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Development of interlocking flyash brick machine and study of brick structural efficiency

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ABSTRACT

Eco friendly manner fly ash management and utilization is the need of the hour and one of the possible ways of using it is by fabrication of interlocking bricks out of it. This research focus on the development of interlocking brick machine and bricks manufactured is tested for dimension stability, water absorption, compressibility strength and efflorescence test. The machine setup was successfully fabricated and used for production of interlocking flyash bricks. The setup mainly consists of machine structure, hydraulic system and pan mixer. Two varieties of interlocking bricks were produced with the size of 12” × 6” × 5” and 12” × 8” × 5”. Based on the results of the test the interlocking bricks are found suitable for better replacement of the ordinary bricks.

Keywords: Dimension stability; Water absorption; Compressibility strength; Efflorescence test; Environment; Solid waste management.

1. INTRODUCTION

Nowadays, in a modern development of civilization, new building materials are introduced based on the requirements, cost effectiveness, modernization and need. In coal-fired power plants, fly ash is a common clay product that is produced during the burning of coal. It is a diverse material with a glossy appearance comprised of iron oxides (hematite and magnetite) and mullite (alumina and silica). Its atomic structure is comparable to brick soils. A significant environmental issue is the storage and disposal of fly ash. In India, where coal-based thermal power plants account for 75% of all power generated, they have been a significant source of electricity [1]. India has an estimated 200 billion tonnes (bt) of coal reserves, and its yearly output is at 250 million tonnes (mt). This is employed in the electricity industry to the tune of 70%. In India, unlike the majority of other affluent nations, the amount of ash in the coal used to generate electricity ranges from 30 to 40% [2]. High ash coal causes the plant and equipment to deteriorate more quickly, reduces the boiler’s thermal efficiency, clogs, chokes and scales the furnace, and most seriously causes the production of a lot of fly ash. India is the fourth country in the world to produce coal ash as a by-product trash, behind the USSR, the USA, and China [3]. Scientists and environmentalists now have concerns about the correct management, disposal, and use of waste products. To protect our environment, solid waste fly ash from thermal power plants must be managed properly. It is necessary to look into all of fly ash’s potential applications due to the high expense of road transportation for the disposal of fly ash. In order to use fly ash in the production of ceramics, cement and building bricks and to reduce unemployment, focused efforts are required. Fly ash may be added to clay to improve brick strength and decrease water absorption. Bricks made from fly ash have been an experiment for a number of researchers. Flyash bricks are produced by Obada Kayali [4] with 100% fly ash without clay and shale. They reported that flyash bricks mechanical qualities are superior to those of conventional load-bearing clay bricks. The compressive strength and tensile strength stand out among these characteristics. Comparing it to high-quality clay bricks, the compressive strength was 24% greater. Nearly three times as much tensile strength was present as compared to typical clay bricks. Bricks made from fired fly ash bricks were 28% lighter than clay bricks of the same size. The findings indicate that when compared to a regular brick, flyash bricks significantly

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enhanced the majority of the attributes. In comparison to a typical clay brick, the tensile strength is 43MPa which is almost three times higher and the compressive strength. The brick also produced a bond that was 44% greater than that of a typical clay brick, and it had exceptional resilience to salt exposure with no mass loss. The burned flyash bricks had a comparable reddish tint to a conventional brick in terms of appearance, but a coarser texture was seen on the brick's surface [5].

