ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Use of Wastes from Thermal Power Industry in Manufacturing of High-Strength Sulfur Concrete.

Galina Alexandrovna Medvedeva*, Rezeda Timerhanovna Akhmetova, and Labutkin Alexandr Grigorievich.

Kazan State University of Architecture and Engineering, Russian Federation, 420043, Kazan, Zelenaya street, 1.

ABSTRACT

In this work we offered recycling technology which turns sulfur waste of oil and gas field and ash-and-slag waste from Thermal power stations (TPS) into silicate concrete, which can be used in manufacturing of concrete products. Thus the structure of materials and features of the processes was studied. Optimized the parameters of technological regime of receiving the modified concrete compositions. It is shown that high physical-mechanical and performance properties of material are determined by chemical interaction between components in the system and by formation of sulphides. It was found that the developed technology is an environmentally and economically sound and allows you to use effectively the sulfur waste of oil and gas field and ash-and-slag waste from TPS and get strong and aggressively steady composite materials, the cost of which is 2.5 times lower than the known analogues.
Keywords: silicate concrete, sulfur composites, sulfur concrete, sulfur, ash-and-slag waste from TPS, calcium glycerophosphate.

Corresponding author

INTRODUCTION

Development of technologies for sulfur concrete on the basis of large tonnage industrial waste is important because these concretes have valuable properties – strength, water resistance, abrasion resistance, resistance to aggressive environment, etc., and have a significant economic effect. The use of large tonnage solid waste of industry is a big national task, solving the question of priorities for further development of national economy and environment. Ash-and-slag waste (ASW) from TPS offers more features for building composite materials manufacturing that have sufficient corrosion resistance and resistance to environmental impact. Large tonnage volumes of ASW in dumps are growing from year to year and are almost not used. Meanwhile, they are affordable, not scarce and cheap aluminosilicate raw materials. The use of ASW in industry, construction industry and agriculture is one of the strategic solutions of an environmental problem in work zone of TPS (Vatin, 2011, pp. 16-18). Ash-and-slag are used very well for the resource-saving purpose that is the solution of economic problems connected with the preservation of natural resources, non-ferrous metals and other materials (Volzhensky, 1984). High strength and density of stone binder based on ASW also allow you to use it in concrete receiving, exploited in aggressive environments.

Currently sulfur has become a large tonnage product in Russia, Kazakhstan and some oil and gas producing countries, as it formed in purification of sulfurous oil as a secondary component. In terms of production of sulfur in the world Russia occupies third place (10 % of the world production volume). USA and Canada produced 26 and 20 % of the world's sulfur production volume, respectively (Kislenko, 2002). Large amounts of sulfur accumulated in gas cleaning systems of the Astrakhan Region complexes, the Republic of Tatarstan. The issue is particularly relevant in connection with commissioning of Nizhnekamsk Oil Refinery capacities, which are intended for regional processing of sulphurous oils from Romashkinskoye field. The scientific community are faced by the question of justification of more efficient use of sulfur, modifying of well-known products and compounds by means of it, getting new materials – sulfur composite materials (SCM) or sulfur concrete. Chemistry of sulfur is distinctive, directly related to the technology and often ambiguous in its interpretation of various specialists. Sulfur sufficiently reactive and reacts under different conditions with a wide variety of both organic and inorganic compounds (Akhmetov, 1998). This is particularly important to know in order to obtain new silicate concretes based on sulfur (Volgushev, 1991). It is known that sulfur-based materials possess a number of disadvantages. These primarily include high brittleness and low enough strength caused by shrink deformations and combustibility and biological instability. The above-mentioned disadvantages can be eliminated by modifying sulfur with various organic and inorganic compounds (Mashkina, 2005). The positive effect of sulfur modification is achieved through the formation of new chemical bonds (chemical reaction), and as a result of physical and chemical phenomena in the system, contributing to the formation of the material optimal structure (Medvedeva, 2014, pp. 47-51). It is believed that the application for modification of organometalphosphatic and other metal compound waste in combination with the fine and coarse aggregate will increase strength, reduce water absorption, and reduce the cost of the finished product, to improve technical, economic and environmental performance.

METHOD

We used the following materials:

- Sulphur – waste of Nizhnekamsk Oil Refinery. The chemical composition of these wastes contain 99,9% sulfur, i. e., virtually represent a marketable product;
- Calcium glycerophosphate (CGP), commercially available under the FS 42-1809-82;
- Silica (quartz sand) of Yudino field (GOST 8736-93. Sand for construction work) of the following composition (table 1).

Table 1: Chemical composition of silica (wt. %)

SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	п.п.п.	Sum
90,82	4,48	0,34	0,95	0,17	0,17	next	0,90	0,65	0,74	100,57

- Ash-and-slag waste TPS-2 of Kazan with the following composition (table 2).

ISSN: 0975-8585

Table 2: The chemical composition of ash-and-slag waste of Kazan TPS-2 (wt. %)

SiO_2	Al_2O_3+TiO_2	Fe_2O_3	CaO+MgO	SO_3 (com)	K_2O+Na_2O	Sum
47,7 - 52,2	21,24 - 25,28	5,2 - 5,9	4,3	0,2	1,84 - 19,03	81,39-106

For a more detailed study by screening ASW were divided into fly and slag components. The study used an ash component having a particle size of less than 1 mm. The samples of sulfur concrete compositions were prepared by hot mixing the starting components at different exposure time (from 10 minutes to 4 hours). Then, the mixtures were directed to the formation of the samples by filling the form of size 2x2x6 cm (vibro-packing) or pressing a standard pressure of 120 kg/cm^2 cylinders 2x2 cm. The resulting materials were tested for physical and mechanical properties according to GOST 10180-90 and studied by physical-chemical analysis: X-ray analysis (X-ray diffractometer DRON-3 with Cu K_α-radiation) (Vasiliev, 1986), electron paramagnetic resonance (device RE-1306), by method of infrared spectroscopy (Vlasov, 1972), differential thermal analysis (derivatograph Q-1500D by Paulik system, Erdei) in thermodynamic mode (Berg, 1969). The impact strength of the samples was evaluated on copra pendulum.

