Utilization of Textile Mill Sludge in Burnt Clay Bricks

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***Abstract*- Investigation of the effect of Textile mill sludge addition in burnt clay bricks is done under this study. Chemical composition of sludge and soil samples was analysed by ICP-AES, SEM and XRF facilities. Sludge percentage is varied from zero to thirty-five percent by weight. Firing temperature and firing period are varied to understand the variations in characteristics of burnt bricks. Parameters such as compressive strength, density, water absorption, efflorescence and ringing sound are studied as per BIS (Bureau of Indian Standards) procedures. Density of bricks, compressive strength and ringing sound reduces as sludge content in bricks increases whereas water absorption and efflorescence increases. Higher firing temperature and firing period i.e. 800^{0}C and 24 hours give good results in terms of compressive strength with same percentage of sludge as compared to other temperature and firing period combinations. Textile mill sludge up to 15% can be added so as to get compressive strength greater than 3.5 N/mm^2.**

Keywords- Firing temperature; Firing period; textile mill sludge; Compressive strength; Water absorption

I. INTRODUCTION

Rapid Industrialization and Urbanisation is causing serious environmental problems. One of the major concerns amongst these is safe and sound disposal of solid wastes. Sugar, paper pulp and Textile are three major agro based industries in India which produce large quantity of solid and liquid wastes after consuming greater amount of fresh water. Textile mills are one of the largest and oldest sectors in India. In Maharashtra state (India) cities like Solapur and Ichalkaranji are famous for textile exports. Every year textile exports generates large amount of revenues for Indian economy.

Textile mill uses large amount of fresh water for wet operations such as Desizing, bleaching, dyeing etc. The wastewater generated from these processes is treated in ETP by adding chemicals such as Alum, Ferric chloride, Lime and Polyelectrolyte to remove traces of cotton and dyes. During the treatment sludge gets accumulated in the primary and secondary clarifiers, which is further dried in sludge drying beds. Sludge generated in ETPs is not only troublesome to that industry but also affects the environment adversely. Many textile mills practice ultimate disposal options like Landfilling. Therefore, there is a growing need to look for various reuse options of waste materials for sustainable development.

On the other hand, building construction sector consumes conventional materials such as clay, sand, gravel, cement, timber, etc which are generated directly or indirectly from natural resources. Fast growth of building construction industry is putting enormous load on the natural resources leading to environmental degradation- [1].

Oven dried sludge obtained from domestic wastewater treatment plant-[2, 3, 4] and sewage sludge ash-[5, 6, 7] can be used as additive in building materials. Also Industrial Sludge such as Paper mill Sludge can be used in brick making-[8], for making green composite pallet making-[9], in producing low cost concrete-[10]. Waste lime sludge-[11], Petroleum plant sludge-[12] also can be used as building material.

Solid waste from textile mill has the potential for use as additive in building material-[1, 13]. Balasubramanian-[14] used up to 30% textile mill sludge in brick making with satisfactory compressive strength. As textile mill sludge contains lesser binding capacity, cement can be added as binding material in order to make hollow bricks, paving blocks, solid blocks etc.-[14, 15]. Baskar et al.-[16] reported that oven dried textile mill sludge can be used as replacement to clay in manufacturing of clay bricks.

II. MATERIALS AND METHODS

A. Materials

Dried textile mill sludge is collected from Somany Evergreen Knits Pvt. Ltd., MIDC Kondi, Solapur, Maharashtra State, India. Collected sludge is packed and stored in good quality polyethylene bags and used for further investigation. Brick manufacturing requires three types of soils (Red soil, White Soil and Black soil). These Soils are collected from one of local brick manufacturers in Solapur.

B. Methods

Textile mill sludge is analysed for important parameters such as pH, specific gravity, dry density and EC by standard methods- [17] and IS codes procedure-[18]. For knowing the chemical composition of textile mill sludge XRF (X-Ray Fluorescence Spectrometer, Phillips - PW 2404 model) analysis is done at the IIT Bombay in Sophisticated Analytical Instrument Facility (SAIF) Laboratory. Soils samples are analysed for chemical contents by using Inductively Coupled Plasma - Atomic Emission Spectrometry (ICP- AES) (Model- Jobin Yuon Ultima II) at the IIT, Bombay in Earth Science Laboratory. To study the effect of temperature textile mill sludge, red, white and black soils are analysed by thermo-gravimetric analysis (TG) at SAIF, IIT, Bombay-[19].