Interlocking brick constructions made without mortar have garnered a lot of interest recently in the building sector [6, 7]. Building quality masonry structures using interlocking bricks can be improved, and the demand for labor skills may be greatly reduced. The interlocking mechanism of bricks may help ensure alignment, durability and strength needs [7, 8]. Due to the removal of mortar bed joints, which significantly enhances the compressive performance of masonry structures, interlocking bricks may also offer a higher mechanical efficiency factor (structure equivalent compressive strength over brick unit compressive strength). The numerical investigation on behavior of mortar less interlocking brick wall under cyclic loading have shown that superior performance in resisting of seismic loading and dissipating seismic energy [9]. 2% of plastic fibre content by weight of concrete show that compressive, splitting and tensile strength of concrete [10]. By using of waste marble powder in manufacturing of interlock brick gives more economical construction [11, 12]. The mechanical performance of interlocking compressed earth brick is mainly dependent on its shape and manufacturing process [13]. Factors that affect the influences of different design parameters are the number of blocks, brick surface roughness, production tolerance, surface unevenness and also material strength [14]. Review made on the performance of the thermal insulation of building by introducing entrenched materials by the production of wall bricks and blocks that control heat transfer between inside and outside of building [15]. It is reported that 50% of ultra-fine ash enhance the additional strength to the conventional mortar and masonry prism due to its size reduction, irregular shape and greater interlocking of hydrated products [16]. To address the repair technique of existing masonry buildings is done by reinforcement of damaged walls by basalt textile reinforced mortar system to increase the resistance, ductility and energy dissipation [17]. Different interlocking design have been developed and introduced moreover samples are prepared by 3D printing technology [18]. A detailed review made on utilization of biomedical waste ash to achieve cleaner production in the construction sector [19]. By experimental and numerical studies the effect of material strength, axial pre compression force, friction coefficients and contact imperfection [20]. An investigation was carried out to study cement clay interlocking hollow brick masonry walls. It was found that the addition of grout improved the peak compressive load. Addition of steel bars increased both peak load as well as peak behavior. The study highlighted linear regressed model is produced to predict compressive strength [21]. It was discovered that the bricks with recycled aggregate additions had greater compressive strength values than the conventional bricks [22]. Rubber reinforced interlocking bricks are fabricated along with 56% of flyash shows compressive strength of 18.4MPa and pre-compression load increased in proportion to flexural strength. Further the rubber reinforced interlocking bricks fabricated through semi automatic machine and it exhibits high porosity and reduced compressive strength at high temperature [23, 24]. The interlocking bricks fabricated with incinerator flyash waste of different weight percentage, which has significant effect on the properties of the bricks. The increase in weight percentage of fly ash decrease the compressive strength, abrasion resistance, bending strength, and bulk density [25]. It is evident from the above literatures that researchers have used the waste materials such as fly ash to manufacturer bricks and studied their performance. This research focus on the development of interlocking bricks machine and various test such as dimension stability, water absorption, compressive strength and efflorescence were conducted on the fabricated interlocking bricks.

2. DESIGN AND DEVELOPMENT OF INTERLOCKING BRICK SETUP

The interlocking brick machine consists of machine structure and die, hydraulic power pack, pan mixer structure and actuator unit.

2.1. Machine structure and die unit

The machine structure is made up of mild steel and die is made up of hardened tool steel. Table 1 presents the details of interlocking brick molding machine. Figures 1(a) & (b) shows the isometric and front view of the machine with pan mixer unit

Table 1: Detailing of machine structure.

FEATURES	SPECIFICATION
Power	5 Phases 7.5 Hp
RPM	1450
Machine weight	1850 (Approximately)
Production capacity	1400 to 1500 (Approximately)
Production timing	30 Sec Per Block
Pressure load	40 Tonnes
Motor	Havells
Hydraulics	All heavy branded materials
Hydraulic tank capacity	260 Litres
Die plates	JSW En8HHCR/EN31
Brick size	Standard 12 × 8 × 5, 12 × 6 × 5 [inches]
Groove size	Standard 15 mm
Raw materials	Cement, Flyash, M Sand, Lubricants, Dr. Fixit, Pidiproof
Pan mixer capacity	400 Kgs
Bolt, nuts	TVS Brand
Flow handling capacity	High pressure max. – 60 l/min Low pressure max. – 160 l/min

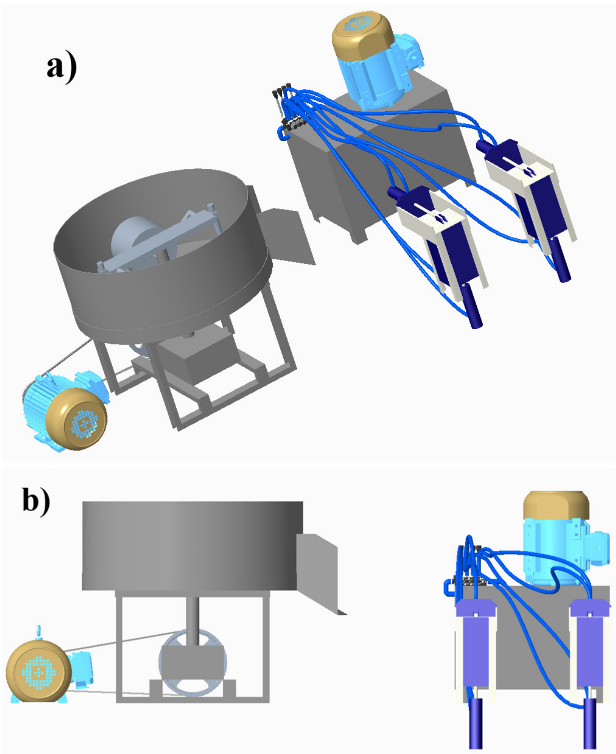

Figure 1: (a): Moulding machine (Isometric view). (b): Moulding machine (Front view).