DISCUSSION OF RESULTS

The dependence of properties of sulfur composition on structure in binary compositions of «sulfur: filler»

It is known that the concrete is composed of binder and fillers. The first stage of interaction between the components of the concrete is the wetting of the surface of filler by binder (Bazhenov, 1987). In this connection, the main structure formation in the manufacture of sulfur concrete occurs during the mixing of the molten sulfur with filler. Therefore, during the cooling of the sulfur on the filler surface more uniform crystals formed whose dimensions are smaller than in the sulfur melt, without filler. When the optimized degree of filling virtually all of the sulfur is moved to a more fine crystalline homogeneous state. Since sulfur crystals are reduced, the formation of optimal film thickness around grain filler, the increase in strength of sulfur concrete take place and thus form a reinforced binder cconnections with the surface of filler. The research had to be conducted in order to establish the structural changes in the contact zone of binder with various fillers. Sulfur concrete is a composite material obtained by molding and hardening of rationally selected mixture of sulfur melt, fine grinding filler and modifying additives (Porfir'eva, 2002, pp. 41-43). Production and physical properties of sulfur concrete depend on the quantity and properties of the binary composition. Therefore, composition should have optimum physical-mechanical properties.

Durability is the most important property of sulfur concretes, which depends on the physical-mechanical properties of the mixture components and the intensity of physical-chemical interactions at the junction of phase division.

In this article we considered the study of effect of different prescription factors on the strength of sulfuric materials sulfur-containing wastes from fine grinding filler and modifying additives used for the manufacture. The silica with a specific surface of 100 cm^2/g and ash-and-slag waste with a specific surface of 2890 cm^2/g was used as the filler.

As it is known the filler content leads to changing the strength of sulfur concrete. Figures 1 and 2 show the experimental data of dependence of compressive strength of the binary system, depending on the ratio of components sulfur:silica and sulfur:ASW and in different technologies. It is seen that all the experimental curves have an extremum, i. e., we can talk about the optimization of the ratio sulfur:filler. The graphs can be seen quite clearly that compression gives a much greater effect. Differences in the application as a filler comprise ASW are 2,7-6,4 MPa. The same we get when using the inert component of silica. However, the differences in strengths are smaller, in the order of 3 MPa. By increasing the duration of synthesis from 30 min. to 1 hour the strength increases – in 1-1,5 times when applying silica, when applying ASW the difference is 0,6-1 MPa smaller. The figures show that the maximum strength in inert filler – silica is 21 MPa, and in the application of ASW – 34,4 MPa (1,5 times), it says that the ASW components are chemically reactive to sulfur and provide a greater strength increase under equal conditions.

ISSN: 0975-8585

The figures show that in terms of the strength properties of the material the ratio of sulfur: filler of 1:1,5 for the samples with vibro-packing and 1:1,5-1:2 for the pressed samples are the best. Therefore for further studies mixing ratio of 1:1,5 was selected. Technological factors - workability, i. e., for a workable mix took a ratio of 1:1,5.

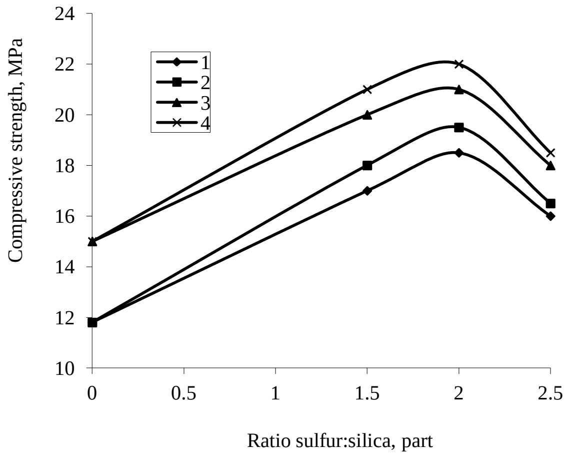

Figure 1: Compressive strength of binary sulfur silica compositions, produced by vibro packing (1, 2) and compression (3, 4) at various ratios of components and time of synthesis samples: 1, 3-30 min; 2, 4-60 min.

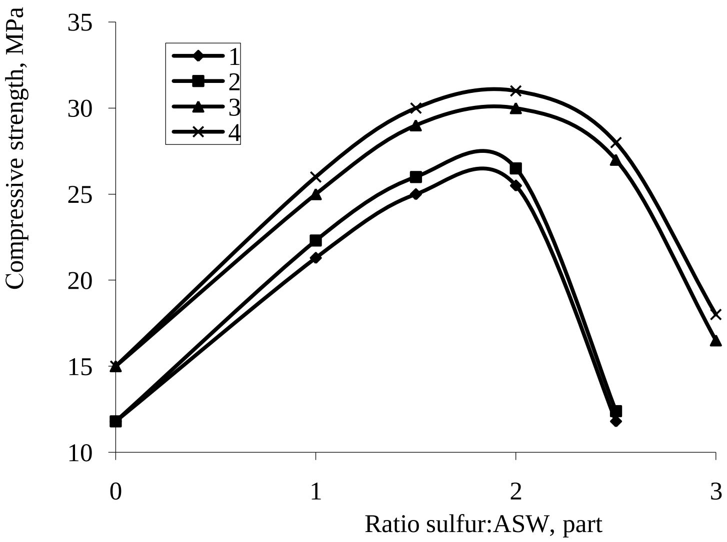

Figure 2: Compressive strength of binary sulfur ash-and-slag waste compositions, produced by vibro packing (1, 2) and compression (3, 4) at various ratios of components and time of samples synthesis: 1, 3-30 min; 2, 4-60 min.

