Fabrication of the Hybrid Bricks Utilizing Multiple Waste Pozzolanic Stabilizers as Fractional Substitution of Fine Aggregate

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Abstract: The world is pounding with millions of tons of industrial wastes such as ground granulated blast furnace slag (GGBS), fly ash, and mine tailings as various industrial wastes. The best way to make use of these wastes is to incorporate these materials as structural elements, which in turn minimizes the carbon footprint. In this context, this study focuses on using iron ore tailings and slag sand as a replacement for clay or natural sand for the production of stabilized blast furnace iron slag brick. Also, in this study sand is used as a stabilizer instead of more clay ratio. The development of sand-based bricks using fly ash and ground granulated blast furnace slag has been carried out in this research. The study includes the mechanical properties of the slag iron bricks. Sodium silicate (Na2SiO3) and sodium hydroxide (NaOH) solutions have been used as alkaline activators. The ratio of alkaline liquid to alumina-silicate concrete ratio and the percentage of the binder had a major influence on the strength of the brick. The bricks were cast and cured at ambient temperature. Compressive strength at 7, 14, and 28 days and the thermal conduction analysis are the major experimental works including some of the minor findings like water absorption, density and other tests were carried out.

Keywords: Iron Ore Tailings, Slag Sand, Fly Ash, Blast Furnace, Iron Slag Bricks, GGBS.

1. INTRODUCTION

World over is a massive interest in normal assets to take into account the lodging, business spaces, and the foundation for the consistently developing population. Once, it has been chosen to assemble another structure or a foundation, an exceptionally critical responsibility to devour common assets is made. Developers and predetermined workers might have the option to help further spread that consumption, yet they can't change the overall responsibility [1]. Meanwhile, huge interest has been put into the building material industry especially in the recent decade, owing to the extending people which causes a progressing absence of building materials, the primary experts have been trying to change the cutting edge wastes over to important structures and improvement materials [2]. The test for the public authority is to diminish the waste's unsafe effects on both well-being and the climate [3]. The concrete industry is especially significant as it isn't just answerable for burning through normal assets and energy but additionally for its ability to retain other mechanical waste and results [4]. It is realized that around 8-10 tons of new concrete waste can be created each day from a concrete clumping plant with an everyday yield of 1,000 m3 of cement [5]. The selection of aggregate is significant, and their quality assumes an incredible job; they can restrict the strength of concrete well as attributable to their attributes, they influence the toughness and execution of cement [6]. The overall utilization of sand as fine aggregates (FA) in concrete production is high, and a few non-industrial nations have experienced some strain in the flexibility of normal sand to meet the expanding needs of infrastructural advancement as of late [7]. Thus, there is an enormous interest in elective materials for fine aggregates in the development business. To beat the pressure and interest for stream sand, scientists have distinguished a few options for sand, to be specific scale, steel chips, squander iron, squashed stone fine, and so on [8].

Ecological administration in non-industrial nations is an unpredictable issue because natural issues are connected with social and monetary angles, which must be considered in the improvement of any ecological program or guideline [9]. The issue of waste amassing exists around the world, explicitly in thickly populated zones [10]. Scale, granulated slag, and steel chips are modern waste in the iron and steel industry and annoys both the well-being and climate when not appropriately discarded. Reusing or reuse of effluent and waste is financially or potentially environmentally significant [11].

The utilization of waste materials can be expanded complex on the off chance that they are utilized as aggregates in both concrete mortar and cement. These kinds of employments of waste materials can take care of

issues of the absence of aggregates in different building locales and decrease ecological issues identified with total mining and garbage removal. A scope of slag surfaces could be framed by the cooling systems and the resultant slag types show various properties. Blast furnace slag is a nonmetallic material comprising silicates and alumino-silicates of calcium and magnesium along with different mixes of sulfur, iron, manganese, and other minor components. Air-cooled slag, which is permitted to harden gradually in scoops or pits, is by a long shot the most plentiful and is a stone-like material that is entirely translucent [12-13]. Late examinations indicated that slag can likewise be supplanted with sand in cement. The purpose behind the utilization of iron waste in development is that it is helpful for both the economy and the climate [14]. There is an expansion in modern and innovative results that are unsafe for both the climate and human well-being if not appropriately discarded. Besides, these wastes are the primary driver of the dissipation of CO2 and other hurtful gases which cause an Earth-wide temperature boost and the demolition of the ozone layer which shields the planet Earth from destructive enormous beams. Likewise, mechanical waste and effluent can be utilized as substitute materials in cement and building units, which in itself is a superior option in contrast to unloading such waste as it will secure the climate and reduce the utilization of regular assets [15].

