HIGH PERFORMANCE TAPHOLE CLAY FOR BLAST FURNACE

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1.0 Abstract
Taphole clay plays very important role in blast furnace cast house operation. In past, taphole clay was used for a mere purpose of plugging of taphole and discharge of iron and slag produced inside blast furnace. However, recently taphole clay is exposed to severe condition as the size of blast furnace become bigger and operation gets severe. The important role for taphole clay are: 1) Stable operation by hearth drainage 2) Reduction of workload and achievement of small refractory consumption by longer tapping duration and 3) Achievement of longer furnace life by protection of hearth side wall with long taphole length.
In order to fulfill these functions, various studies have been conducted on binders and fine additives. It is also important to evaluate taphole clay as a structure rather than just chemical and physical properties. Therefore, it is important to understand the characteristic of taphole clay behavior under hot and confined situation. With these studies and evaluation method, it is possible to customize the taphole clay based on the requirement of customer to provide reliable performance.

There are three basic factors of taphole clays i.e. ramming, tapping and sidewall protection (Fig.1). Subsequent requirement and features of taphole clay are complicated and mutually inter-related. First of all, it is necessary to have appropriate extrusion pressure at the time of ramming so that taphole clay can create compact texture inside taphole. Therefore, adjustment of the taphole clay strength by controlling sintering characteristic is important in accordance with the type of drilling machine such as pneumatic or hydraulic driven. This longer cast duration contributes to not only the reduction of clay consumption or other consumables but also reduction of workload at cast house such as gun up and drilling. Thirdly, taphole clay is also expected to protect hearth side wall by creating protection layer of taphole clay called mushroom inside taphole. In order to create good mushroom, it is important to have higher plasticity and excellent adhesion with old clay inside the on exposure to hot and confined space. By achieving all aforementioned requirements, it is possible not only to reduce refractory consumption but also to have stable operation of Blast Furnace.
3.0 Experimental and Discussion

3.1 High Plasticity: Plasticity of tap hole clay has been measured with compressive load test. The cylindrical samples (Height = 50mm; Diameter = 50mm) were prepared and heat treated it in an Electric Furnace at 150°C for one hour. Then plasticity was determined with uniform loading rate of 4mm per minute as shown in Fig.2. Taphole clay A, with low viscosity of tar, showed stagnant load at 8 mm stroke position. This means sample A suffered severe cracks, whereas release of load was observed in sample C with high viscosity of tar, resulting linear increase of compression stroke and load. The photographs of the samples after destructive test are shown in the Fig.3. Sample C with higher plasticity showed fewer cracks compared with sample A with lower plasticity. Based on the above results, it is clear that taphole clay with higher plasticity gives longer and good texture inside the taphole under hot condition.

3.2 High Corrosion Resistance: Schematic diagram of rotary slag corrosion test is shown in the Fig.4. Samples are formed into mold with 7MPa pressure and pre-fired in reduced atmosphere at 500°C. Then samples are placed in rotary slag corrosion test equipment and fired at 1580°C. During experiment, slag is removed and fresh slag is added every 30 minutes repeatedly for 10 cycles. The cross sectional views of the samples after slag corrosion test are shown in Fig.5.

Wear resistance of tap hole clay can be improved by adding nitride compounds. Nitrides form strong bond during tapping. The relationship between nitride content and wear index is shown in the Fig.6. It has been observed that longer cast duration can be achieved with increased amount of nitride.
Quality and quantity of metallic addition in tap hole clay improve the strength and porosity. The Modulus of Rapture and apparent porosity of clay are shown in presence of two different kinds of metallic additives X and Y (Fig.7). Strength and apparent porosity were measured after firing the sample at 1200°C/3hrs in reducing atmosphere. Metallic additive X shows higher strength, whereas metallic additive Y shows lower apparent porosity. Therefore, it is essential to select suitable metallic additive to get optimized properties both in terms of strength and apparent porosity.

Fig.6 Additive Contents and Wear Index / Modulous of Rupture

Fig.7 Modulus of Rupture and Apparent Porosity with Metallic Additives X and Y

3.3 Optimization of Binder:
In order to reduce the defect caused by volatilization of binder under hot condition, in general, it is important to reduce the binder content as minimum as possible with certain extrusion pressure. Fig.8 shows the effect of binder addition along with ultra fine powder content on apparent porosity of clay after heat treatment at 1200°C in reducing atmosphere. It indicates that for this type of taphole mixes, an addition of 26% of ultra fine powder results in the highest reduction of tar binder content while keeping extrusion pressure at same level. By doing so, it is possible to achieve lower apparent porosity and dense structure.