By increasing the filling degree the strength of the sulfur compositions increases and it can be explained by a uniform distribution of ASW and silica, and by the formation of a strong frame structure. At the optimum degree of filling the grains of the filler are not allowed to grow cracks that formed during the loading of the sample. Exceeding the optimum degree of filling water-resistant properties and strength properties of the compositions deteriorate. This can be explained by the lack of binding and consequently the formation of cavities and voids because the grains of the mineral filler are not completely wetted and enveloped by astringent. Thus, ASW are active excipients and form compositions with sulfur of a maximum strength in a ratio of 1:1.5. However, these compositions have a drawback: increased water absorption, reduced strength, and low compressive toughness. One could believe that the introduction of modifiers by sulfur chains crosslinking and surface factors improvement on the boundary sulfur:filler will be able in some way to remove these shortcomings.

Selecting modifier

The main characteristic of a sulfur atom, essentially defining the features of the forming processes, types of chemical bonds and the physical-chemical properties of the sulfide phases, is its ability to serve both as a donor and as an acceptor. Acceptor ability caused by the aim to complete the shell to the configuration s^2p^6, inherent in inert gases and meet the minimum energy. This feature of the sulfur atom causes significant fraction of ionic bonding Me–S in many sulfides, and forming covalent groups S_n by sulfur atoms, which determines in particular the tendency to form polysulfide phases and polymer sulfur (Porfir'eva, 2007).

Materials based on crystalline sulfur because of the tendency to shrinkage have insufficient strength, impact resistance, etc. We hypothesized that component modifying by the metal-containing compounds will contribute to the formation of a homogeneous composition of dense structure and, therefore, to the improvement of its physical and mechanical characteristics due to the formation of polysulfide substances, to the elimination of irregularities in the densities of the components and to the improvement of adhesion characteristics. Calcium glycerophosphate – an organic inorganic compound was used in this work as such a reagent-modifier. Its use as a modifier will allow, in our opinion, to obtain polymer sulfur and, therefore, increase the mechanical strength of the product due to the formation of sulfide linkages. Available organic moiety will increase the impact strength of the material. Polymeric sulfur has a number of advantages over crystalline. These include a high resistance to aggressive media, high impact strength, the absence of thermal shrinkage deformation in the compositions, etc. (Paturoev, 1987).

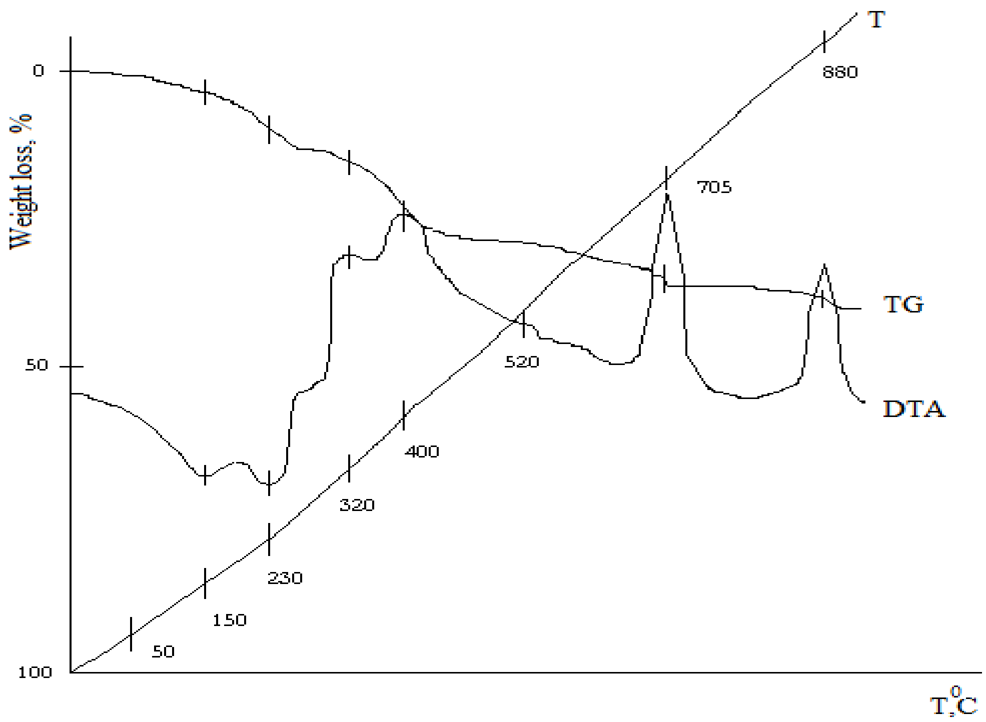

Figure 3: Derivation of calcium glycerophosphate

Calcium glycerophosphate (CGP) is a compound with a specific ester bond –P–O–C– (Gerasimov, 1996). But in contrast to classical organic esters and polyesters the compound has an inorganic moiety represented the disodium salt of phosphoric acid and organic moiety represented the glycerol residue. The compounds lack acidic OH-groups, but have reactive alcoholic OH-groups. Characteristically, in the temperature range of 150-230 °C calcium glycerophosphate dehydration occurs and forms the unsaturated compounds which are able to react chemically with sulfur. Polysulfides with crosslinked structure formed differ in chemical resistance, high adhesive and elastic properties, that basically contribute to the formation of a homogeneous composite material of the matrix composition with improved physical and mechanical properties. At termodestruction of CGP (Calcium glycerophosphate) could be expected reactions in the glycerol and phosphate moieties with a gap of P–O–C bond. Glycerol moiety had to form intumescing components – gases CO_2, CO, H_2O. The presence of alcohol OH-groups could also result to the formation of the intermediate unsaturated compounds in elimination of water. The phosphate moiety in connection with a gap of P–O–C bond could recombine in dimeric salt - $M_4P_2O_7$ pyrophosphate as a result of thermal disproportionation. $M_4P_2O_7$ pyrophosphate, undergoing the thermal dissociation by scheme $M_4P_2O_7$=M_3PO_4+ $(MPO_3)_n$ must form the desired component – polysulfide. As a result of chemical interaction the formation of polysulfide of different structure take place, characterized by high adhesion and elastic properties that will contribute to the formation of a homogeneous composition of the material with high physical and mechanical properties. Polysulfides can enhance the strength of products. From this standpoint, it was interesting to examine the thermal behavior of the CGP, sulfur and compositions based on them. Figure 3 shows the Derivation of calcium glycerophosphate.