Researchers used granular slag as a substitution for the regular fine total in development applications, for example, stonework and putting. In this examination, concrete mortar blends 1:3, 1:4, 1:5, and 1:6 by volume were chosen for 0%, 25%, half, 75%, and 100% supplanting of common sand using granular slag for w/c proportions of 0.60, 0.65, 0.70 and 0.72, individually. The sand substitution from half 75% improved mortar stream stuff by 7%, while the compressive strength improved by 11–15% at the substitution level from 25% to 75%. Simultaneously block mortar squashing and pull qualities improved by 10–13% at 50– 75% substitution levels [16].

The following are the objectives of this investigation.

- To compare the crushing strength of the brick manufactured by partial replacement of sand with iron slag as with ordinary brick.
- To compare the hardness of brick manufactured by partial replacement of sand with iron slag as with ordinary brick.
- To compare the water absorption capacity of brick manufactured by partial replacement of sand with iron slag as ordinary brick.
- To compare the salinity percentage of brick manufactured by partial replacement of sand with iron slag as with ordinary brick.

2. METHOD AND MATERIALS

To accomplish study objectives, execution would incorporate the accompanying:

- Literature survey of past investigations which incorporate updates of books, logical papers, and reports in the field of utilization of blast furnace slag as an additive to be used in the manufacturing of bricks.
- Site visits and examinations of the utilization of blast furnaces as an additive to get more data.
- Deep investigation of blast furnace usage as an additive in brick manufacturing research by different scientists.
- Identifying the impacts of including the blast furnace slag sample in different bricks by using special mixing methods.
- Discussion of the experimental program having details of the different testing in the laboratory.
- Drawing conclusions and suggestions.

Number of samples

There are 3 samples of each survey with time interval. It was taking the rate of variation in 7, 14 & 28 days difference by Conventional tests. A total number of samples required approximately 10 samples for each type.

Study Area

Research work was directed in Peshawar city, district of Khyber Pakhtunkhwa (KP), Pakistan. It is the capital of Khyber Pakhtunkhwa (KP) territory. It is the 6th biggest in Pakistan. Peshawar is additionally the biggest Pashtun-dominant part city in Pakistan situated inside the wide valley of Peshawar close to the eastern finish from the memorable Khyber Pass, near the fringe of Afghanistan.

Peshawar includes a sweltering semi-parched atmosphere with exceptionally blistering, delayed summers and brief, mellow to cool winters. Winter in Peshawar begins in November and closures in late March, however, some of the time stretches out into mid-April, while the mid-year months are from mid-May to mid-September. The mean greatest summer temperature outperforms 40 °C (104 °F) during the sultriest month, and the mean least temperature is 25 °C (77 °F). The mean lowest temperature during the coolest month is 4 °C (39 °F), while the most extreme is 18.3 °C (64.9 °F).

A respectable square earth, which is available as a trademark resource, typically contains 50–60% of silica, 20–30% of alumina, 5% of lime, and 5–6% of oxide of iron. In any case, for non-ended green squares which can be made by using current wastes, materials to be used join iron metal tailings (IOT), slag sand, fly trash, and ground granulated effect warmer slag (GGBS), which can replace incredible square earth of near constituents. With extra alternative of sand in squares is mixed by using fly garbage, GGBS, sodium hydroxide (NaOH), sodium silicate (Na2SiO3), and water. These squares can be made without ending, yet used as latches.