The Figure 2 shows the die unit used for making the interlocking bricks. The die unit is detachable and the die assembly can be divided into four portions namely, top, bottom, left and right as depicted in the Figure 2. The die assembly can be interchanged for production of every 30000 unit and by doing the same, 120000 interlocking bricks can be manufactured before replacement of the die. Figure 3 show the line sketch of the die unit and the total height of the die is 409 mm and inside the die the hydraulic operated ram moves up and down. The size of brick manufactured are 6 and 8 inches and L*B*H is 12” × 6” × 5” and 12” × 8” × 5” respectively.

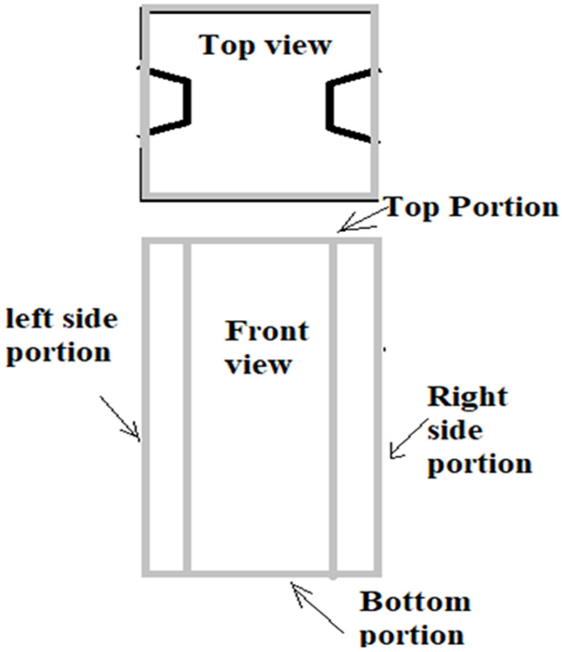

Figure 2: Sketch of die.

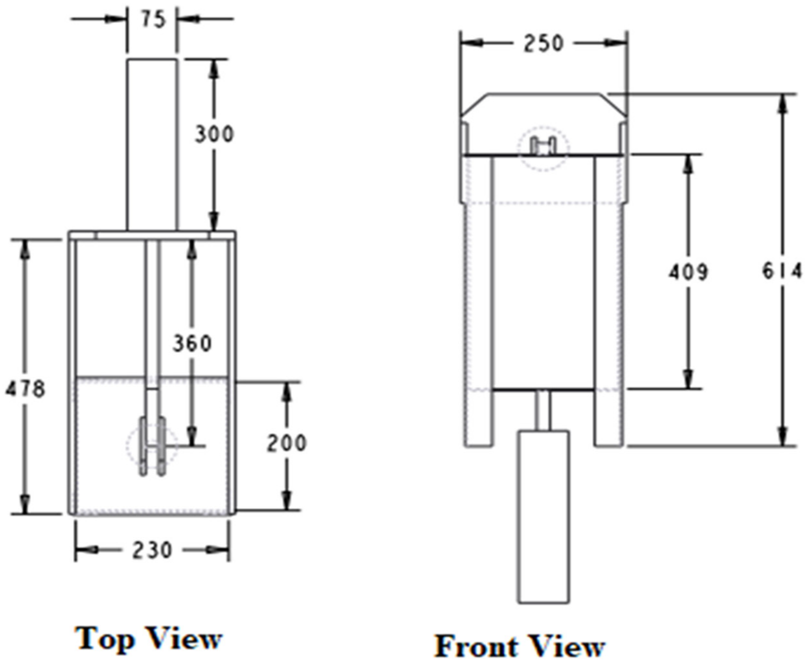

Figure 3: Block die.

2.2. Hydraulic power pack

Hydraulic power pack is the central controlling unit used to compress the brick materials and eject the molded interlocking from the die. It consists of hydraulic oil tank, motor and pump, hose, and ram. The hydraulic tank is kept at the trench made exclusively for it and oil is pumped by the motor unit through the hose. The hoses are connected to the mold unit rams at the bottom and top as shown in Figure 4(a). The tank has the capacity of 200 liters and total hydraulic unit is presented in Figure 4(b).The hydraulic oil is transported with the help of pump and direction control valve is used to change the flow direction. The 4/2 solenoid operated spring return direction control valve is used along with pressure switches. The hydraulic power pack is operated manually and Figure 4(c)–(d) shows the photograph and block diagram of pressure control module and Table 2 presents the connection details of pressure control module.