Proportioning of three types of soils (red, White and black) is done as per the practice followed by the local brick manufacturer for comparison purpose. Initially bricks are prepared by using 40% red soil, 40% white soil and 20% black soil by weight. Combination of these soils is called base material. Later, this base material is replaced with textile mill sludge starting from (95% base material and 5% textile mill sludge) up to (65% base material and 35% textile mill sludge). For casting of bricks, 70 mm x 70 mm x 70 mm moulds are used. After casting, bricks are air dried in (in laboratory) shade for two days and then dried in sunlight for the next four days. Weight of sundried bricks is noted. Sun dried bricks are kept in muffle furnace for varying temperatures (600^0C, 700^0C and 800^0C) and varying firing /baking periods (8 hrs. 16 hrs. and 24 hrs.). Bricks are allowed to cool down completely and weight of bricks after firing is noted. Bricks are then used for compressive strength determinations as per IS 3495 (Part-I) – 1992-[20].

Durability of the bricks can be judged by water absorption test [IS 3495 (Part-II) - 1992]-[20]. Baked and cooled bricks are weighed and kept in water for 24 hrs. Bricks are weighed again after 24 hrs to determine the percent water absorption. Efflorescence of bricks is measured as per IS code procedure described in IS 3495 (Part-III) – 1992- [20].

III. RESULTS AND DISCUSSIONS

A. Analysis of Textile mill sludge and soil samples

Table I shows results for important properties of textile mill sludge.

TABLE I BASIC PARAMETERS OF TEXTILE MILL SLUDGE

Sr. No.	Parameter	Value
1	Specific Gravity	1.2-1.5
2	Dry density	1200-1500 kg/m^3
3	pH (1:5 sludge suspension)	6.46
4	EC (25^o C)	11.93 mS
5	TDS	6.072 ppt

Specific gravity and dry density of the textile mill sludge is less, therefore if it is added in building materials, it will reduce resultant unit weight of the material.

Results of XRF analysis of textile mill sludge are shown in Table II

TABLE II XRF ANALYSIS OF TEXTILE MILL SLUDGE

Sr. No.	Chemical Compound	Presence in the sludge in %
1	Al_2O_3	3.59
2	CaO	22.09
3	Cr_2O_3	0.07
4	FeO	26.92
5	P_2O_5	3.47
6	SiO_2	15.16
7	TiO_2	1.32
8	SO_4	1.62
9	V_2O_5	0.01
10	MgO	9.49
11	MnO	0.56

XRF analysis shows, presence of Al_2O_3, CaO and FeO in significant amount. From these results it can be said that if textile mill sludge is used as additive in building material, it may contribute to strength up to some extent.

Elemental analysis of sludge under SEM (Scanning Electron Microscope, JEOL make, NITK Surathkal) is made for confirming presence of heavy metals. Analysis showed heavy metals such as Nickel and Lead are absent; Mercury and Molybdenum are present but less than 0.4%. Leachatability studies are not carried out because negligible amount of heavy metals are present. All the soil samples were analysed by using ICP-AES. Results are shown in Table III.

TABLE III ICP-AES ANALYSIS OF SOIL SAMPLES

Chemical Compound	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**K_2O**	**Na_2O**	**TiO_2**	**MnO**	**P_2O_5**
Presence in White soil (%)	41.70	12.18	19.24	6.25	5.69	0.18	0.88	3.29	0.26	0.14
Presence in red soil (%)	41.35	19.31	19.31	6.40	5.48	0.23	0.94	3.54	0.27	0.13
Presence in black soil (%)	39.27	20.42	20.42	3.80	3.77	0.09	0.47	4.56	0.28	0.09

As per IS 2117-1991-[21] Soil samples should not contain CaO and MgO more than 15%. All soil samples are satisfying the above requirement. The analysis of clay samples shows that Silica content is slightly less. For good quality brick silica content should be more than 50 - 60%. Class III bricks are possible with these soil samples.