Fig.8 Ultra-Fine Powder Content & Wear Index/ Apparent Porosity

3.4 Faster Setting: In order to reduce initial spitting during tapping, faster hardening speed is important. Fig.9 shows hardening characteristic of clay in presence of different binders. The test was conducted with cylindrical sample (Height = 30mm; Diameter = 35mm) and were kept in electric furnace preheated at 450°C. Each samples were taken out from the Furnace at certain interval and crushing strengths were measured. Resin bonded clay shows very high hardening speed in comparison with tar bonded clay. So, it is possible to adjust the hardening speed of the clay by proper mixing of tar and resin.

Fig.9 Hardening behaviour of Clay in Presence of Different Binders

3.5 Good Adhesion: The blast pressure inside the Blast Furnace is high with larger size of furnace and higher productivity. To give the satisfactory performance under severe condition, taphole clay with good adhesive characteristic is necessary to form uniform and strong protection layer, called mushroom inside the furnace. For this purpose, taphole clay containing Roseki aggregates show better ability to form mushroom. It has been observed that Roseki aggregate containing clay shows better performance than taphole clay with alumina aggregates, in spite of the fact that alumina aggregate
has higher refractoriness than pyrophyllitic aggregate. Roseki aggregates have unique expansion characteristic and gives good creep characteristic under hot and confined condition. So taphole clay with Roseki shows unique thermal expansion (Fig. 10). This means that taphole clay texture becomes denser and at the same time gives better adhesion to existing taphole clay and creates longer taphole. Fig. 11 shows the result of adhesion test with SiC crucible. Crucibles are filled with clay having Roseki aggregate and Al₂O₃ aggregate followed by firing at 1450°C/3hrs in reducing atmosphere. It has been observed that there is gap formation between SiC crucible and clay having Al₂O₃ aggregate whereas no gap formation observed in case of clay with Roseki aggregate. This gap may results loose texture and cracking during operation.

![Fig. 10 Thermal Expansion of the Clay](image)

![Fig. 11 Adhesion Test in SiC Crucible](image)

3.6 Evaluation Method of Taphole Clay as Structure:
Since the different functions of taphole clay are very much complicated as mentioned in Fig. 1; therefore, by evaluating only chemical and physical properties are sometimes misleading. In order to evaluate taphole clay performance in actual case (as a structure), laboratory equipment for simulation tests are very much essential. A series of equipment like taphole, mud gun, drilling machine etc. have been developed for simulation test in laboratory.

![Fig. 12 Schematic Taphole Clay Ramming Test & Rammed](image)

![Fig. 13 Photographs of Rammed Taphole Clay (Resin & Tar Bonded)](image)

![Fig. 14 Schematic Ramming Test Followed by Firing in SiC Crucible](image)

![Fig. 15 Appearance of Taphole Clay after SiC Crucible Test](image)
3.7 Simulation of Taphole Clay Ramming and Drilling:

Fig.12 shows the schematic diagram for taphole clay ramming test and rammed sample. This test has been carried out by filling the furnace with coke followed by heating up to 1000°C. In red hot coke, taphole clay is rammed and cooled down the furnace. On cooling, furnace is taken apart and spreading of taphole clay is observed inside the coke. Photographs of the rammed samples (both for Resin and Tar bonded Taphole Clays) are shown in the Fig.13. It is also possible to see the drilling condition of taphole clay at 1200°C by using hydraulic drilling machine. Taphole clay is rammed into SiC sleeve and cured it with certain time before drilling (Fig.14). After the drilling, SiC sleeve is taken out and cut into half section for observation (Fig.15). With this test, it is possible to evaluate the taphole clay as a structure such as drilling time as well as crack generation.

4.0 Conclusions:

Basic functions of taphole clay are: 1) Stable operation by hearth drainage 2) Achievement of low specific consumption of refractory by longer cast duration, and 3) Achievement of longer furnace life by protection of hearth side wall with long taphole length. In order to fulfill these functions, various studies have been conducted on binders and fine additives. It is also important to evaluate taphole clay as a structure rather than just evaluation of chemical and physical properties. Therefore, it is inevitable to understand the characteristic of taphole clay behavior under hot and confined situation. With these studies and evaluation method, it is possible to customize the taphole clay with requirement of customers for smooth and reliable operation of Blast Furnace.

5.0 References