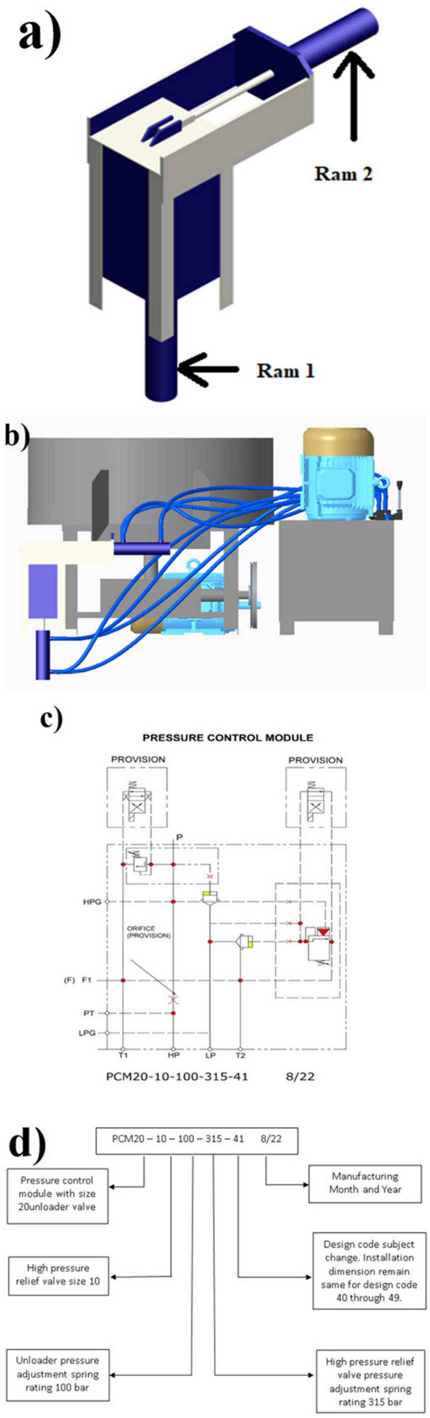

Figure 4: (a): Hydraulic ram. (b): Hydraulic tank. (c): Pressure control module. (d): Detailing of pressure control module.

Table 2: Connection details of pressure control module.

SYMBOL	DESCRIPTION
HP	High pressure pump connection
LP	Low pressure pump connection
P	Outlet connection
HPG	Gauge connection on high pressure pump line
LPG	Gauge connection on low pressure pump line
Pt	Pilot pressure connection [Optional]
T1	Tank connection of high pressure relief valve
T2	Tank connection of low pressure unloading valve
F	Filter port connection [T1&T2]
R	Outlet connection [Reduced Pressure]

2.3. Pan mixer structure and actuator unit (motor)

The pan mixer is used to mix the fly ash, cement and M-sand which is powered by the 3-phase motor. Table 3 shows the details of the pan mixer and Figures 5(a) and (b) shows the isometric and top view of the pan mixer.

Table 3: Detailing of pan mixer.

FEATURES	SPECIFICATION
Power	3 Phases (7.5 + 5) – 12.5 Hp
Weight	1150 Kgs (Approximately)
Drum Dia Meter	1350 mm
Drum Height	550 mm
Motor	Havells
Cell Plate Thickness	10 mm Thick and Additional 8 mm
Drum Plate Thickness	6 mm Thick and Additional 6 mm Half Drum
Cycle Time	8 to 10 Minutes
Hopper Loading Capacity	250 to 300 Kgs

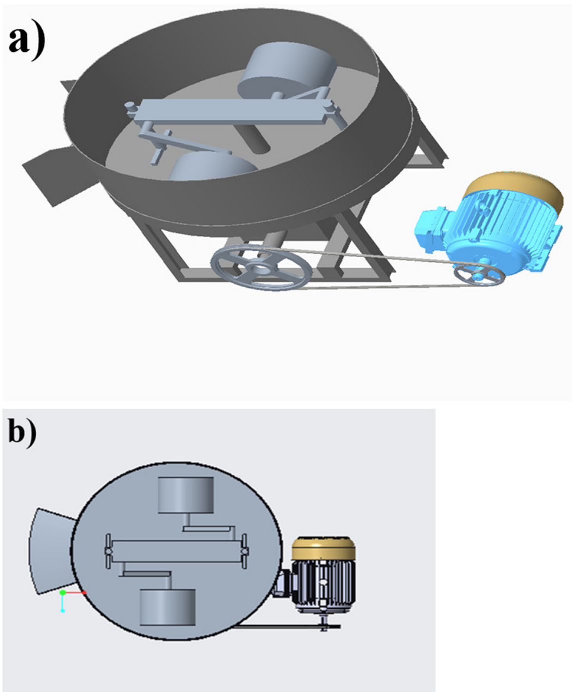

Figure 5: (a) Pan Mixer Drum (Isometric view). (b): Pan Mixer Drum (Top View).

