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ADDITIVES INFLUENCE ON THE PROCESSING CHARACTERISTICS OF REFRACTORY MIXTURES

In this publication, the authors report on improving processability of concrete mixtures and the quality of monolithic linings for thermal metallurgical units and constructions. The certain result have been achieved with the introduction of expanded pearlitic sand as the additive of the mixtures thereof: the compositions of refractory mixtures with the additives of pearlitic sand (0.1%-1.8%) have been developed in order to permit both required placeability and structural strength of the mixtures.
The work produced has allowed revealing the lamellar sliding effect which occurs with the grains of the filling between the pearlite layers. This effect provides the opportunities of both better placeability and structural strength of the mixture. In its turn, the better quality of monolithic linings is achieved.

Key words: *lining, lining quality, refractory mixture, placeability, structural strength, additives, expanded pearlitic sand.*

Introduction. Currently, the metallurgical industry employs refractory concretes formed mainly by the methods of vibratory ramming and spouting for manufacturing monolithic linings of metallurgical thermal units and constructions. As the examples can serve the linings of teeming ladles, feed head linings, launder linings, the linings of tuyere devices, the linings for the elements of soaking pits, etc. Considering the high temperatures of operation for such devices and metallurgical constructions as well as the aggressive influence of molten metal and slag, the special attention is focused around the lining quality (lining structure equi-density, even surface, unchangeability of the shape at the early time of demoulding operations).

From the standpoint of the service life, the most preferable are stiff concrete mixtures as they show high strength characteristics, suitable stress-strain performance and refractory performance of the lining made from them after vibratory ramming applied for the lining preparation.

The operation experience with feed head linings from stiff concrete mixtures [1,2] (containing chamotte filler, aluminosilicate finely grounded additions, fluid glass and ferrochrome slag) has proved that this type of linings does not deliver sufficient adaptability to manufacture, in particular, it is not feasible to attain simultaneously the required placeability (able to provide equi-dense structure and the surface of good quality) and sufficient structural strength of as-formed mixture (able to ensure the unchangeable character of lining geometry and the conditions for feed heads to be put off from the vibrating core earlier before the beginning of the structural processes within the feed heads).

The attempts to improve the mixture placeability characteristic by increasing fluid glass content have shown a drastic decrease in the structural strength values of the as-formed mixture: when the feed heads are put off from vibrating core, their linings lose the shapes due to the plastic deformation.

The refractory mixtures with the smaller content of fluid glass (as compared with the optimal rate) possess the structural strength needed, however, it does not permit equi-dense lining surfaces of good quality.

Thus, we evidently face the contradiction which demands the engineering solution: the optimal mixture in terms of placeability does not have the necessary structural strength, otherwise, the mixture with the sufficient structural strength and fast setting does not possess the required placeability.

The problem indicated appears mostly when thin-wall linings are made, for instance, in cases when the permanent layer and the working one are produced for feed heads. Thanks to the insufficient structural strength of the concrete mixture, the permanent layer made from it (its surface is usually longer than that of the working layer) changes the shape formed when it is put off from the vibrating core. Thus, the permanent layer surface is deformed in the area of the part contacting with the permanent layer. This produces an adverse effect and retards the working layer shifting in respect to the permanent layer when removing after the lining is worn and needs relining. The similar drawbacks of thin-wall combined lining are described in publication [3].

Here, the previous findings should be noted wherein the authors study the various engineering techniques targeting the improvement on the lining quality along with the introduction of light fillings within its mixture, in particular pearlitic sand [4. p.p. 42-43]. However, they failed to achieve the required adaptability of the mixture to the manufacturing conditions for providing its quality at the stage of its manufacture. In particular, the application of the refractory mixtures based on the pearlitic sand possessed better structural strength, however, they demonstrated the drastically worsen properties of fluidity. The preliminary saturation of the pearlitic filler with water turned to be a remedy found by the authors for this situation but it caused low structural strength within the mixtures.

Research Target. In the light of the problem reviewed above, the current research aims at improving the lining quality along with attaining better placeability and higher structural strength of the refractory mixture.

Experiments and their Results. In order to find the solution for the indicated research problem we experimentally have determined that there is a positive influence of the expanded pearlitic sand if it is added in small amounts.

The quantitative assessment for the expanded pearlitic sand influence has been carried out with the employment of the additives widely adopted for the lining production, namely, aluminosilicate finely grounded additions: kyanite-sillimanite concentrate and IM-2201 catalyst.

The experiment results are summarized in the tables presented below: Table 1 describes the contents of the refractory mixtures with the finely grounded additions of IM-2201 catalyst while table 2 – the results with kyanite-sillimanite concentrate.

Each refractory mixture composition has been prepared individually as described. In the cement-mixer we put chamotte filler, finely grounded addition, ferrochrome slag and pearlitic sand. The dry components were mixed during 2 minutes, after that the fluid glass was poured in and carefully mixed during 3 minutes. The samples were prepared by vibrating method on the standard vibrating table.