Iron Ore Tailings

Iron ore tailings (IOT) are the waste materials on the way toward isolating important parts of iron from the iron metal. Various advances associated with this cycle are pulverizing, screening, granulating, washing, jigging, cyclizing, and so on The Iron metal following ordinarily contains around 20–30% of iron [17]. Additional withdrawal of iron is excessively costly. The arrangement of metal also a cycle of mineral extraction received has an immediate impact on synthesis of the tailings. Iron metal tailings have been obtained from Peshawar, Khyber Pakhtunkhwa (KP), Pakistan where heater organizations are found. Comparative iron metal tailings are accessible in different pieces of Pakistan which have diverse levels of iron in the investigations.

Table 1: Chemical compositions of iron ore tailings

S. No.	Constituents	Percentage (%)
1	SiO_2	16.05
2	Fe	44.82
3	Al_2O_3	6.34
4	CaO	1.52
5	MgO	0.28
6	MnO	1.20
7	TiO_2	0.38
8	L.O.I	10.09

Table 2: Physical properties of iron ore tailings

S. No.	Properties	Results
1	Specific gravity	3.4
2	Fineness modulus	2.81
3	Optimum moisture content	13%
4	Bulk density	2.54
5	Maximum dry density	2.25

Slag Sand

Slag sand, are eco-accommodating structure substantially acquired as a side-effect of the modern cycle which can supplant customary stream sand in are development of the structures [18]. This one takes into account the expanding request and quality necessities of the fine aggregates. Slag sand as an option in contrast to waterway sand would secure stream banks and spare the climate as portrayed in the table for compound production and another table for the actual possessions of slag sand. In this way, supplanting stream sand with slag sand prompts a superior climate and turns into a monetarily reasonable answer for the lack of fine aggregates.

Table 3: Chemical composition of slag sand

S. No.	Constituents	Percentage (%)
1	SiO_2	30.73
2	Fe_2O_3	0.56
3	$Al2O_3$	16.32
4	CaO	38.47
5	MgO	6.41

Table 4: Physical properties of slag sand

S. No.	Properties	Results
1	Specific gravity	2.65
2	Water absorption	1%
3	Fineness modulus	3.363

Fly Ash

Fly ash is removed after pipe gases through methods for electrostatic precipitator in dry structure. This one is substantial and has great pozzolanic properties. Fly ash is the result of the warm force positions of India, acceptable excellence as it contains low sulfur and low un-consumed carbon. The pozzolanic property of fly ash makes it hold for the production of additional ash-based items [19]. The particular seriousness of fly ash utilized is 2.17 current works. The table clarifies the compound synthesis of Fly ash utilized.

Table 5: chemical composition of fly ash

S. No.	Constituents	Percentage (%)
1	SiO_2	66.87
2	Fe_2O_3	4.41
3	$Al2O_3$	23.34
4	CaO	1.17
5	MgO	0.31

Ground Granulated Blast Furnace Slag (GGBS)

Granulated blast furnace slag (GGBS), is obtained by quickly chilling (extinguishing) liquid ash with the heater with the assistance of water. Throughout the cycle, slag gets divided also changed into nebulous granules (glass). The granulated slag is formerly ground from ideal excellence to delivering GGBS [20]. This one is one of the olive green development materials. GGBS replaces something that is created by an exceptionally energy-concentrated cycle. The particular significance of GGBS utilized in this work is 2.61. Table clarifies the substance piece of GGBS.

Table 6: Chemical composition of GGBS

S. No.	Constituents	Percentage (%)
1	SiO_2	31.79
2	Fe_2O_3	0.49
3	Al_2O_3	17.07
4	CaO	38.78
5	MgO	6.23

Sodium Hydroxide

Sodium hydroxide is obtained from sodium carbonate which was once in the past known as unforgiving pop. At room temperature, sodium hydroxide exists as a white clear unscented concrete that holds sogginess from the air. Exactly when separated in water or executed with destructive it liberates liberal warmth, which may be sufficient to ignite ignitable materials. It is damaging. It is usually used as a concrete or as a half plan. Sodium hydroxide is one of the extensively used manufactured substances in exploration places and organizations. It is moreover used in amassing various things like paper pounds and diverse compound things like plastics, designed materials, geopolymers, etc. The table portrays the specific sodium hydroxide, NaOH.

