Development and use of high alumina plastic in reheating furnaces of Tisco

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Laboratory work was taken up to develop high alumina plastic for maintenance of furnaces in authors' plant. Laboratory data of raw materials taken are given. In order to have a product with better workability an attempt was made to improve the plasticity of clay. Laboratory data of different mixes are mentioned.

The developed material was put on trial at various installations in the plant. One of the areas where extensive trial was conducted is the mill side. The plant trials gave quite encouraging results which are stated in detail.

Introduction

Now a days plastic refractories are gaining wide popularity in Steel Plants and other industries due to certain advantages in application. They have got the advantageous property of deformability without rupture and retentivity of deformed shape after release of stress. They are monolithics prepared in stiff plastic condition of proper workability for use without further preparation. They are mixtures of graded refractory aggregate and a plastic fraction with or without plasticizers. Their application is easy and time saving. They can be applied in intricate positions locally without disturbing the rest of the lining and can be moulded to any shape in situ, thus eliminating the requirement of special refractory shapes.

A number of monolithic refractories such as, ramming masses, castables and gunniting materials were developed and used successfully in Tata Iron and Steel Company till recently. But plastics were yet to be developed. Feeling the necessity of plastics for better maintenance at certain locations, development work of high alumina plastic was taken up.

Experimental work

Laboratory data on raw materials are given in Table I and Table II.

The high plasticity of plastic fraction in a plastic mix is of prime importance. If the clay available is highly plastic, mere mixing of graded refractory aggregate and plastic in right proportion will give a suitable material. But in absence of highly plastic clay the alternatives left are, addition of plasticizers or ageing of clay or blending it with another clay of more plastic nature.

Since no highly plastic clay was available an attempt was made to enhance the plasticity of available clay by addition of plasticizers and by ageing.

Addition of plasticizers

Plasticity index (Atterberg number) of clay (as such) i. e. B was determined according to standard method (IS-4589-1968). Different plasticizers Ad1, Ad2 and Ad3 were added in different percentages to B and after thorough mixing, plasticity indices were determined. The results are given in Table III.

Ageing

Weighed quantity of powdered clay was taken in a clean glass container and measured volume (43%) of water was added to it. After thorough mixing the slurry was left for ageing. To prevent rapid vaporisation of water, the container was kept covered with moist gunny bag. The slurry was agitated once a day. From 6th day onwards the consistency of slurry was watched. On eleventh day when the consistency was found suitable the flow limit was determined. The paste was then dried and plastic limit was found out at proper time. From the two figures of flow limit and plastic limit plasticity index was found out.

Little more water was added to the paste in the glass container and thoroughly mixed and left for further ageing. Consistency was watched daily. On 16th day when the proper consistency was arrived, plasticity index was determined as already stated.

Some more water was added to the paste and after thorough mixing left for still further ageing. On 31st day when the right consistency was arrived plasticity index was determined. The results are given in Table IV

After working on the aspect of improving the plasticity of clay (B), the grading of refractory aggregate was done. The selected plasticizer was added in required percentage to clay (B) and intimate mixing was done.

The graded refractory aggregate and the above clay plasticizer mix were mixed in different proportions and required quantity of liquid was added to each mix.

The different compositions were tested for workability index as per ASTM standard method (ASTM Designation C—181—47 (1971).

175 mm x 25 mm x 25 mm briquettes and 50 mm x 50 mm cylinders were made from these compositions. The briquettes were tested for drying and firing changes, apparent porosity, bulk density, apparent density and cold crushing strength after firing at different temperatures.

The properties are mentioned in Table V. Chemical analysis, P. C. E. and screen analysis of the selected high alumina plastic are given in Table VI and VII.

Discussion

A survey of Table III reveals that the plasticity index of B rises from 20 to 27.5 with 5% of Ad1. and to 31 with 10% of the same material. In case of Ad3 the plasticity index rises from 20 to 25.6 with 5% and to 29.6 with 10% of the material.

But addition of 5% and 10% of Ad2 increases the plasticity index from 20 to only 20.5 and 21.5 respectively. That means among the plasticizers added Ad1 was most effective whereas Ad2 was the least. Ad3 is an organic plasticizer added in the form of paste. Table IV shows that plasticity index of B rises from 20.0 to 22.5 after 10 days of ageing, 20 to 23.0 after fifteen days of ageing and 20.0 to 23.5 after ageing for a month. This leads to the inference that process of ageing is not enhancing the plasticity of the clay in question to that extent as is obtained by addition of plasticizer Ad1.