B. TG-DTA Analysis of Textile mill sludge and soil samples-[19]

Figure 1 shows TG-DTA curve for textile mill sludge

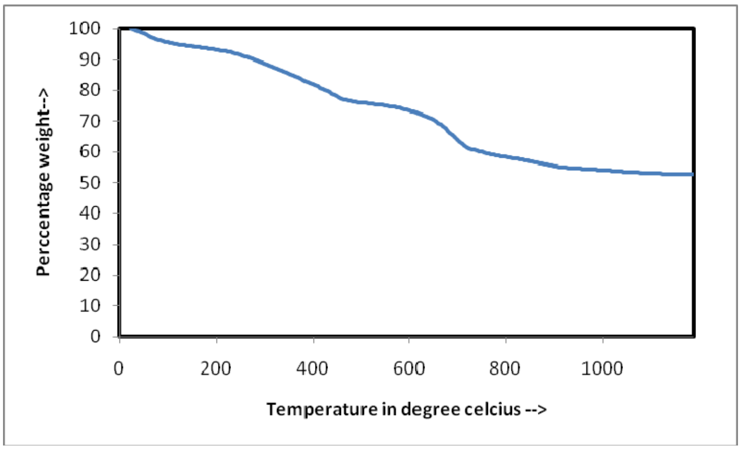

Fig. 1 TG-DTA curve for textile mill sludge

TG-DTA analysis shows that textile mill sludge looses it weight as temperature is increased. This is because of organic matter present in the sludge. The weight loss in temperature range of 600^0C to 800^0C is 30% to 40%.

Figure 2 shows TD-DTA curve for red, black and white soils.

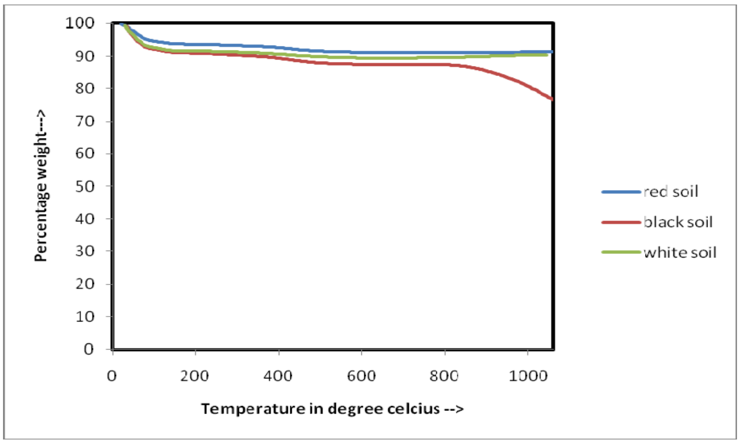

Fig. 2 TG-DTA curve for red, black and white soil

9 to 13% weight loss is observed for all three types of soils in the temperature range of 600^0C to 800^0C. About 8% weight loss is observed at lower temperatures i.e. 100^0C to 200^0C this is because moisture presents in the soils.

C. Deciding the Water content and firing temperature for casting of bricks

For determining the percentage of water is to be added during the brick preparations, Standard Proctor test was conducted for each type of soil sample according to IS: 2720 (Part VII) 1980-[22].

Optimum Moisture content (OMC) values obtained for White, red and black soils are 18.72%, 19.27% and 21.22% respectively. But for casting of bricks water content of 23-25% is maintained for ease of workability of the mixture.

Firing temperature of bricks inside the brick kilns should be about 750^0C as described in IS 2117-1991-[21]. But in actual practice temperature of 500^0C to 800^0C is attained in brick kilns as per Indian brick manufacturers on site practice. Therefore, it is decided to vary temperatures from 600^0C to 800^0C.

D. Density variations

Figure 3 shows density variations for 8hrs firing period and firing temperatures of 600^0C, 700^0C and 800^0C.