Table 7: Specifications of sodium hydroxide (NaOH)

S. No.	Specifications of NaOH	Results
1	M	40.0 g/mole
2	Assay (NaOH)	≥97%
3	Carbonate (Na_2CO_3)	≤2%
4	Heavy metals (as Pb)	≤0.002%

Sodium Silicate

Sodium silicate is generally known as water glass or fluid glass. These are notable because of its extensive business also mechanical demands. It is made of oxygen-silicon polymer spine-dwelling water in atomic grid holes. Sodium silicate items of produced as concretes or thick fluids, contingent upon the proposed work. Sodium silicate is an adaptable, inorganic substance fabricated by joining various proportions of sand and soft drink ash at high temperatures. This cycle stretches an assortment of items with special science which is utilized in numerous modern sciences that are used in many mechanical and client submissions.

Water

Drinkable water is cast for the manufacturing of bricks using blast furnace iron slag as a partial replacement for sand.

Mix Proportion

Six diverse blend extents will be measured viz.; GB-1, GB-2, GB-3, GB-4, GB-5, and GB-6. The slag sand will blended in through partitions 40, 40, 50, 30, 30, 20% and IOT as fractional supplanting using accompanying rates; 20, 30, and 40% of the all-out dry blend. Fly ash (15%) and ground granulated blast furnace slag (15%), which are kept consistent; all together contribute 30% of the all-out dry blend. The molarity of the sodium hydroxide arrangement received will be 8 and 10 M. The antacid arrangement will contribute 10% of the all-out blend. An ideal dampness content embraced will be 8%. The Na2SiO3 to NaOH proportion received will be 2.5. The soluble answer for the fastener material proportion embraced will be 0.35. It is portrayed in Table 8 for the blend extent counting molarity.

Table 8: Mix proportions of Blast furnace bricks

Quantity of ingredients/stabilizer					
Brick ID I	IOT %	Soil %	Fly ash %	GGBS %	Alkaline solution %
GB-1	20	40	15	15	8 M NaOH Soln.
GB-2	30	40	15	15	
GB-3	40	50	15	15	
GB-4	20	30	15	15	8 M NaOH Soln.
GB-5	30	30	15	15	
GB-6	40	20	15	15	

Process of Block-Making

'MARDINI' is a serious rendition of the mud block press machine created at the Department of Electrical Engineering, University of Sarhad, Peshawar, KP, Pakistan. The size of the settled mud block produced in the machine will be 230 × 110 × 100 mm. The cycle of square production includes a progression of consecutive strides as underneath.

- Preparation of soil
- Stabilizer arrangement preparation
- Blending of soil and stabilizer
- Expansion of additional water with sand
- Weighing of soil in scoop
- Bricks molding
- Stacking of the bricks
- Experimental performances
- Results analysis

Tests on Bricks

Following experiments in the laboratory have been performed on the samples.

Particle Size Distribution Curve

This test is done on the soil sample used for the manufacturing of the bricks to know the particle size distribution curve.

Compressive Strength

Their compressive trial with the block is measured as a list of his sturdiness and capacity in a brickwork divider as opposed to smashing burdens. Even though the greater part of the bricks is indicated as far as asset, which significant not to forfeit on the possessions of sturdiness and pledge for advanced compressive qualities. A large portion of the bricks will have strength for the most part going from 3.5 MPa to more than 10 MPa [21].

Figure 1: Compressive strength of Brick test.

Five bricks per mix shall be taken for testing and their average value turns will be the “Dry Compressive Strength” of the brick.

Compressive Strength = Failure Load / Area of Bed Face.

Brick Density

Brick density is one of the primary tests on bricks. This test shall be done for both dry and wet bricks. The formula used for finding brick density is as below.

Brick density = Dry weight (kg) / Volume (m3)

Water Absorption

The water assimilation for dry bricks ought not to surpass 20% of the heaviness of the block. The adequate qualities for the introductory pace of ingestion (IRA) range from 10 to 30 grams. A dry block with an IRA over 30 should be wetted before being utilized for development.