3. MATERIALS AND METHODS

3.1. Materials

Material such as cement, flyash, M-Sand, water collected from various sources and conducted the preliminary investigation on materials. The following represents the physical properties of collected materials.

3.2. Cement

Cement as per IS 1489 (Part 1): 1991 was used for the experimental work and properties of cement is presented in the Table 4.

Table 4: Properties of cement.

S. NO	PROPERTIES	RESULT
1.	Fineness	300 m^2/kg
2.	Normal Consistency	33%
3.	Initial Setting Time	30 Mins
4.	Final Setting Time	600 Mins
5.	Compressive Strength 3 Days 7 Days 28 Days	 27 MPa 37 MPa 53 MPa

3.3. Flyash

Thermal power plant flyash collected from mettur, confirming to IS 3812 (Part 1): 2013 was used for the experiment and properties are given in Table 5.

Table 5: Properties of flyash.

S. NO	PROPERTIES	RESULT
1.	Specific Gravity	2.15
2.	Initial Setting Time	130 Mins
3.	Final Setting Time	290 Mins
4.	Retained on 45 Micron	2.66 %
5.	Specific Surface	320 m^2/kg
6.	Soundness	0.15%
7.	Water Requirements	96%

3.4. M-Sand

M-Sand (manufactured sand) confirming to Zone – II as per IS383-1970 is used and its properties are given in Table 6.

Table 6: Properties of M-Sand.

S. NO	PROPERTIES	RESULT
1.	Specific Gravity	2.5
2.	Fineness Modulus	2.75
3.	Water Absorption	0.26%

3.5. Water

It's crucial that there are no harmful substances in the water used for mixing and curing. Both the concrete mix and curing procedures require portable water with pH of 6.9. Using a pan mixer with a steady rate of revolution, various ratios of raw components are weighed and mixed along with water until a consistent mixer is achieved. The mixture, prepared is transported to the mold manually and hydraulic pressure was applied for compression of mixed materials resulting in casting of interlocking bricks to the required size. To produce high quality interlocking brick, the manufacture of brick was maintained at room temperature for 24 hours before being stacked for 21 days of curing.

4. RESULTS AND DISCUSSION

4.1. Dimension test

The Figure 6 show the photograph of 6" and 8" interlocking bricks, 10 samples were randomly selected from the cured sample, and the blisters were scraped off with a trowel before to the test. According to Indian industry standards (IS: 1077(1992), clause 6.2), brick dimensions were checked. Prior to measuring the length of the total bricks, all the chosen bricks were first stacked lengthwise in five rows on a level surface. Each row's values were written down. The bricks were also positioned widthwise, and the values were observed. After all the bricks had been placed according to height, the final height was calculated. The measured values were noted, and the tolerances are shown in Table 7 and 8. Figure 6 shows the sample interlocking brick of size 6" and 8

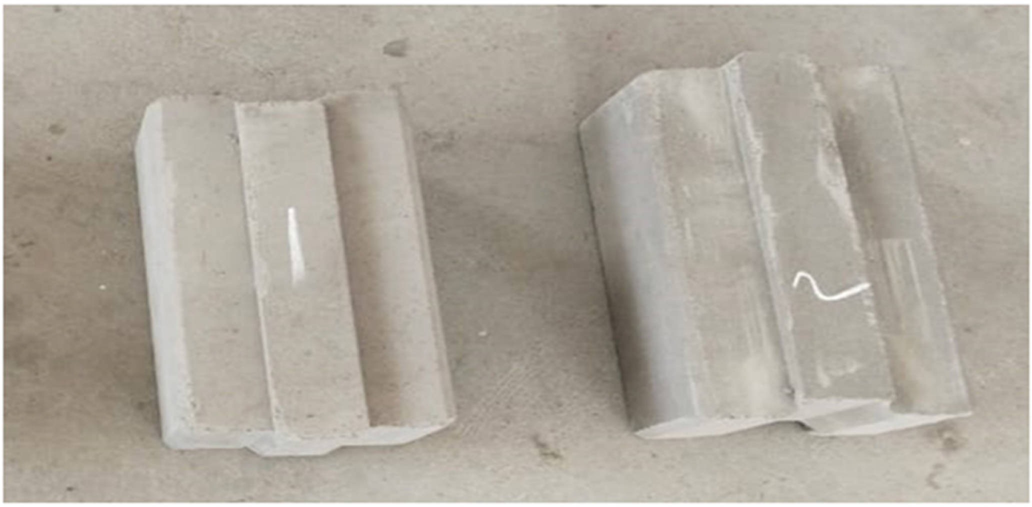

Figure 6: Shape of interlocking brick.

Table 7: Dimension of interlocking brick.