In view of the above findings, compositions were made with clay which was intimately mixed with 10% of Ad1. Table V reveals that out of three compositions made, P2 is having lower drying and firing changes compared to P1 and higher C. C. S. than P3.

Considering the workability index it is observed that workability index of P2 is lower than that of P1 and P3 crumbled during the test.

On the basis of applicability P2 was preferred to P1 and P3 was discarded due to poor workability. Thus P2 was selected from the lot.

Plant trials

The developed high alumina plastic was first manufactured by extrusion process in Refractories Plant in the form of 230 mm x 114 mm x 75 mm bricks on 23rd December, 1974, for trial purpose. The bricks were wrapped in plastic paper and sent to the site of trial. The trial was conducted first in reheating furnace No. 2 of Rail Mill which is a continuous type gas fired furnace and works at a temperature of 1300°C.

The plastic was applied at a few places on roof in the heating zone of the furnace covering a total area of roughly three square meters. At one or two places full bricks were introduced and compacted by wooden mallet to fill the cavity. Over and above the rectangular areas between burners above the suspended arch in soaking zone were filled up by plastic bricks at three places. After roughly one and half months when the furnace was down the area was inspected. All the patches were found in-tact. There was neither any trace of crack nor any patch or part of patch had fallen. Figs 1 and 2 are the photographs of a few patches taken during inspection. In Fig. 1, the plastic patches are marked as P. The photograph clearly shows that the patches were in good condition. Fig. 2 shows the photograph of plastic brick introduced into the cavity and placed by hammering. Some plastic patches are also visible in the top of the photograph. A fresh lot of plastic was made and applied in the

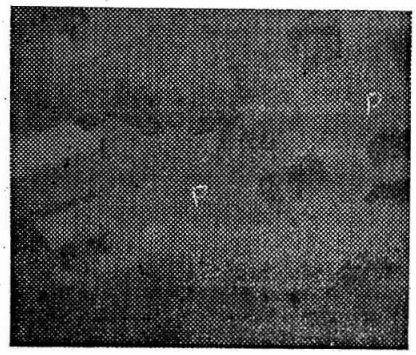

Fig. 1 Plastic patches (P) in the roof of Rail Mill, Reheating Furnace No. 2 in heating zone (after one and a half months of service).

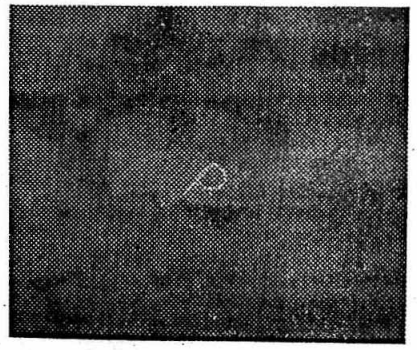

Fig. 2 Plastic brick in the roof of Rail Mill, Reheating Furnace No. 2, in heating zone (after one and a half months of service).

soaking zone of the same furnace on 6-2-1975, covering a total area of roughly three to four square meters. Fig. 3 is the photograph of the same old plastic brick taken after a service of 13 months. A look at the photograph very clearly shows that the surface is exactly in the same condition as it was earlier. Fig. 4 is the photograph of patches in the soaking zone of the same furnace after a service of roughly one year. The patches are visible in the top and right side of the photograph. Getting the encouraging trend the trial was extended to reheating furnace in other mills.

The next reheating furnace where trial of high alumina plastic was conducted was Merchant Mill furnace. This also is a continuous type gas fired furnace and is operating regularly at a temperature of 1250°C-1300°C. Though

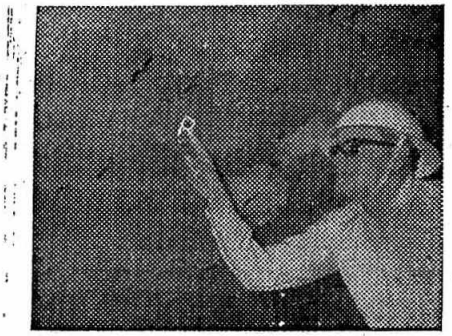

Fig. 3 Plastic brick in the roof of Rail Mill, reheating furnace No. 2 in the heating zone (after 13 months of service).