Dimensionality Test

Dimensionality test will be done by figure. In this test, at least 20 bricks will be chosen aimlessly and will be organized in columns and the measurements will be estimated closest millimeter. General measurements of masterminded bricks will be estimated with the assistance of steel tape. Likewise width also profundity of the organized bricks remains estimated along conventional line.

Falling Test

In this test, dried bricks after relieving will be permitted to tumble from a stature of 1m from the beginning. Ground will firm also level. At that point the perceptions will be noted down indicating whether breaks showed up, disappointment happened and so on, all the examples tried show moderate edge disappointment which is adequate.

Efflorescence Test

Flowering is produced because of the existence of salts in bricks. At the point when bricks become presented to dampness, water is consumed by them. Because of vanishing water ingested dries out from the uncovered countenances. Accordingly, the solvent salts contained inside them take shape out onto the surface. This cycle proceeds for quite a while relying upon the measure of salts present in the bricks and their dissolvability. All the examples tried indicated extremely slight blossom which is worthy.

Soundness Test

An adequacy test is directed at arresting two bricks in contradiction of one another or by a light sled. If the bricks create a reasonable metallic ringing sound and don't break, at that point those are acceptable quality bricks. All the examples tried for sufficiency indicated that they are substantial also acceptable producing a metallic ringing sound when struck in contradiction of one another.

Hardness test

Hardness bricks can discovered with a guide of scratch of a fingernail. On the off chance that no effect is had over the surface, the block is blessed to receive be adequately hard. All the examples tried indicated slight space, which is satisfactory.

Structure test

In the structure test, a block is broken and its structure is assessed. It is seen that the bricks are minimized, homogeneous, and liberated from any flaws, for example, irregularities, openings, and so on.

Thermal Conduction

Locally constructed thermocouples are embedded in the bricks of different types of stabilizers in various quantities during the time of molding. Samples after the hardening are used for thermal conduction tests. Every time the samples reached 60 °C in the oven, the time intervals between those temperatures were recorded. The time will be recorded either increasing or decreasing by increasing the stabilizer quantities replacing the amount of sand in the brick samples after reaching 60 °C temperature. This will illustrate how the thermal conductivity of the samples transforms through diverse types of brick samples.

3. RESULTS AND DATA ANALYSIS

There are variations in compressive strength, brick density, water absorption, Dimensionality test, falling test, Efflorescence test, Soundness test, hardness test, and structure test for various percentage replacements of sand with welding slag for the 7th, 14th, and 28th day.

Following are the results of experiments performed on the bricks manufactured.

Soil Sample Properties

Following are the geotechnical properties of the soil sample utilized in this research work for the production of the bricks.

Table 9: Geotechnical properties of the soil sample in the investigation

S. No.	Properties	Results
1	Moisture Content (%)	5.98
2	Liquid Limit (%)	25.44
3	Plastic Limit (%)	14.90
4	Plasticity Index	10.54
5	Specific Gravity	2.64
6	Maximum Dry Density (gm/cc)	1.82
7	Optimum Moisture Content	17.05
8	USCS Classification	CL-ML

Particle Size Distribution

The soil sample taken from the field for the manufacturing of the bricks was clayey soil and later was brought to the laboratory for the particle size distribution analysis. Also, the soil sample was investigated for its group classification under which the sample lies based on the values of the different performances which is CL-ML as mentioned above.