As it can be seen from the figure, the weight loss of the sample upon heating begins to 500°C and is associated with the removal of the water absorbent. At a temperature of 150 and 230 °C observed the dehydration of calcium glycerophosphate, accompanied by heat absorption and the weight loss of 5.8 and 6.9 % respectively, corresponding to the loss of 5 moles of H_2O. Thermal decomposition of calcium glycerophosphate on the organic and inorganic parts, burning and removal of gaseous decomposition products occurs at temperatures between 320 and 400 °C. The weight loss of the sample is thus 29.0 %. In the solid decomposition product contains calcium diphosphate and polyphosphate. On radiographs of the end product of pyrolysis CGP (Figure 4) marked the emergence of the crystalline β-$Ca_2P_2O_7$. In the temperature range of 700-900 °C partial separation of P_4O_{10} occurs in the gas phase which in the presence of reducing agents (C, CO) is reduced to a volatile phosphorus P_4, followed by loss of 12,5 % of the sample weight.

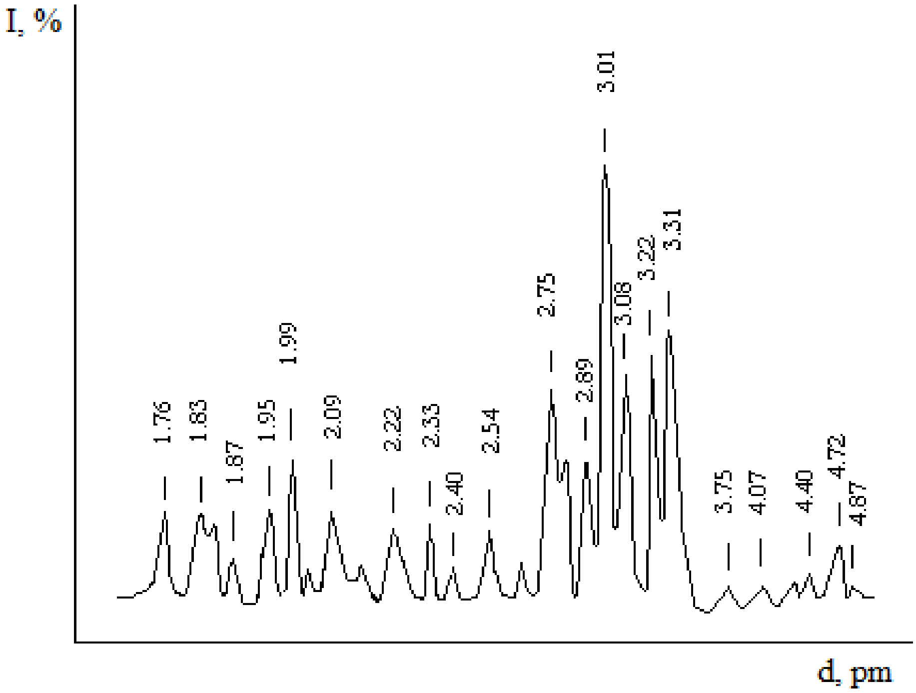

Figure 4: Roentgenogram of the pyrolysis products of calcium glycerophosphate

Thus, in the temperature range of 150-230 °C the dehydration of CGP with the form of unsaturated compounds (acrolein, styrene, propylene) capable to enter into chemical reaction with the sulfur component is possible. Based on the foregoing, it can be concluded about the possibility of using the CGP as a complex modifying additive in the manufacture of sulfur concrete due to the formation of sulfide and polysulfide compounds.

The dependence of sulfur concrete properties of the composition in the ternary systems

This section considers the influence of various prescription factors on the strength of sulfuric concrete for the manufacture of which sulfur-containing wastes, fine grinded filler and modifying additive – calcium glycerophosphate were used. Calcium glycerophosphate administered in an amount up to 7 %.

Figures 5-6 shows the dependence of the compressive strength of sulfuric-silica and sulfur ash-and-slag compositions modified by calcium glycerophosphate received by two technologies: vibro-packing and compression. With increasing content of CGP (up to 3 %), the strength increases and reaches it's maximum (37 MPa) at a content of CGP of 2 % in sulfuric-silica compositions 34-36 MPa and 41-42 MPa in sulfur ash-and-slag compositions with a ratio of binder:filler mass % – 40:60. Further increase of the CGP (7 %), leads to decrease in strength. The extreme nature is also evident in water absorption and specific toughness of the content builder CGP in samples (Figures 7-8).

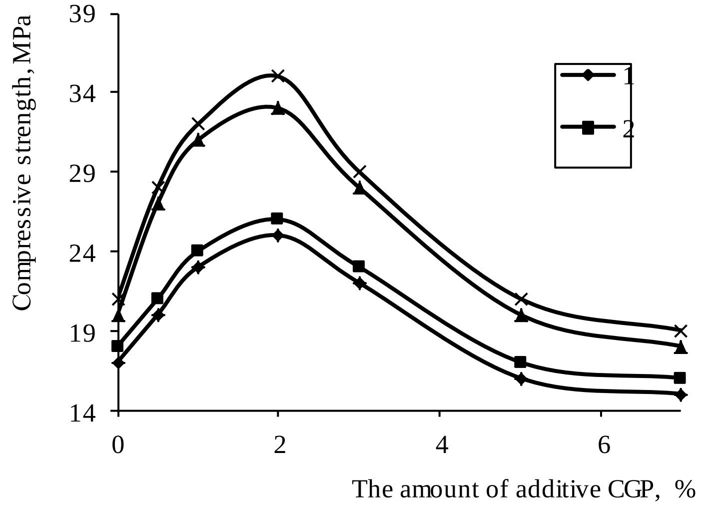

Figure 5: Compressive strength of sulfuric-silica compositions, modified by CGP obtained by technology: vibro-packing (1, 2) and compression (3, 4), with different contents of modifying additive CGP and time of synthesis: 1, 3-30 minutes; 2, 4-60