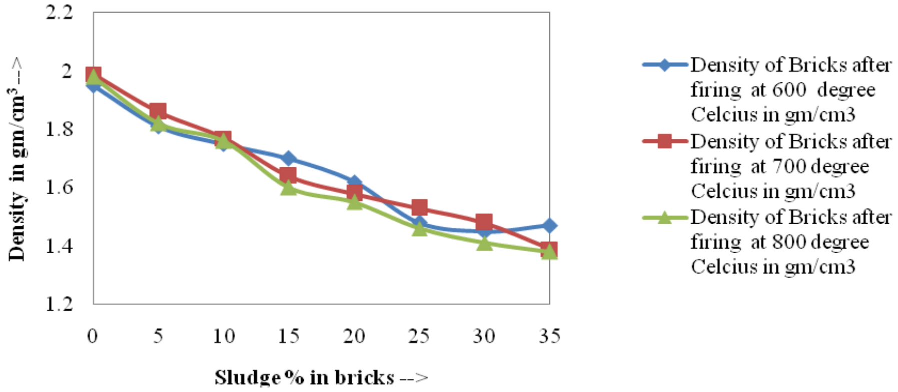

Fig. 3 Density variations for 8 hrs firing period at firing temperatures of 600^0C, 700^0C and 800^0C respectively

Figure 4 shows density variations for 16 hrs firing period and firing temperatures of 600^0C, 700^0C and 800^0C.

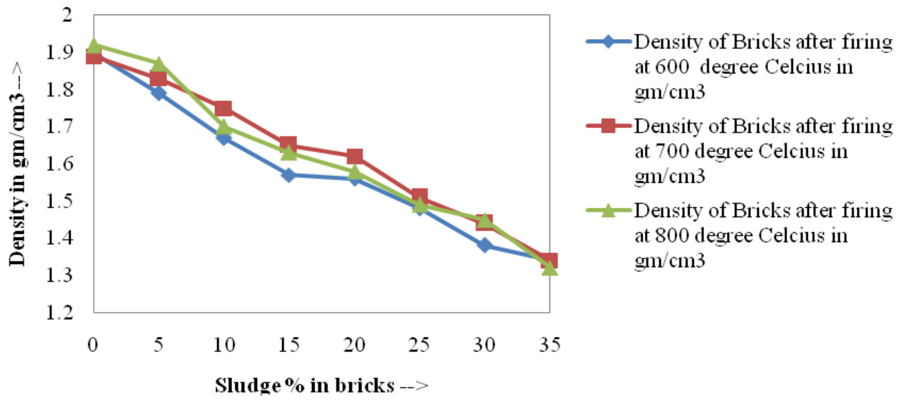

Fig. 4 Density variations for 16 hrs firing period at firing temperatures of 600^0C, 700^0C and 800^0C respectively

Figure 5 shows density variations for 24 hrs firing period and 600^0C, 700^0C and 800^0C.

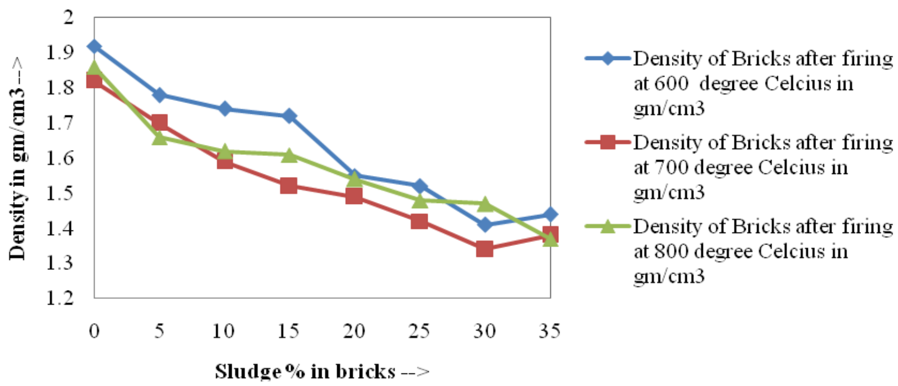

Fig. 5 Density variations for 24 hrs firing period at firing temperatures of 600^0C, 700^0C and 800^0C respectively