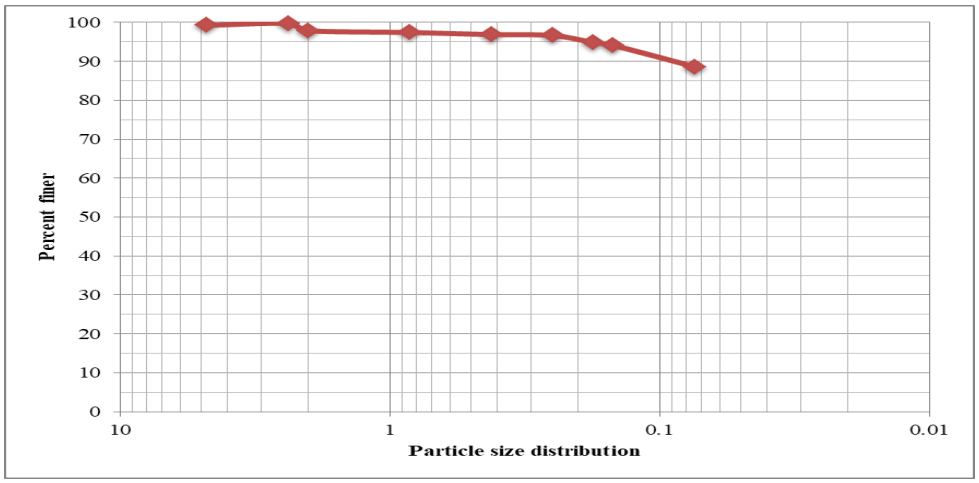

Figure 2: Particle size distribution curve of the soil sample.

Compressive Strength

In this work, a progression of tests was done to contemplate the strength and sturdiness properties of the blast furnace bricks. Additionally, field tests were led to check the nature of bricks.

Table 10: Compressive strength of blast furnace bricks

Brick ID	Dry compressive strength (N/mm^2)			Wet compressive strength(N/mm^2)
	7^{th} day	14^{th} day	28^{th} day	
GB-1	15.41	17.79	21.86	13.79
GB-2	13.04	14.82	18.46	11.70
GB-3	11.86	13.44	16.68	10.67
GB-4	17.59	20.16	25.3	20.95
GB-5	15.22	17.39	21.58	17.39
GB-6	13.24	15.02	18.38	15.18

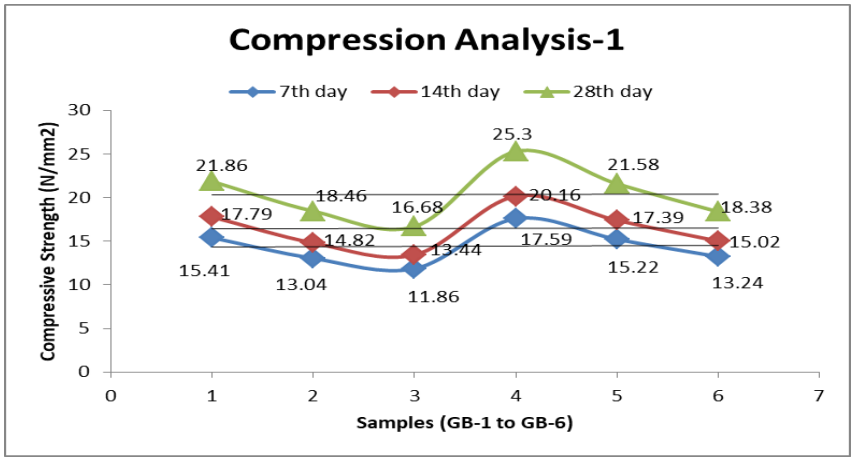

Figure 3: Compressive strength analysis-1 of blast furnace bricks.

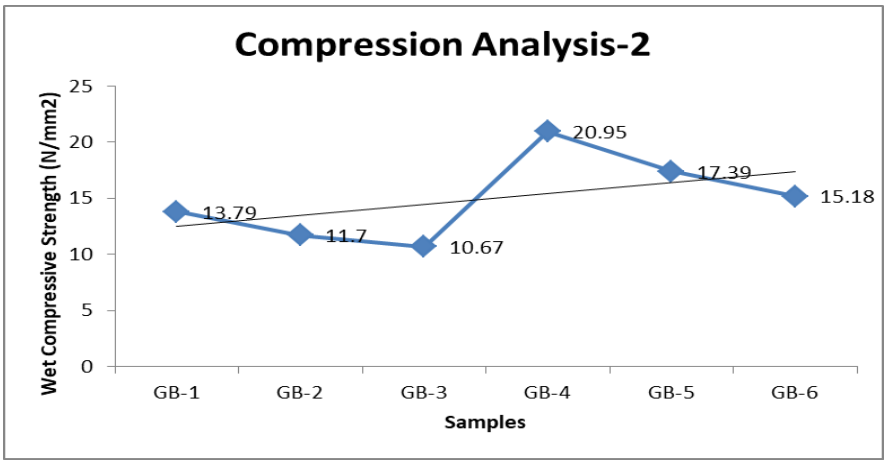

Figure 4: Compressive strength analysis-2 of blast furnace bricks.