	6"				8"			
Trail	L#	W#	H#	h#	L#	W#	H#	h#
1	296	148	124	123	297	197	123	124
2	298	147	123	124	296	197	123	124
3	298	148	124	123	297	198	124	124
4	295	148	123	124	296	199	124	123
5	296	147	124	124	297	198	123	124
6	295	149	124	123	295	197	124	124
7	295	147	123	123	294	197	123	123
8	298	148	123	124	297	199	124	123
9	298	147	124	123	296	198	124	123
10	295	149	123	124	295	197	123	124

L# length in mm, W# width in mm, H# height in mm h# web height in mm.

Table 8: Tolerance in %.

	TOLERANCE IN % FOR 6"				TOLERANCE IN % FOR 8"			
Trail	L#	W#	H#	h#	L#	W#	H#	h#
1	–1.33	–1.33	–0.80	–1.60	–1.00	–1.50	–1.60	–0.80
2	–0.67	–2.00	–1.60	–0.80	–1.33	–1.50	–1.60	–0.80
3	–0.67	–1.33	–0.80	–1.60	–1.00	–1.00	–0.80	–0.80
4	–1.67	–1.33	–1.60	–0.80	–1.33	–0.50	–0.80	–1.60
5	–1.33	–2.00	–0.80	–0.80	–1.00	–1.00	–1.60	–0.80
6	–1.67	–0.67	–0.80	–1.60	–1.67	–1.50	–0.80	–0.80
7	–1.67	–2.00	–1.60	–1.60	–2.00	–1.50	–1.60	–1.60
8	–0.67	–1.33	–1.60	–0.80	–1.00	–0.50	–0.80	–1.60
9	–0.67	–2.00	–0.80	–1.60	–1.33	–1.00	–0.80	–1.60
10	–1.67	–0.67	–1.60	–0.80	–1.67	–1.50	–1.60	–0.80

"respectively. The tolerance % is in acceptable level as per the IS. As a result the slight dimension discrepancy does not affect brick's strength, cause cracks or cause any other issues during the construction phase. The flyash brick is accordingly homogenous in size and suitable for construction.

4.2. Water absorption test

Brick's durability is impacted by water absorption. Three samples of each brick size were chosen for this investigation. The samples were initially heated to 105 °C in the oven until they attained a constant density. The bricks were over dried and then submerged in water for 24 hours. The samples were then taken out of the water and washed using a moist towel. The air in the pores of the bricks is not completely expelled from them because the water is not totally saturated. The test setup shown in Figure 7 and result for the water absorption in Table 9. The amount of water in the samples was calculated using:

Water absorption = {[W2–W1]/W1}*100

As per IS code water absorption of burnt clay ranges from 4% to a maximum of 12%. Average water absorption test result shows 4.81% and 5.41% for 6" and 8" interlocking bricks respectively and these values are within the IS code.

Figure 7: Water absorption test.

Table 9: Water absorption test values of interlocking bricks.

SPECIMEN NUMBER	SIZE OF BRICK (mm)	W_1 (KG)	W_2 (KG)	WATER ABSORPTION (%)	AVERAGE WATER ABSORPTION (%)
1	300 × 150 × 125	10.180	10.680	4.91	4.81
2		10.160	10.640	4.72	
3		10.180	10.670	4.81	
4	300 × 200 × 125	14.160	14.940	5.51	5.41
5		14.160	14.910	5.30	
6		14.180	14.950	5.43	

4.3. Compressive strength test

The interlocking brick compression test was performed using a compressive testing apparatus. The dimensions were measured in order to calculate area. Before being put into the compression machine, the samples of interlocking bricks were weighed using the weighing scale. The top and bottom surfaces of the sample are coated with steel plate to guarantee that the load is dispersed evenly throughout the brick. The sample and steel plate were centered with respect to the bottom plate. Compressive loads were applied to the sample to determine the brick's compressive strength, and the ultimate load was then calculated. Figure 8 indicates the testing of interlocking brick by applying compressive load. The result of compressive strength is presented in Table 10.

$$\textbf{Compressive Strength} = \textbf{Load/Area}$$

As per IS code minimum compressive strength of burnt clay is 3.5 N/mm^2. Compressive strength of clay brick varies between 2.5 to 3.5 N/mm^2. However the compressive strength of different size interlocking brick results is ranging between 5 to 7.22 N/mm^2.

Figure 8: Compressive strength test.

Table 10: Compressive strength test values of interlocking bricks.