Density variations graphs show that density of bricks goes on reducing with increase in firing temperature and increase in firing period. The obvious reason is textile mill sludge that has lesser specific weight. Another reason is textile mill contains about 30% of organic material; the same is getting burnt at temperatures greater than 550^0C. Because of which there is weight loss and reduction in density as sludge percentage in the bricks increases

E. Compressive strength

Figure 6 shows compressive strengths results for 8 hrs firing period and firing temperatures of 600^0C, 700^0C and 800^0C respectively.

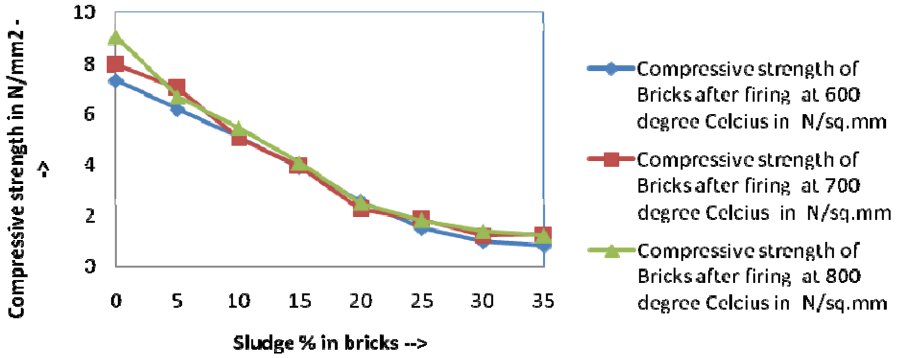

Fig. 6 Compressive strength Results for 8 hrs firing period at firing temperatures of 600^0C, 700^0C and 800^0C respectively

Figure 7 shows compressive strengths results for 16 hrs firing period and firing temperatures of 600^0C, 700^0C and 800^0C respectively.

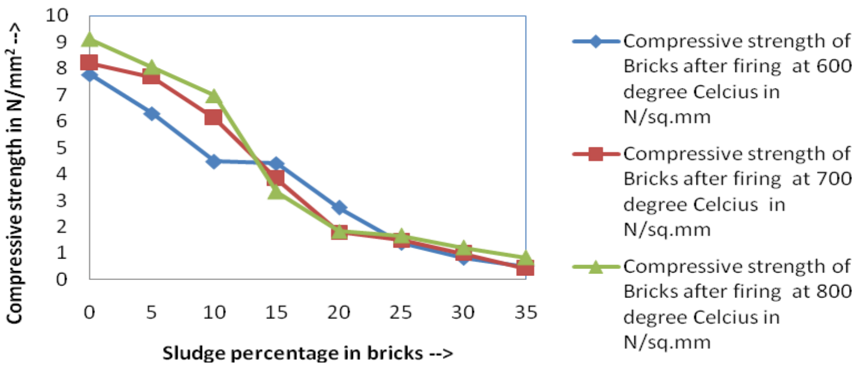

Fig. 7 Compressive strength Results for 16 hrs firing period at firing temperatures of 600^0C, 700^0C and 800^0C respectively

Figure 8 shows compressive strengths results for 24 hrs firing period and firing temperatures of 600^0C, 700^0C and 800^0C respectively.

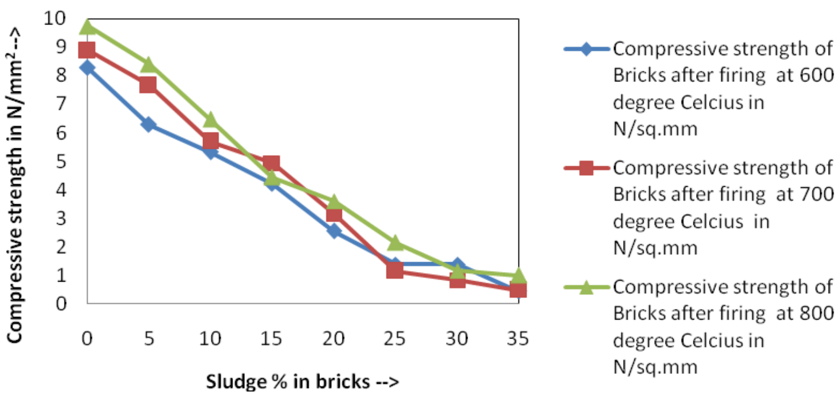

Fig. 8 Compressive strength Results for 24 hrs firing period at firing temperatures of 600^0C, 700^0C and 800^0C respectively