Fig. 4 Plastic patches in the roof of Rail Mill, reheating furnace No. 2 in the soaking zone (after a year of service)

the shut down period alloted was only 48 hours still plastic could be applied in the furnace roof on 26-2-1975 in heating as well as soaking zone, covering a total area of roughly 4—5 square meters. When observed on 28-3-75 the condition of the patches was found to be good. Patch work was done in other areas on 28-3-75. On 3-4-76 the bricks in a very big area of the roof were found to have badly spalled. So a decision was taken to knock the area and do a fresh brick work in the region. In the process of knocking the roof in that region the plastic patches automatically came out along with the bricks. Fresh plastic was applied in other part of the roof.

The next place where high alumina plastic was applied in re-heating furnace was Skelp Mill. This furnace is also a continuous type gas fired furnace and is being operated at a temperature of 1250°C. On 16-4-75, a total area of roughly 5 square meters was covered with this plastic in the heating and soaking zone. The patched area was inspected thrice i. e. on 20-7-75, 17-9-75 and 8-10-75. Every time the patches were found in good condition. But the roof was changed during the annual shut-down period when the bottom of the furnace was laid with fusion cast blocks.

High alumina plastic was also applied in roof of Plate Mill reheating furnace on 4-6-75 at some places covering a total area of five square meters. It is a gas fired batch type of furnace operating at a temperature of 1300°C. The patches were observed on 2-8-75, 30-10-75 and 6-12-75. No flow was observed any time in any of the patches. Another fresh lot of material was applied at few other places covering a total area of 3—4 square meters on 3-10-75. On 7-3-77 when observed all the patches were found to be in position. The patches are still surviving.

The trial of high alumina plastic was at length extended to medium & light structural mill reheating furnace. The plastic was applied in the whole lintel arch area over delivery slope of furnace No. 2. The skid supporting cross pipe of the furnace was also covered with plastic at few places. Fig. 5 is the photograph of the lintel arch area taken after 433 days of service. The photograph clearly shows that the plastic is still in position. Fig. 6 is the photograph of the skid supporting cross pipe taken after 433 days of service. Here also the plastic was found in fairly good condition.

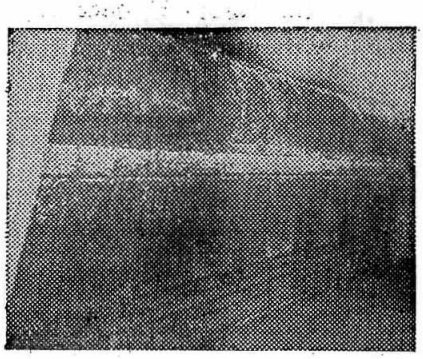

Fig. 5 Lintel arch of medium & light Structural Mill, Furnace No. 1 covered with high alumina plastic (after 433 days of service).

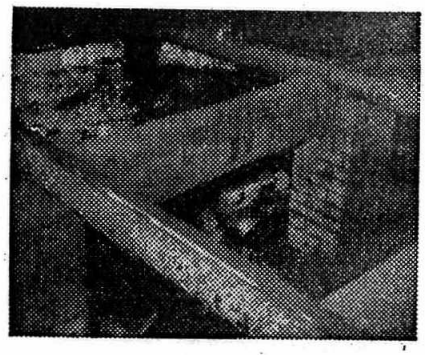

Fig. 6 Skid supporting cross pipe of medium & structural mill. Furnace No. 1, covered with high alumina plastic. (after 433 days).

The trial details are given in Table VIII.

Use of high alumina plastic in reheating furnaces has become a common feature of the day. Its application has simplified the repair job at a lower cost.

Conclusion

1. High alumina plastic of suitable workability was developed for the maintenance of reheating furnaces.

2. Even without a plastic clay, plastics can be developed with the help of suitable plasticizer.

3. Major shut downs in reheating furnaces were avoided by application of high alumina plastic. The down time, cost and man-power have been saved considerably.

