight loss , %	Weight loss rate, mg/min
1	100	-0,00105	0,075	0,0155
2	200	-0,09585	0,84	0,6452
3	300	-0,856	43.206	0,688
4	400	-0,101	88,338	0,0538
5	500	-0,01322	91,855	0,018
6	600	-0,0125	93.022	0,0212
7	700	-0,0159	94.425	0,0258
8	800	-0,00725	96.114	0,0032
9	900	0,0109	96.312	0,00315
10	1000	0,00056	96,44	0,0031

The coefficient of thermal expansion value indicates the performance of concrete under different temperature conditions. The data obtained indicate that the coefficient of thermal expansion of concrete with the addition of the modifier sulfur-2,4-dinitrophenylhydrazine is 14.8 x 10 -6/0 C. This low value suggests that the selected sulfur concrete demonstrates increased efficiency in response to thermal changes. It is also worth noting that the coefficient of thermal expansion of concrete based on sulfur-2,4-dinitrophenylhydrazine modifier exceeds that of conventional concrete, since the coefficient of thermal expansion of Portland cement concrete is in the range of 10.0 × 10 -6/0 C. to 13.0 ×10 -6/0 C. However, advances in concrete technology have led to the development of innovative concrete mixtures with modified thermal expansion coefficients. For example, concrete incorporating sulfur-2,4-dinitrophenylhydrazine modifiers exhibits a lower coefficient of thermal expansion of about 14.8×10 -6/0 C, indicating increased efficiency in response to temperature changes.

Conclusion

In this study, a new type of concrete using sulfur modification 2,4-dinitrophenylhydrazine was introduced and its varied characteristics were studied. A new modifier sulfur-2,4-dinitrophenylhydrazine has been developed, its structure has been confirmed by physicochemical methods of analysis. Innovative concrete has been developed with 2,4-dinitrophenylhydrazine sulfur modification and various components. The properties of this concrete were determined, leading to the following key conclusions:

The results showed that the coefficient of thermal expansion value for concrete modified with sulfur-2,4-dinitrophenylhydrazine was 14.8 × 10 -6/0 C.

The sulfur-2,4-dinitrophenylhydrazine modification undergoes a one-step thermal mass loss, and the mass loss process is endothermic.

Thus, the extensive research in this study indicates the potential of nitrogen-containing organic compounds as a modifier for sulfur concrete.

REFERENCES

1. Shavkatova D.Sh., Amanova N.D., To‘rayev X.X., Bir va ko‘p komponentli azot saqlovchi organik modifikatorlar asosida oltingugurtli beton olish.// Fan va texnologiyalar taraqqiyoti ilmiy-texnikaviy jurnal, Buxoro. -2022, -№4, 64-70-b. (02.00.00. No. 14).
2. Shavkatova D.Sh., Amanova N.D., Turayev X.X. Modifikatsiyalangan oltingugurt va melamin asosida oltingugurtli beton olish // QarDU xabarlari ilmiy-nazariy, uslubiy jurnal. Qarshi. -2022. -5/1. 55-61-b. OAK Rayosatining 2022 yil 31 martdagi 314/9.2-son qarori. https://oak.uz/pages/4802
3. Turayev X.X., Shavkatova D.Sh., Amanova N.D., Raxmatova G. Study of the physical and mechanical properties of concrete based on modified sulfur and melamine // ACTA NUUz. -2023. -p. 503-505. (02.00.00. No. 12).
4. Turaev Kh.Kh., Shavkatova D.Sh., Beknazarov Kh., Amanova N.D. Berdimurodov E. Preparing a new tupe of concrete based on Sulfur-melamine modifier // Baghdad Science Journal. Baghdad.-2023. 08/20/2023. https://doi.org/10.21123/bsj.2023.0000. No. 3. Scopus. CiteScore 2022-1.3.
5. Erofeev, V. Yusupova, A. Bobrishev, A. In the book. Activation of sulfur and opal-cristobalite-tridymite phase in sulfur concrete technology, IOP Conf Ser Mater Sci Eng 2018, 342: 042033.
DOI 10.1088/1757-899X/463/4/042033
6. Ghasemi S. Nikudel, M. R. Zaluli, A. Hamehchiyan M., Alizadeh A., Yusefvand F., Rais Ghasemi A. M. Assessment of the durability of sulfur concrete and Portland concrete in laboratory conditions and the marine environment. J Mater Civil Eng 2022, 34(8): 04022167. https://doi.org/10.1061/(ASCE)MT.1943-5533.0004320
7. Gladkikh, V. Korolev, E. Khusid, D. Sukhachev, I. Properties of sulfur-containing asphalt concrete, EPJ Web Conf 2016, 110: 04024.
https://doi.org/10.1051/matecconf/20168604024
8. Grabowski L., Gliniak M., Polek D. Possibilities of using sulfur waste for the production of technical concrete, EPJ Web Conf 2017, 143: 01032.
https://doi.org/10.1051/e3sconf/20171801032
9. Gulzar M.A., Rahim A., Ali B., Khan A.H. Research on the potential of sulfur concrete recycling. J Build Eng 2021, 38:102175.
https://doi.org/10.1016/j.jobe.2021.102175
10. Gumenyuk A., Hela R., Polyanskikh I., Gordina A., Yakovlev G. Durability of concrete with artificial thermoplastic sulfur additive, IOP Conf Ser Earth Environ Sci 2020, 522: 032012. DOI 10.1088/1757-899X/869/3/032012
11. Gutarovskaya B., Kotynia R., Belinsky D., Aniska R., Vrenchicki Y., Piotrovskaya M., Kozirog A., Berlovska J., Dzyugan P., New organosulfur acid. Polymer concrete composites containing waste: Mechanical characteristics and resistance to biocorrosion. Materials 2019, 12(16): 2602.
https://doi.org/10.3390/ma12162602