SPECIMEN NUMBER	SIZE OF BRICK (mm)	WEIGHT (W) (KG)	LOAD (KG)	COMPRESSIVE STRENGTH (N/mm^2)	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)
1	300 × 150 × 125	10.460	240	5.33	5.26
2		10.450	250	5.56	
3		10.420	220	4.89	
4	300 × 200 × 125	13.580	430	7.17	7.22
5		13.410	420	7.00	
6		13.260	450	7.50	

4.4. Efflorescence test

In accordance with IS3495 (Part 3) the efflorescence test was conducted. 2.5 cm of water was put onto a flat, shallow tray. The samples were maintained vertically stacked until the water was drained. Finally, it is proved that no samples had ever been exposed to sulphate attack and that there had never been any efflorescence in interlocking brick.

According to the standards, efflorescence cannot be more than moderate (10–50%) up to class level and cannot be more than minimum (10%) for higher classes. Obtained nil report for interlocking brick demonstrate that there is no noticeable deposit of efflorescence.

5. CONCLUSION

The main basic material used to make bricks is clay. Clay usage, however, lowers the water table and contributes to erosion. In this project, an effort was made to replace clay in brick manufacture using industrial waste materials. To evaluate the brick's quality, tests on their dimension, compressive strength, water absorption and efflorescence were performed.

1. The dimension test results are within the acceptance level. It is evident that average compressive strength of interlocking bricks are 5.23 and 7.22 N/mm^2 for 12” × 6” × 5” and 12” × 8” × 5” size respectively.
2. The average water absorption capacity of 12” × 6” × 5” and 12” × 8” × 5” size bricks are 4.81% and 5.41% respectively.
3. No perceptible deposit occurs on interlocking brick while conducting efflorescence test.
4. The flyash interlocking brick fabricated demonstrate high compressive strength and cost effectiveness.
5. Future studies will concentrate on fabrication of fire retardant interlocking bricks.

6. BIBLIOGRAPHY

[1] SINGH, K., MEENA, R.S., KUMAR, S., *et al*., “India's renewable energy research and policies to phase down coal: success after Paris agreement and possibilities post-Glasgow Climate Pact”, *Biomass and Bioenergy*, v. 177, pp. 106944, 2023. doi: http://doi.org/10.1016/j.biombioe.2023.106944.

[2] SHARMA, Y.C., SINGH, S.N., GODE, F., “Fly ash for the removal of Mn (II) from aqueous solutions and wastewaters”, *Chemical Engineering Journal*, v. 132, n. 1–3, pp. 319–323, 2007. doi: http://doi.org/10.1016/j.cej.2007.01.018.

[3] SENAPATI, M.R., “Fly ash from thermal power plants–waste management and overview”, *Current Science*, v. 100, n. 12, pp. 1791–1794, 2011.

[4] *OBADA KAYALI*., “High performance bricks from fly ash”, In: *Proceedings of the World of Coal Ash Conference*, v. 11, Lexinton, Kentucky, 2005.

[5] XIE, G., ZHAMG, X., HAO, H., *et al*., “Behaviour of reinforced mortarless interlocking brick wall under cyclic loading”, *Engineering Structures*, v. 283, pp. 115890, 2023. doi: https://doi.org/10.1016/j.engstruct.2023.115890.

[6] STURM, T., RAMOS, L.F., LOURENÇO, P.B., “Characterization of dry-stack interlocking compressed earth blocks”, *Material Structure,* v. 48, pp. 3059–3074, 2015. doi: http://doi.org/10.1617/s11527-014-0379-3.

[7] WANG, G., LI, Y., ZHENG, N., *et al*., “Testing and modelling the in-plane seismic response of clay brick masonry walls with boundary columns made of precast concrete interlocking blocks”, *Engineering Structures*, v. 131, pp. 513–529, 2017. doi: http://doi.org/10.1016/j.engstruct.2016.10.035.

[8] ALI, M., GULTOM, R.J., CHOUW, N., “Capacity of innovative interlocking blocks under monotonic loading”, *Construction & Building Materials*, v. 37, pp. 812–821, 2012. doi: http://doi.org/10.1016/j.conbuildmat.2012.08.002.

[9] XIE, G., ZHANG, X., HAO, H., *et al*., “Response of reinforced mortar-less interlocking brick wall under seismic loading”, *Bulletin of Earthquake Engineering*, v. 20, n. 11, pp. 6129–6165, 2022. doi: http://doi.org/10.1007/s10518-022-01436-6.

[10] AWOYERA, P.A., OLALUSI, O.B., IBIA, S., *et al*., “Water absorption, strength and micro scale properties of interlocking concrete blocks made with plastic fibre and ceramic aggregates”, *Case Studies in Construction Materials*, v. 15, pp. e00677, 2021. doi: https://doi.org/10.1016/j.cscm.2021.e00677.

[11] AFZAL, O., ABBAS, S., ABBASS, W., *et al*., “Characterization of sustainable interlocking burnt clay brick wall panels: an alternative to conventional bricks”, *Building Materials*, v. 231, pp. 117190, 2020. doi: https://doi.org/10.1016/j.conbuildmat.2019.117190.