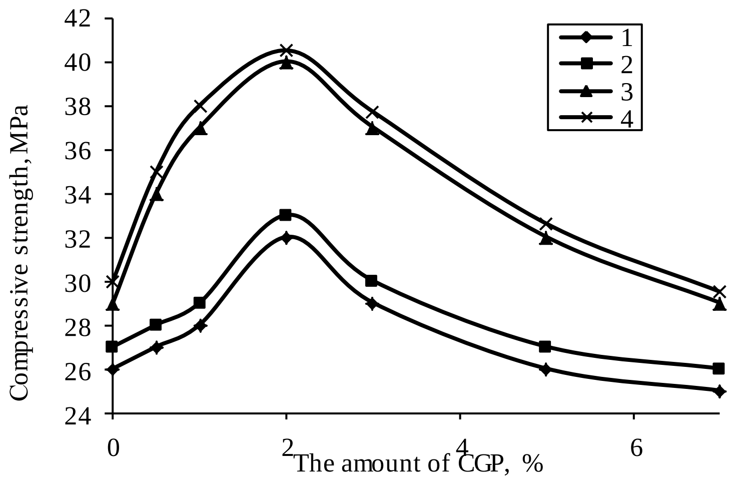

Figure 6: Compressive strength of sulfuric-ash-and-slag compositions, modified by CGP obtained by technology: vibro-packing (1, 2) and compression (3, 4), with different contents of modifying additive CGP and time of synthesis: 1, 3-30 minutes; 2, 4-60

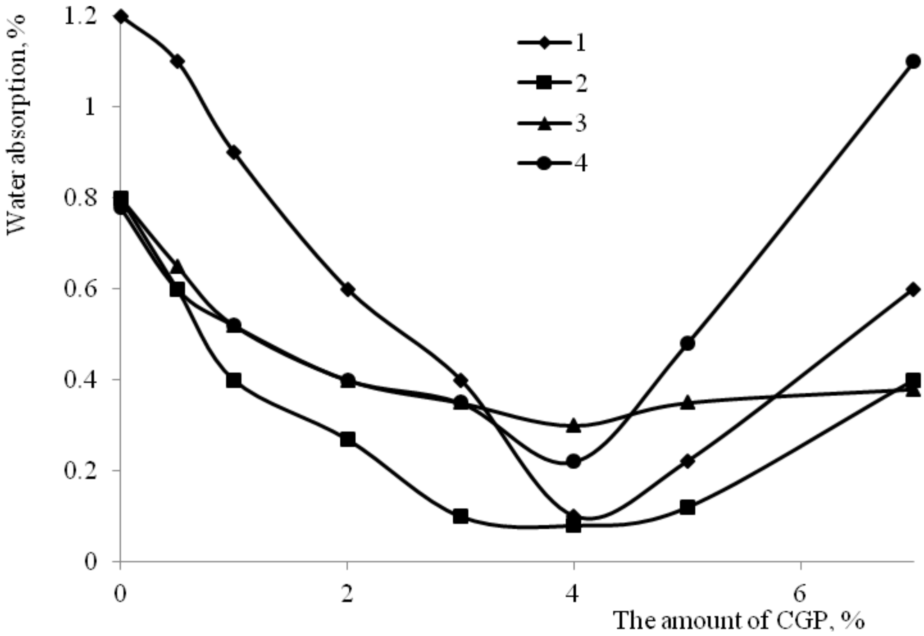

Figure 7: Dependence of water absorption of sulfuric-ash-and-slag samples with modifying additive calcium glycerophosphate from amount of additive and time samples synthesis: 1– 10 min, 2 – 30 min, 3 – 1 hour, 4 – 2 hours

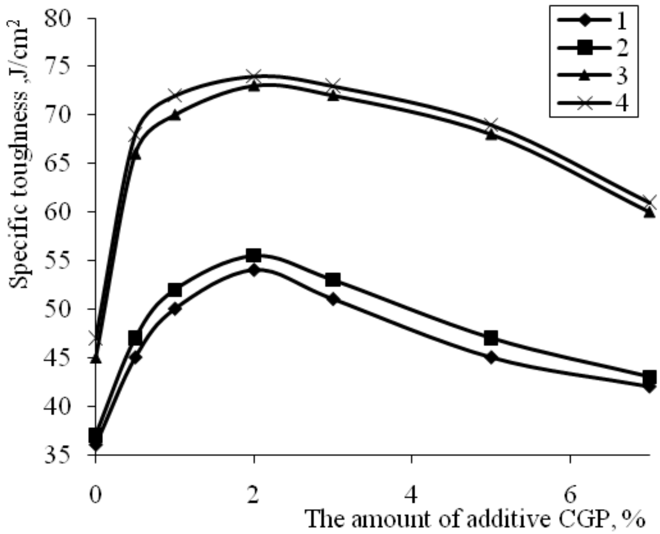

Figure 8: The dependence of the specific toughness of sulfuric-silica (1, 2) and sulfuric ash-and-slag (3, 4) compositions, modifying by CGP at different contents of modifying additive CGP and synthesis time: 1,3 – 30 min; 2,4 – 60 min.

Thus, the recommended composition has a composition (wt. %):
Sulfur-containing waste-37-39,5;
ash-and-slag waste-60-57,5;
Calcium glycerophosphate 2-3.

When using calcium glycerophosphate (CGP) as a modifying additive observed a slight increase in strength due to addition of a small amount of additive (less than 1 %). It is assumed that a phosphate moiety of CGP promotes the hardening of sulfur concretes. Chemical bonds formed between the sulfur and the organic moiety of CGP should also improve the mechanical strength of the samples. By increasing the amount of CGP additive to 3 % the strength of the samples increases by 22 %. In the IR spectra of these samples (Figure 12), there is an increase of the absorption bands intensity that is typical for the sulfide bonds, i. e. you can talk about the chemical interaction of sulfur and modifying additive. Excessive amount of additives CGP (over 3%) leads to a loosening of the structure and the strength of the samples decreased. The optimum amount of additive is 2-3 % of CGP. Water absorption of the sample does not exceed 1 %, which corresponds to the requirements of GOST (State Standard).