The placeability of the refractory mixture was determined in accordance to the standard obligatory requirements of DSTU B V. 2.7-96-2000 (GOST 10181.1-81).

The structural strength of as-formed mixture was indicated by the compression test conducted for the samples with the geometry of 5x5x5 cm with the time interval of 10 minutes, 20 minutes and 30 minutes after mixing concrete ingredients with the fluid glass. The test was performed at the hydrostatic press of lower capacity equipped with the manometer with the scale graduation value of 10 kilogram-force. The force increase rate was 2-3 kilogram-force per second.

The indicators of the placeability and the structural strength of the refractory mixture with respect to their dependence on the pearlitic sand addition are presented in Fig. 1 and Fig. 2.

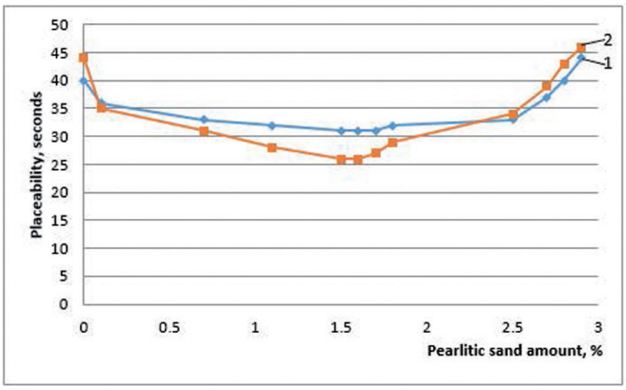

Figure 1. Placeability of Refractory Mixtures: 1- Mixtures with Finely Grounded Addition of IM-2201 Catalyst; 2- Mixtures with Finely Grounded Addition of Kyanite-Sillimanite Concentrate.

Constituents	Composition/ Constituent Amounts, %wt											
	1	2	3	4	5	6	7	8	9	10	11	12
Chamotte filler of 0.14-20 mm size	63.3	63.0	60.8	60.0	58.5	58.4	57.4	55.7	53.4	52.8	52.5	52.1
IM-2201 catalyst	20.4	20.5	21.5	21.6	22.0	22.2	22.3	22.3	22.5	22.6	22.7	22.8
Fluid Glass	14.5	14.6	15.1	15.4	16.0	15.8	16.5	17.2	19.6	19.9	20.0	20.2
Ferrochrome slag	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Expanded pearlitic sand	-	0.1	0.7	1.1	1.5	1.6	1.7	1.8	2.5	2.7	2.8	2.9

Table 1. Refractory Mixture Composition with Aluminosilicate Finely Grounded Addition of IM-2201 Catalyst

Constituents	Composition/ Constituent Amounts, %wt											
	13	14	15	16	17	18	19	20	21	22	23	24
Chamotte filler of 0.14-20 mm size	63.9	63.6	61.8	60.8	59.1	58.8	58.3	58.0	56.1	55.4	55.0	54.6
Kyanite-sillimanite concentrate	18.3	18.4	19.0	19.4	19.7	19.9	20.1	20.1	20.2	20.3	20.3	20.4
Fluid Glass	16.0	16.1	16.6	17.0	17.7	17.7	17.9	18.1	19.2	19.6	19.9	20.1
Ferrochrome slag	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Expanded pearlitic sand	-	0.1	0.7	1.1	1.5	1.6	1.7	1.8	2.5	2.7	2.8	2.9

Table 1. Refractory MixTable 2
Refractory Mixture Composition with Aluminosilicate Finely Grounded Addition of Kyanite-Sillimanite Concentrate

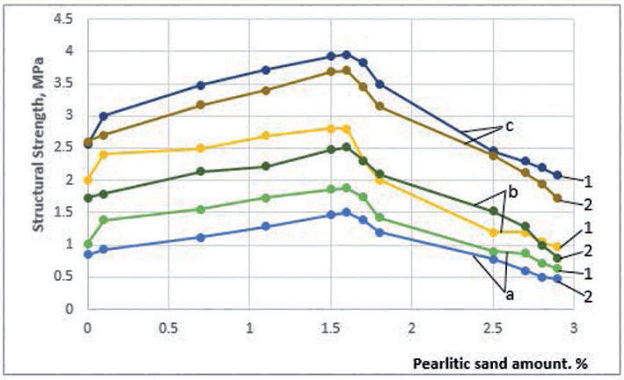

Figure 2. Structural Strength of Refractory Mixtures: 1 – Mixtures with Finely Grounded Addition of IM-2201 Catalyst; 2 - Mixtures with Finely Grounded Addition of Kyanite-Sillimanite Concentrate; a - After 10 min of Mixing Concrete Ingredients with Fluid Glass; b – After 20 min; c – After 30 min.