Density Test

Following are the results of the dry and wet densities of the bricks under consideration in this investigation given in tabular and graphical form.

Table 11: Density of blast furnace bricks

S. No.	Brick ID	Dry density (kg/m3)	Wet density (kg/m3)
1	GB-1	1978	2110
2	GB-2	2001	2086
3	GB-3	2055	2152
4	GB-4	2006	2127
5	GB-5	2061	2136
6	GB-6	2120	2180

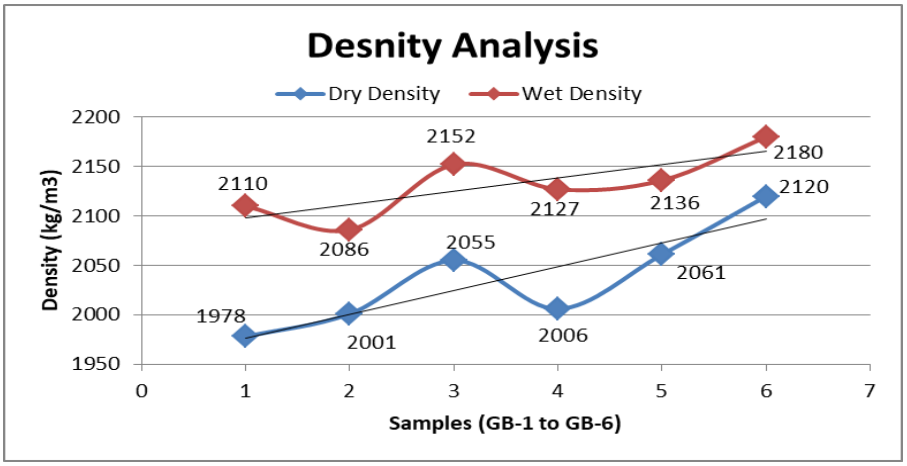

Figure 5: Density of blast furnace bricks.

Water Absorption

Following are the results of water absorption test.

Table 12: Water absorption test results of furnace bricks

S. No.	Brick ID	Initial rate of absorption (kg/m2/min) or (g)	Water absorption (%)
1	GB-1	1.06 (27)	6.67
2	GB-2	0.94 (24)	4.22
3	GB-3	1.03 (26)	4.71
4	GB-4	1.28 (32)	6.04
5	GB-5	1.06 (27)	3.71
6	GB-6	0.90 (23)	2.83

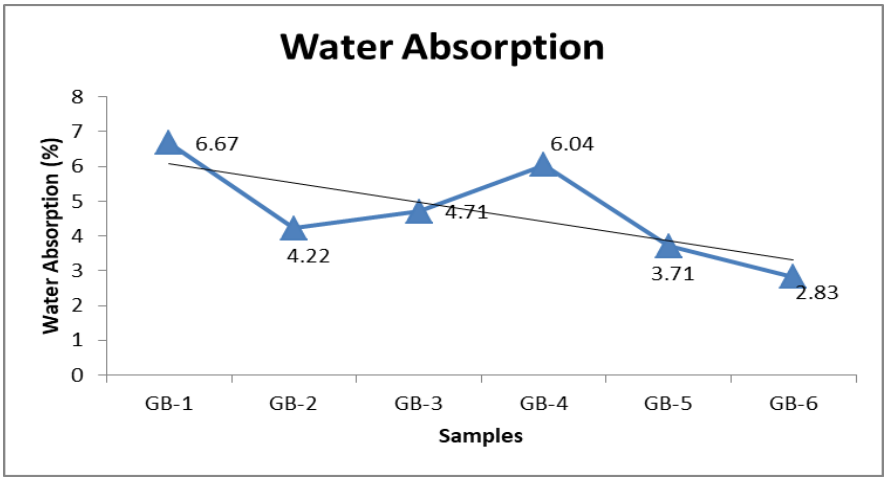

Figure 6: Water absorption test results of furnace bricks.