[12] SAARI, S., *et al*., "Factors of non-uniform properties of interlocking compressed earth brick units", *Developments in the Built Environment*, v. 5, pp. 100042,2021. https://doi.org/10.1016/j.dibe.2021.100042.

[13] SHI, T., ZHANG, X., HAO, H., *et al*., "Experimental and numerical investigation on the compressive properties of interlocking blocks", *Engineering Structures*, v. 228, pp. 111561, 2021. doi: https://doi.org/10.1016/j.engstruct.2020.111561.

[14] OLOFINNADE, O., MORAWO, A., OKEDAIRO, O., *et al*., "Solid waste management in developing countries: reusing of steel slag aggregate in eco-friendly interlocking concrete paving blocks production", *Construction Materials*, v. 14, pp. e00532, 2021. doi: https://doi.org/10.1016/j.cscm.2021.e00532.

[15] VIJAYAN, D.S., MOHAN, A., REVATHY, J., *et al*., "Evaluation of the impact of thermal performance on various building and blocks: a review", *Engineering Technology & Innovation,* v. 23, pp. 101577, 2021. doi: https://doi.org/10.1016/j.eti.2021.101577.

[16] KRISHNARAJ, L., NIRANJAN, R., KUMAR, G.P., *et al*., "Numerical and experimental investigation on mechanical and thermal behaviour of brick masonry: an efficient consumption of ultrafine flyash", *Construction and Building Materials*, v. 253, pp. 119232, 2021. https://doi.org/10.1016/j.conbuildmat.2020.119232.

[17] GARCIA-RAMONDA, L., PELÀ, L., ROCA, P., *et al*., "Cyclic shear-compression testing of brick masonry walls repaired and retrofitted with basalt textile reinforced mortar", *Composite Structures*, v. 283, pp. 115068, 2022. https://doi.org/10.1016/j.compstruct.2021.115068.

[18] LIU, B., XU, X., "Study on impact resistance of bionic interlocking brick-mud structures", *Composite Structures*, v. 318, pp. 117103, 2023. doi: https://doi.org/10.1016/j.compstruct.2023.117103.

[19] MANJUNATH, B., DI MARE, M., OUELLET-PLAMONDON, M.M., *et al*., "Exploring the potential use of incinerated biomedical waste ash as an ecofriendly solution in concrete composites: a review", *Construction & Building Materials*, v. 387, pp. 131595, 2023. doi: https://doi.org/10.1016/j.conbuildmat.2023.131595.

[20] TINGWEI, S., ZHANG, X., HAO,L H., *et al*., "Experimental and numerical studies of the shear resistance capacities of interlocking blocks", *Journal of Building Engineering*, v. 44, pp. 103230, 2021. doi: https://doi.org/10.1016/j.jobe.2021.103230.

[21] PANUWAT, J., ALI, N., YOOPRASERTCHAI, E., *et al*., "An investigate study for the prediction of compressive strength of cement-clay interlocking (CCI) hollow brick masonry walls", *Case Studies in Construction Materials*, v. 16, pp. e01001, 2022. doi: https://doi.org/10.1016/j.cscm.2022.e01001.

[22] EUPHROSINO, C.A., JACINTHO, A.E.P.G.A., PIMENTEL, L.L., *et al*., "Soil-cement brick used in Social Housing (HIS) in housing cooperative construction – A case study in a community brick making", *Revista Matéria (Rio de Janeiro)*, v. 27, n. 1, pp. e20147087, 2022. https://doi.org/10.1590/1517-7076-RMAT-2021-47087.

[23] AL-FAKIH, A., MOHAMMED, B.S., WAHAB, M.M.A., *et al*., "Flexural behavior of rubberized concrete interlocking masonry walls under out-of-plane load", *Construction & Building Materials*, v. 263, pp. 120661, 2020. doi: http://doi.org/10.1016/j.conbuildmat.2020.120661.

[24] MOHAMMED, B.S., AL-FAKIH, A., LIEW, M.S., "Characteristics of interlocking concrete bricks incorporated crumb rubber and fly ash", In *ICCOEE2020: Proceedings of the 6th International Conference on Civil, Offshore and Environmental Engineering (ICCOEE2020)*, pp. 631–639, Singapore, 2021. doi: http://doi.org/10.1007/978-981-33-6311-3_72.

[25] NGUYEN, M.H., HUYNH, T.-P., "Turning incinerator waste fly ash into interlocking concrete bricks for sustainable development", *Construction & Building Materials*, v. 321, pp. 126385, 2022. doi: http://doi.org/10.1016/j.conbuildmat.2022.126385.