Acknowledgement

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TABLE—I Chemical analysis and P. C. E. of raw materials

Sl. No.	Material	Symbol	Chemical Analysis (%)									P. C. E. (Orton)
			SiO_2	Al_2O_3	FeO	Fe_2O_3	CaO	MgO	TiO_2	T. Aik	Loss	
1.	Non plastic fraction	A.	35.10	61.28	Tr	1.72	0.80	0.28	0.51	—	0.30	34—35
2.	Plastic fraction	B.	60.60	25.79	0.73	2.14	0.10	0.29	1.12	0.50	9.18	30—31
3.	Additive	Ad1	57.30	21.68	—	4.68	2.34	2.27	—	1.19	11.05	1330°C (Opt.)
4.	Additive	Ad2	52.82	23.31	0.13	2.14	0.80	0.22	1.12	0.90	17.80	1575°C (Opt.)
5.	Additive	Ad3	organic paste									

TABLE—II Screen analysis of raw materials

Sl. No.	Material	Symbol	Screen Analysis (%)							
			+8mesh	+12mesh	+20mesh	+35mesh	+60mesh	+100mesh	−100mesh	Total
1.	Non plastic fraction (graded)	A.	4.9	16.4	18.3	13.4	5.00	5.6	36.4	100.0
2.	Plastic fraction	B.	—	—	1.1	21.3	18.6	9.6	49.3	99.9

TABLE—III Plasticity index of clay with different plasticizer

Sl. No.	Material spmbol	Plasticizer additive	% by weight	Flow limit	Plastic limit	Plasticity index (Atterberg number)
1.	B.	—	—	41.0	21.0	20.0
2.	B.	Ad1	5	43.5	16.0	27.5
3.	B.	Ad1	10	51.6	20.6	31.0
4.	B.	Ad2	5	37.4	16.9	20.5
5.	B.	Ad2	10	38.5	17.5	21.5
6.	B.	Ad3	5	43.7	18.1	25.6
7.	B.	Ad3	10	48.7	19.1	29.6

TABLE—IV Plasticity index of aged clay

Sl. No.	Material	Flow limit	Plastic limit	Plasticity index (Atterberg number %)
1.	B.	41.0	21.0	20.0
2.	B. (Aged for 10 days)	38.0	15.5	22.5
3.	B. (Aged for 15 days)	37.5	14.5	23.0
4.	B. (Aged for 1 month)	36.0	12.5	23.5

TABLE—V Properties of different compositions

Sl. No.	Composition symbol	Properties	Temperature °C				
			R. T.	300	600	900	1300
1.	P1 (Water added 13%)	Lin. Change (%)	1.3 (s)	0.40 (s)	0.65 (s)	0.80 (s)	1.06 (s)
		App. Poro (%)	22.3	24.4	25.1	25.4	22.3
		B. D. (gm/cc)	2.19	3.14	2.12	2.11	2.16
		A. D. (gm/cc)	2.82	2.83	2.83	2.83	2.80
		C. C. S. (kg/cm²)	68.2	75.6	87.7	112.0	154.3
		Workability index (%)	23.0				
2.	P2 Water added 12%)	Lin. Change (%)	0.90 (s)	0.17 (s)	0.30 (s)	0.33 (s)	0.61 (s)
		App. Porosity (%)	23.3	24.7	26.4	26.7	25.0
		B. D. (gm/cc)	2.20	2.16	2.12	2.11	2.15
		A. D. (gm/cc)	2.87	2.87	2.88	2.88	2.88
		C. C. S. (kg/cm²)	50.5	81.0	86.0	116.0	138.0
		Workability index (%)	18				
3.	P3 (Water added 10%)	Lin Change (%)	0.60 (s)	0.10 (s)	0.16 (s)	0.22 (s)	0.30 (s)
		Appr. Porosity %	26.3	28.2	29.3	30.6	29.9
		B. D. (gm/cc)	2.14	2.11	2.07	2.04	2.06
		A. D. (gm/cc)	2.92	3.94	2.93	2.94	2.94
		C. C. S (kg/cm²)	34.5	56.4	75.4	89.8	105 0
		Workability index (%)	Crumbled in second impact.				

TABLE—VI Chemical analysis of plastic compositions

Sl. No.	Composition	Chemical Analysis (%)									P. C. E.
		SiO_2	Al_2O_3	FeO	Fe_2O_3	CaO	MgO	TiO_2	T. Alk.	Loss	
1.	P—1	43.82	49.18	0.22	2.00	0.63	0.32	0.70	0.17	2.82	N. D.
2.	P—2*	41.53	52.12	0.14	1.88	0.73	0.33	0.64	0.12	2.29	32—32½ (Close to 32)
3.	P—3	38.10	56.42	Tr.	1.82	0.75	0.32	0.58	0.07	1.38	N. D.