Dimensionality Test

Table 13: Dimensionality test results of blast furnace bricks

Dimensions	No. of units	Dimension (mm)	Average dimensions (mm)	Code recommendations (mm)
L	30	230	230	230 ± 5
B		110	110	110 ± 3
H		100	100	100 ± 3

Thermal Conduction

The purpose of this evaluation is to determine the relationship between heat resistance and stabilizers used in this research work. We designed and fabricated a device that resembles a local thermocouple for this purpose. It can measure the rate of heat transmission through a variety of brick samples composed of different configurations of aggregates. Thermo Couple is the device that was used in this experiment to verify the heat conductivity of the brick samples. It is made out of wire, a sophisticated thermometer, and a steel pole [22].

Table 14: Result of thermal conduction assessment on different brick samples having multiple stabilizers in terms of time differences

Samples Percentage (%)	Time to reach 60°C (hours and min)	Time to reach 60°C (hours)	Temperature (°C)	Differences of Time (min)
GB-1	4h 02m	4.03	60	--
GB-2	4h 55m	4.91	60	53
GB-3	5h 42m	5.07	60	47
GB-4	6h 35m	6.58	60	53
GB-5	7h 40m	7.66	60	65
GB-6	8h 51 m	8.85	60	71

4. CONCLUSION & RECOMMENDATION

Following are the conclusions and recommendations of the investigation.

CONCLUSION

- The heater and welding slags have been used in the work by utilizing the structure materials as expansion to sand which makes the heater block all the more delicate and simple to form.

- The blast furnace iron slag as an incomplete swap of sand also utilized as a stabilizer for bricks. Fly ash and ground granulated blast furnace piece goes about as amazing strong folios for the amalgamation of blast furnace iron slag bricks.

- The compressive strength of utilizing blast furnace iron slag as a halfway supplanting of sand bricks through iron metal tailings, slag sand, fly ash, and GGBS increments with the expansion in the molarity of the basic arrangement and increments along increment in the level of slag sand. The base obligatory compressive strength blast furnace iron slag as a fractional substitution of the sand block will be accomplished by all the distinctive blends demonstrated.

- Iron ore tailings (IOT), and slag sand could be utilized to assemble settled utilizing blast furnace iron slag squares for good excellence and asset.

- There are field tests directed to blast furnace iron slag as a halfway substitution of sand bricks show magnificent outcomes for embracing them for maintainable development.

- Blast heater iron slag as an incomplete substitution of sand bricks ends up being a great trade for terminated bricks dependent on the examinations led.

Recommendations

There are few suggestions which are given below:

- The compressive strength of blast furnace bricks blend has advanced convergence on the basic arrangement, for example, 10 M when contrasted with 8M and it has the most noteworthy level of Slag sand.

- The compressive strength is a low amount to blast furnace bricks that have a minimal level of slag sand and with most elevated level of iron mineral tailings.

- The most elevated water retention rate acquired additionally demonstrated a similar example.

- The dimensionality test results were inside the Indian Standard code proposals.

- In the falling test, the disappointment blast furnace bricks were not extreme also the greatest examples of disappointments were confined to mellow edge disappointment, moderate edge disappointment, and no disappointment.

- The blooming test demonstrated that the bricks were inclined to flower marginally. Along these lines, it fulfilled the explanation "Flowering will not be more than Slight for Higher class-bricks" as all the bricks have a place with class AA classification, the most elevated class.

- The blast furnace bricks delivered a clear ringing sound when hit with another block and ended up being acceptable. Bricks exposed to rigidity test by rubbing by nail didn't have some effects on a superficial level and also ended up being adequately hard.

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