Compressive strength goes on reducing as percentage of sludge increases in bricks. This is because sludge contains less silica content as compares to base material. Compressive strength increases as firing temperature and firing period are increased. Firing temperature of 800^0C and firing period of 24 hrs gives good compressive strength with same percentage of sludge in the bricks. As per the IS code classification-[23] of the bricks compressive strength requirement is 3.5 N/mm^2. Without compromising the compressive strength of 3.5 N/mm^2, the maximum percentage of sludge which can be added is 15% by weight.

F. Water absorption

Figure 9 shows percent water absorption results for 8 hrs firing period and firing temperatures of 600^{0}C, 700^{0}C and 800^{0}C respectively.

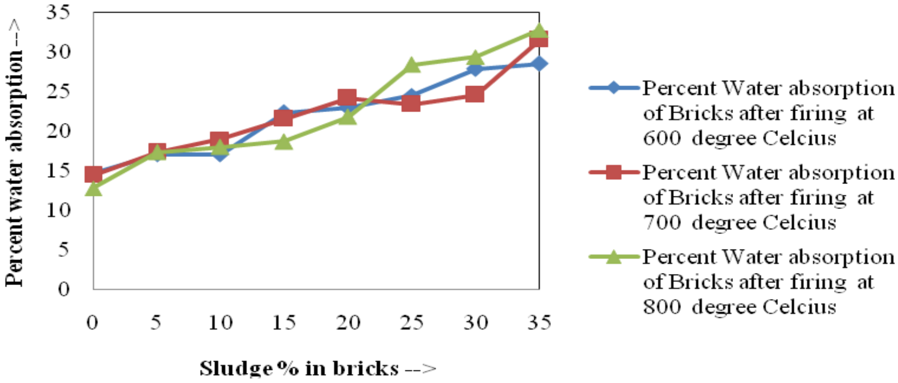

Fig. 9 Percent Water absorption of Bricks after firing for 8 hrs at firing temperatures 600^{0}C, 700^{0}C and 800^{0}C respectively

Figure 10 shows percent water absorption results for 16 hrs firing period and firing temperatures of 600^{0}C, 700^{0}C and 800^{0}C respectively.

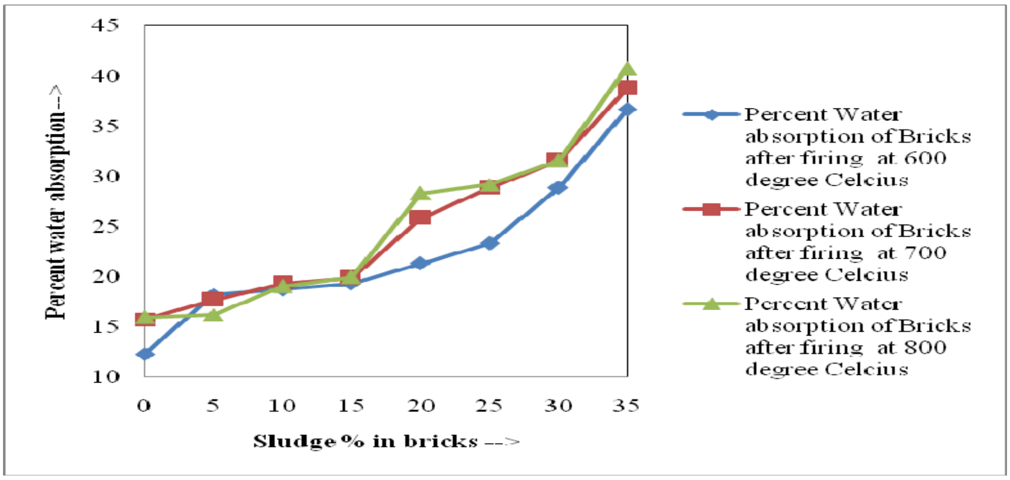

Fig. 10 Percent Water absorption of Bricks after firing for 16 hrs at firing temperatures 600^{0}C, 700^{0}C and 800^{0}C respectively