The results of studies (Figure 8) show that the introduction of the modifying additive leads to a significant increase of the specific toughness of sulfur concretes. For example, the specific toughness of sulfur concrete with silica modified by CGP is 54-55 J/cm^2, and the ash-and-slag waste – 73-74 J/cm^2, which is approximately larger in 1.5 times. However, at high levels of the modifying additive specific toughness decreases in 1.2 times.

The properties of the material in relation to the closest literary analogue (Orlovsky, 1981) are listed in Table 3.

Table 3

The amount of calcium glycero-phosphate	Properties				
	σ_{st}, MPa	σ_t, MPa	Specific toughness, J/cm^2	Density ρ, g/cm^2	Water absorption W, %
0	29	5,1	45	2,5	0,78
0,5	34	5,9	66,2	2,6	0,59
1	37,4	6,1	69,8	2,69	0,37
2	39,9	7,1	73	2,80	0,28
3	37,2	6	72,5	2,75	0,13
5	31,8	5,7	68	2,7	0,18
An analogue	20–26	3–3,5	60–64	-	-

The developed material has a high resistance to aggressive environment. Thus, the stability coefficient in 5 % HCl is 0,987, in 5 % H_2SO_4 – 0,987; in 5 % $CaCl_2$ – 0,987; in 5 % NaCl – 0,987; in 5 % $MgSO_4$ – 0,987.

Physical-chemical studies

To clarify the mechanism of transformation in the system and to confirm the formation of new chemical compounds – polysulfide –physical-chemical studies were carried out.

Investigation of the structure of polysulfide compounds was performed using X-ray diffraction (Figure 9).

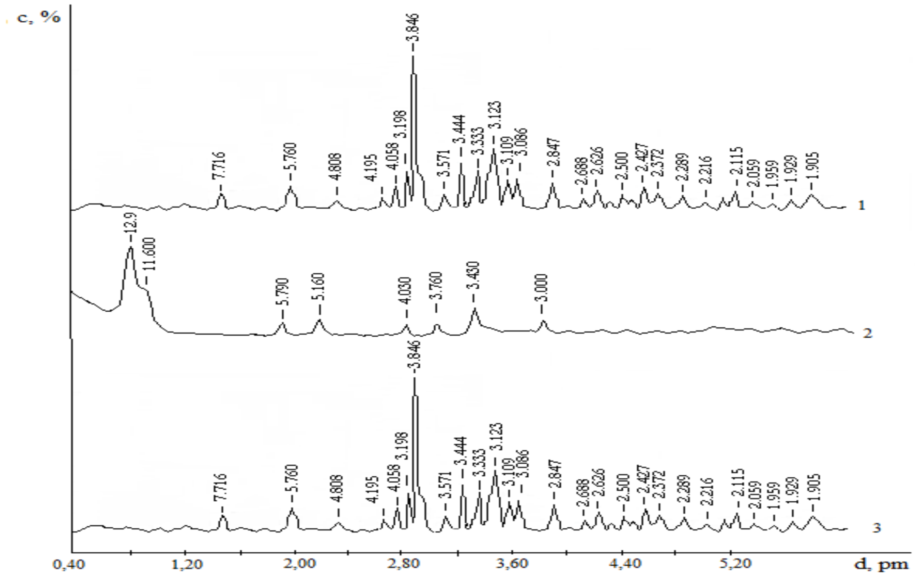

Figure 9: Roentgenogram of sulfur samples (1), calcium glycerophosphate (2) and polysulfide material with the addition of calcium glycerophosphate (3)

As it can be seen from the figure, calcium glycerophosphate has the following characteristic reflections – 12.9; 11.6; 5.79; 3.00 pm, sulfur - 1,905; 2,115; 2,427; 2,626; 2,847; 3,846; 5.76; 7,716 pm, i. e. starting substance – crystalline compound. A decrease in the crystalline orthorhombic sulfur by 33 % is seen on roentgenogram. Since the products of interaction of sulfur and CGP reaction are amorphous, non crystalline, so there are no corresponding reflexes on the roentgenogram. On composition roentgenogram there is the appearance of an amorphous halo and marked the increase of the proportion of the amorphous phase of 33 %, which also favors the formation of polymeric sulfur. It is also possible to believe that along with the formation of the polymer modification of sulfur there is the replacement of oxygen in CGP by sulfur atoms to form compounds such as 1, 2 – calcium dimercaptantiosulfate. A significant increase in the specific toughness appears to be due to this circumstance.

Investigations by paramagnetic resonance (Figure 10) found that in sulfur at 180 °C contains a significant amount of paramagnetic centers, i. e. highly reactive free radicals, which disappear when added modifying additives of calcium glycerophosphate to molten sulfur. It also indicates the probable chemical interaction of components with the possible formation of polymer modification of sulfur, explains the increase in the mechanical strength of the samples.