TABLE—VII Screen analysis (Tyler) of plastic compositions

Sl. No.	Composition	Screen Analysis (%)							
		+8mesh	+12mesh	+20mesh	+35mesh	+60mesh	+100mesh	−100mesh	Total
1.	P—1	3.3	11.2	12.8	15.5	8.8	6.7	41.6	99.9
2.	P—2*	3.9	12.7	14.7	14.8	7.5	6.2	40.0	99.8
3.	P—3	4.3	14.5	16.3	13.9	6.3	5.9	38.6	99.8

* Selected composition

TABLE—VIII Details of plant trial

Sl. No.	Date of application	Mill, Furnace No.	Location and Area covered	Date of observation	Observational remarks	Life
1.	25-12-1974	Rail Mill, Furnace No. 2	Roof heating zone & three rectangular areas between burners above the suspended arch. Area—roughly three square metres.	6- 2-75	Condition good. (No flaw observed).	Over 2 yrs 11 months
				20- 7-75	No change.	
				25-10-75	No change.	
				2- 4-76	Surface uneven at few places (some patches near the door were removed because of fresh brick-work).	
				1- 6-76	A few patches removed while doing brick-work at the junction of heating and soaking zones.	
				Nov. 77	Remaining still surviving.	
2.	8- 2-1975	Same	Roof—applied at some places in soaking zone. Area—3-4 square metres	20 7-75	Condition good. Patches near the arch acquired little glazy appearance.	Over 2 yrs. 11 months
				25-10-75	No change observed.	
				25- 1-76	Practically same.	
				1- 6-76	Practically same.	
				Nov. 77	No change. Still surviving.	
3.	20- 7-1975	Same	A few more places in heating and soaking zones. Area—roughly two square metres	25-10-75	Condition good.	Over 2 yrs. 5 months.
				25- 1-76	Same.	
				1- 6-76	Still in good condition.	
				15- 9-76	Same.	
				15-12-76	Little unevenness observed at few places.	
				Nov. 77	Same. Still continued.	
4.	15- 9-1976	Same	Applied at some more places in spalled area in heating and soaking zones.	15-12-76	Condition good.	Over 1 yr. 2 months.
				25- 2-77	No change observed.	
				Nov. 77	Continued.	
5.	20- 9-1975	Merchant Mill No. 2	Soaking zone and parts of	28- 2-75	Condition of the plastic was good	1 year

5.	26- 2-1975	Merchant Mill No. 2. Furnace	Soaking zone and parts of roof heating zone (applied quickly in 48 hrs. Total shut down period). Area—4-5 square meters.	28- 3-75 3- 4-76	Condition of the plastic was good. Practically same. Knocked out during fresh brick-work.	1 year 2 month.
6.	28- 3-1975	Merchant Mill No. 2 Furnace roof	Roof—Soaking zone. Area 3 square metres.	3- 4-76	Little vitrification at few places. Bigger area of roof had spalled. Fresh brick-work done, but in other areas of the high alumina plastic was applied.	1 year 1 month
7.	16- 4-1975	Skelp Mill, Reheating Furnace	Roof. Area 5 square metres.	20- 7-75 17- 9-75 8-10-75	No flaw observed (intact). No change. Practically no change (whole roof was made during laying the bottom with imported fusion cast blocks).	1 year 6 months.
8.	4- 6-1975	Plate Mill roof	Some places in roof were patched. Area 5 square metres.	2- 8-75 3-10-75 6-12-75 7- 3-77	Condition good (No flaw observed). No change. No change. No change. Still continuing.	Over 2 yrs. 6 months.
9.	3-10-1975		Same, other spots. Area 3—4 square metres.	6-12-76 7- 3-77	Good condition. Practically no change. Still continuing.	Over 2 yrs. 2 months.
10.	20- 8-1976	Med. & Light Structural Mill Furnace No. 1.	Full lintel arch area.	5-12-77	Condition good.	Over 1 yr. 2 months.
11.	20- 8-1976	—do—	Skid supporting cross pipe.	5-12-77	Condition O. K.	Over 1 yr. 2 months.