It is apparent from Fig. 1 that the placeability of the initial refractory without additions (composition 1 and composition 13) improves with the introduction of expanded pearlitic sand as much as 0.1%. The maximal content of the pearlitic sand which does not interfere in placeability characteristics is 2.7% for the compositions containing IM-2201 catalyst while for those with kyanite-sillimanite, the pearlitic sand should not exceed 2.8%. The further increase of the pearlitic sand share within the mixture recipe brings the adverse effect on the placeability of the refractory mixtures.

The best placeability results registered are a slightly different in their values with the compositions containing IM-2201 catalyst and those with kyanite-sillimanite. Thus, for the compositions with IM-2201 catalyst, the best result is 31 seconds and is achieved if the pearlitic sand percentage is within the range of 1.5-1.7% (refer to compositions 4 and 6) while for the mixtures with kyanite-sillimanite it is 26 seconds (compositions 15-16) on condition that the pearlitic sand introduced is within 1.5-1.6%.

Moreover, the improved characteristics of the refractory mixtures in terms of their structural strength are also observed with the introduction of the expanded pearlitic sand amount of 0.1 % (Fig. 2).

Further, the maximal content of the pearlitic sand, which permits the sustainability of the structural strength improvement for the both types, is 1.8% since the higher pearlitic sand content worsens the named parameter. The best structural strength of the mixtures is observed when the pearlitic sand within the mixture is 1.5-1.6 %. At this, the structural strength of the mixture with finely grounded addition of IM-2201 catalyst can reach 3.92-3.95 MPa at 30 min after mixing the mixture ingredients but for the mixtures with finely grounded addition of kyanite-sillimanite concentrate, it is 3.68-3.7 MPa.

Eventually, the test results with the refractory mixtures evidence that the 0.1-1.8% content of expanded pearlitic sand within the refractory mixture structure allows both their improved placeability and their increased structural strength.

Results and Discussion. In our opinion, the simultaneous effect of better placeability and higher structural strength is achieved due to the positive effect of lamellar sliding. The essence of this phenomenon is that in the process of mixture vibratory ramming there are pearlite lamellas found between the chamotte grains within the mixture structure, these pearlite lamellas are present in minimal but sufficient quantity. During this process, the filler grains slide on the surface of the pearlite lamellas (refer to Fig. 3) and therefore the placeability of the mixture improves, the process becomes more effective than the process of water-cement paste dewatering which simultaneously occurs and worsens its placeability.

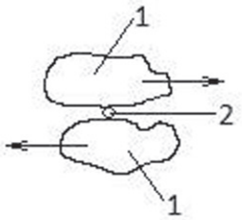

Figure 3. Characteristics of Lamellar Sliding Effect: 1 – Chamotte Grains; 2 – Pearlite Lamella.

Conclusions and Perspective for Further Researches. Experimentally, we have determined the positive effect of small additions of expanded pearlitic sand on refractory mixture placeability and structural strengths. The optimal content of the pearlitic sand additions to deliver the required processing characteristics is found to be within 0.1-1.8%. We have determined the effect of filler grains lamellar sliding between the pearlite lamella. This allows improved placeability accompanied by improved structural strength. It is advisable to introduce the indicated optimal amount of the pearlitic sand addition for attaining better adaptability of the mixture to the manufacture process with the purpose to improve the quality of monolithic linings of metallurgical thermal units and constructions.

REFERENCES

1. Zavadskij M. Ja., Konopljanik A.Ju., Belkin A.I. (1990) Primenenie zharostojkogo betona v futerovke pribyl'nyh nadstavok izlozhnic dlja slitkov massoj 24 t [Heat-Resistant Concrete in Feed Head Lining for 24 Ton Ingot Molds] *Ogneupory* [Refractories]. No 7. p. p. 52-56.
2. Zavadskij M. Ja., Prjadko V. M., Konopljanik A. Ju. (1991) Tehnologija izgotovlenija futerovki pribyl'nyh nadstavok iz zharostijkogo betona [Production Technology for Feed Head Lining Made from Heat-Resistant Concrete]. *Chernaja Metallurgija. Bjulleten' Nauchno-Tehnicheskoj Informacii* [Ferrous Metallurgy. Bulletin of Scientific and Technical Information]. No. 11. p. p. 72-74.
3. Tkachenko Je. A., Ermokrat'ev V.A., Grishin V.S. (2014) Metodika rascheta nesushhej sposobnosti shpinel'soderzhashhih futerovok metallurgicheskih agregatov [Strength Calculation Methodology for Metallurgical Linings Containing Spinel Material]. *Metallurgicheskaja i gornorudnaja promyshlennost'* [Metallurgical and Mining Industry]. No 4. p. p. 79-83.
4. Majzel' I.L., Suharev M.F. (1965) Zharoprochnyj Teploizoljacionnyj Perlitobeton [Heat-Resistance and Thermally Insulating Pearlitic Concrete]. Moscow Strojizdat 128 p.