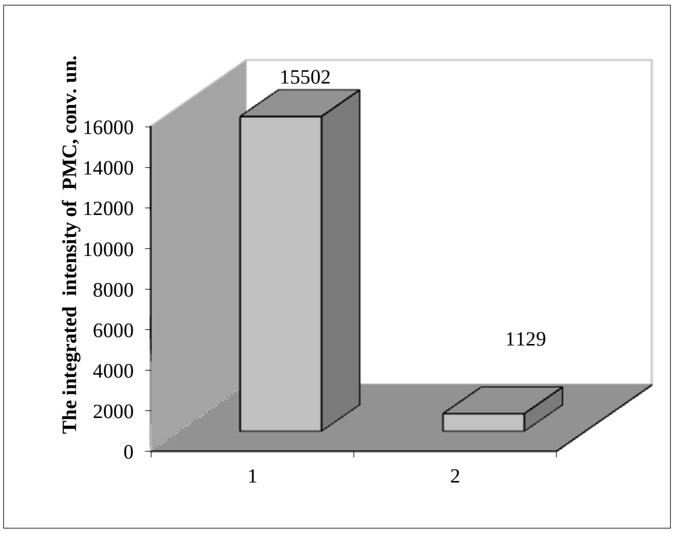

Figure 10: Results of studies EPR sulfur samples heat treated at 180 ° C (1), and sulfur compositions supplemented with calcium glycerophosphate (2)

Thus, at a temperature of 180 °C in the test sulphur free radicals appear and the system becomes reactive and chemically active. The presence of the active centers in the heat-treated sulfur talks about breaking of the sulfur rings and appearance of biradicals in the system, and the interaction of sulfur with CGP leads to a drastic reduction in the number of PMC in the system (1129 conventional units). «Damping» PMC after mixing sulfur with the additive containing calcium glycerophosphate, says chemical interaction in the system.

Figure 11 shows the curves of differential thermal analysis of the initial components and compositions on their basis. As the figure shows the character of the curves (the presence or absence of endoeffect, the temperature range of the exothermic effects) quite different for them, which also indicates of the interaction of the components and the formation of new connections.

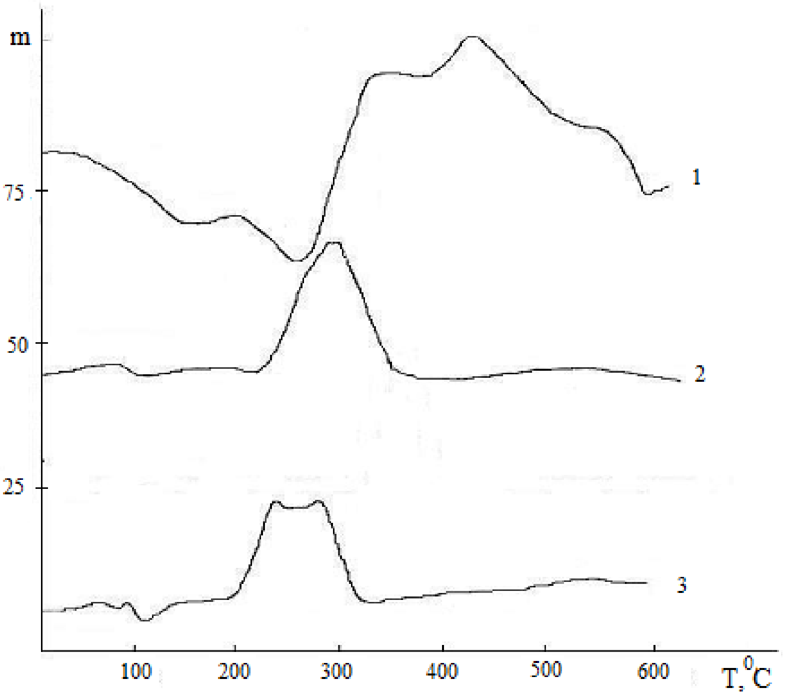

Figure 11: The curves of differential thermal analysis of calcium glycerophosphate (1), sulfur (2) and compositions based on them (3)

Considering the IR spectrum of the CGP and their compositions synthesized at few and the long-lasting time (Figure 12) there is a gradual reduction in the absorption peaks (10 min., 1 hour) reacted to deformation and stretching vibrations of water (3300, 2930-2850 cm^{-1}, 1650) and the appearance of the absorption band of 419 cm^{-1}, reacted to sulfide bonds (Nakamoto, 1991).

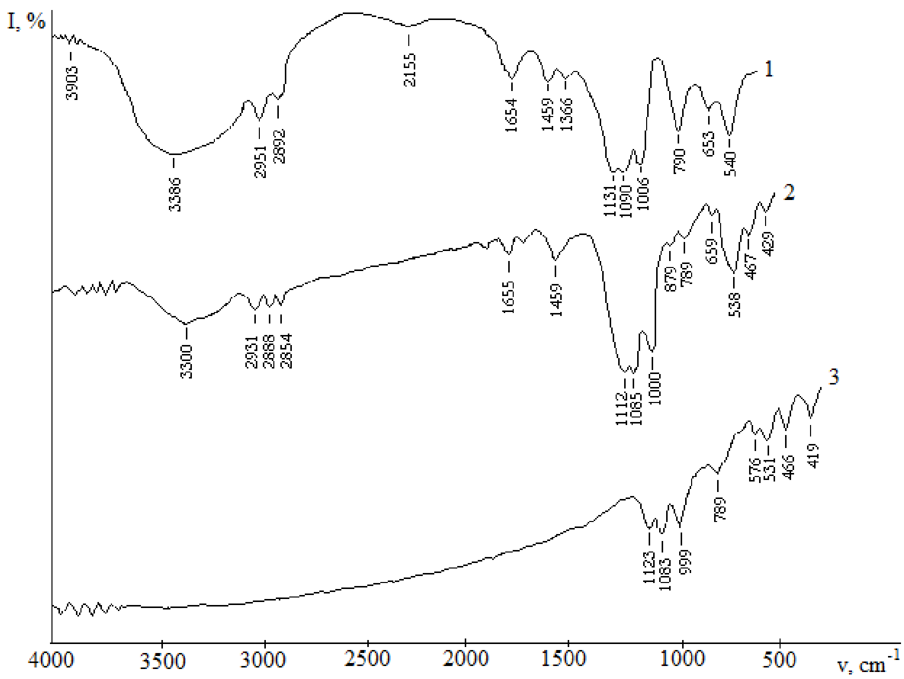

Figure 12: IR spectra of the samples of calcium glycerophosphate (1), and polysulfide compounds with addition of calcium glycerophosphate of a small synthesis time (2) and the long lasting time of synthesis (3)

Valuation ratio of the degrees of covalence, metallicity and ionicity of appropriate bonds in the received polysulfide of calcium glycerophosphate (table 4) was evaluated by the method described in the work (Sirotkin, 2005).