Figure 11 shows percent water absorption results for 8 hrs firing period and firing temperatures of 600^{0}C, 700^{0}C and 800^{0}C respectively.

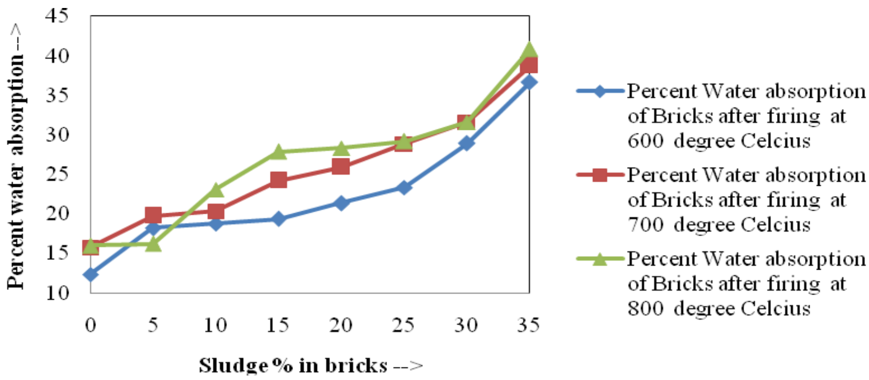

Fig. 11 Percent Water absorption of Bricks after firing for 24 hrs at firing temperatures 600^{0}C, 700^{0}C and 800^{0}C respectively

Percent water absorption of bricks increases as sludge percentage increases. Increase in firing temperatures and firing period also increases water absorption of bricks. Reason for this is organic matter present in the sludge burns at higher temperatures and volatile matter escapes out during the baking process producing voids in the body of the bricks. Voids thus produced causes increase in the water absorption of the bricks. Water absorption should be less than 20%. This requirement is satisfied with maximum sludge content of 15%. Maximum water absorption of 42% is observed is with sludge content of 35% at all temperatures and firing period combinations.

G. Ringing sound and efflorescence

Efflorescence goes on increasing i.e. no efflorescence for 0% sludge to Slight to moderate efflorescence for increasing sludge percentage up to 35%. In case of bricks with 15% sludge addition very less efflorescence is observed.

Ringing sound goes on decreasing with increase in the sludge content. Ringing sound is excellent for original base material bricks with 0% sludge. Ringing sound is least heard in case of bricks with 35% of sludge addition. This may be because of increased porosity of the bricks. %. For bricks with 15% sludge addition good ringing sound is heard.

IV. CONCLUSIONS-[19]

- The study demonstrates that textile mill sludge can be used as partial replacement for clays in burnt clay bricks.
- Textile mill sludge can be used up to 15% without compromising on the compressive strength of 3.5 N/mm^2 and water absorption of 20% as per the IS code requirements.
- Organic matter present in the sludge gets burnt at temperature more than 550^{0}C, because of which large number of voids are created in the body of the bricks. This makes bricks porous resulting in lesser compressive strength and greater water absorption capacity.
- TG-DTA analysis shows there is decrease in weight of sludge with increase in temperature because of burning of organic matter present in the sludge. Due to which large number of voids are created in the body of the bricks. This results in porous brick structure and lesser compressive strength and increased water absorption.
- Firing temperature of 800^{0}C and firing period of 24 hrs gives good results in terms of compressive strength with same percentage of sludge.

Use of 15% textile mill sludge in making burnt clay bricks is recommended and it will increase the bulk usage of sludge in building bricks, thus eliminating the problem of ultimate disposal i.e. landfilling.

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