Table 4

Degree	Bonds					
	S-C	C-C	H-C	C-O	P-O	Ca-O
D_c	48,71	68,35	57,20	70,61	57,90	34,68
D_m	37,99	31,65	36,92	18,91	21,41	25,16
D_i	13,30	-	5,89	10,48	20,69	40,16

Where D_c – degree of covalence; D_m – degree of metallicity; D_i – degree of ionicity.

The table shows that the formed polysulfide of calcium glycerophosphate is characterized by bond (S–C) with a high degree of covalence (D_c = 48.71 %), which, combined with rather high ionic character (D_{ci} = 37.99) leads, according to the rule Shomeker-Stevenson (Sirotkin, 2003) to decrease of the internuclear distance and bond strengthening. Also confirmed predominantly ionic type of bond Ca–O (Pauling rule) (Sirotkin, 2003).

CONCLUSION

Thus obtained sulfur concretes based on sulfur – byproduct of petrochemistry with the use of metal-containing modifying additive – calcium glycerophosphate. By the methods of physical-chemical studies, the possibility of chemical interaction between the components of sulfur composite material together installed. The influence of the modifying additive CGP on chemical resistance sulfur concrete investigated. It was found that the modified sulfur concrete based on the ash-and-slag waste of TPS has a high water and acid durability. The article shows that the high performance and physical-mechanical properties (including impact strength, density, water absorption, etc.) of developed sulfur concretes determined by the form of polysulfide compounds which provide the formation of a dense and homogeneous structure. It is found that the reaction of sulfur with modifying additive of calcium glycerophosphate is in the direction of formation of unsaturated reactive compounds by dehydration of glycerol moiety and the attachment of sulfur to the double bond to form polysulfides. Practical use of sulfur concrete technology will provide significant economic effect. The cost of sulfur concretes based on ASW is reduced by 55 % over the prior analogue – concrete cement of brand M350 and by 30 % over the closest technological analogue – concrete on the basis of low molecular weight sulfides. Thus, increased physical- mechanical and performance properties of the developed sulfur concrete can be explained by the chemical interaction of components in the system and the formation of polymeric sulphides. These compositions may be used for the manufacture of road and paving slabs, curbs, grape racks, trays, pipes, tubings, sections of desalination plants, elements of marine berths, frame towers, units seepage towers and of many other designs, arrangement of floors in industrial premises to which increased demands on strength and frost resistance to aggressive environment.

REFERENCES

[1] Akhmetov, T.G., Busygin, V.M., & Gaisin, L.G. (1998). *Chemical technology of inorganic materials*. Moscow, M.: Chemistry.
[2] Bazhenov, Y.M. (1987) *Technology of concrete*. Moscow, M.: Higher school.
[3] Berg L.G., (1969). Introduction to thermography. Moscow, M.: Nauka.
[4] Gerasimov, V.V. & Porfir'eva, R.T. (1996) High-temperature pyrolysis of glycerophosphate of some metals. *ZHPH, Volume 69, Issue 2*.
[5] Kislenko, N.N. & Motin, N.V. (2002). The production and consumption of sulfur in Russia. The future of the new sulfur-containing products. *Proceedings of the International Conference «Seurat 2002»*. Austria.
[6] Mashkina, A.V. (2005) *Catalysis reactions of organic sulfur compounds*. Novosibirsk: Publishing House of SB RAS.

[7] Medvedeva, G.A., Akhmetova, R.T. & Pyatko, Y.N. (2014). Use of waste power system in production of the heat-insulating materials impregnated with fusion of sulfur. *News of the KGASU, № 2(28) (310-315)*.

[8] Medvedeva, G.A., Akhmetova, R.T. & Pyatko, Y.N. (2014). Impregnating technology of thermal insulating materials using zinc chloride activator. *Bulletin of Kazan Technological University*, 5 (47-51).

[9] Nakamoto, K. (1991) Infrared spectra of inorganic compounds. Moscow. M.: World, 411.

[10] Orlovsky, Y.I., Duleba, M.T. & Trush, L.E. (1981). Astringent: Description of the invention to the USSR author's certificates 876596. Byul. Invention, 40.

[11] Paturoev, V.V. (1987). *Polymer concrete*. Moscow. M.: Stroyizdat.

[12] Porfir'eva, R.T. & Gerasimov, V.V. (2002). Sulfuric composite materials for power system. *Proceedings of the universities. Problems of energetic № 1-2. (*pp 41-43). Kazan.

[13] Porfir'eva, R.T. (2007). *Low-waste technology for processing of sulfur in sulfides and polysulfides.* Kazan: Publishing House of Kazan state technological University Press,

[14] Sirotkin, O.S. (2003). *The beginning of single chemistry*. Kazan: Publishing House of the «Feng».

[15] Sirotkin, O.S., Sirotkin, R.O. & Trubacheva, A.M. (2005). On the need and options for addressing the metal components in the heteronuclear connections. *Journal of Inorganic Chemistry.* 50(1) (71-75).

[16] Vasiliev E.K. & Nakhmanson N.S. (1986). *High-quality x-ray phase analysis*. Novosibirsk: Nauka.

[17] Vatin N.I., Petrosov D.V. & Kalacheva A.I. Use of ashes and ash-and-slag wastes in construction. *Magazine* of *Civil Engineering*, 4 (16-18), 2071-4726. DOI: 10.5862/MCE.22.2.

[18] Volgushev, A.N. & Shesterkina, N.F. (1991). *Production and use of sulfur concrete. Overview*. Moscow. M: TSNIITEMS, 51.

[19] Volzhensky, A.V., Ivanov, I.A. & Vinogradov, B.N. (1984) *Use of ash and slag in the production of building materials*. Moscow. M.: Stroyizdat.

[20] Vlasov, A.G. & Florinskaya, V.A. (1972). *Infrared spectra of inorganic glasses and crystals*. Leningrad, L.: Chemistry.