This is to certify that the

BE Civil Engineering Project entitled

COMPARATIVE STUDY OF EARTHEN BRICKS AND MECHANICALLY COMPRESSED FLY ASH BRICKS

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Dedication

This Thesis is dedicated to our beloved

Parents

&

Teachers

ACKNOWLEDGEMENT

Praise to ALMIGHTY ALLAH for providing us the strength and knowledge to complete the research assignment as it would not have been possible without His blessings. We greatly indebted to Lt Col Dr. Muhammad Jawed Iqbal who has provided us a continuous support, encouraged, and guided us during the entire course of research. It was due to his continuous persuasion that led us towards completion of this research work. We also owe our deepest regards & appreciation to our family, course mates, degree mates and seniors; for their love, support, well wishes and much needed prayers.

ABSTRACT

In Pakistan, coal share in power generation has risen to 25% but lack of disposal arrangements of it's waste byproduct remains a serious concern. Fly Ash is a waste byproduct when coal is burnt which, if not disposed of correctly, is a serious environmental hazard. With the use of fly ash as a construction material, the natural environment angle has been sufficiently dealt with. Although fly ash bricks display better material and mechanical properties than conventional clay bricks, yet there remains room for improvement. The purpose of this research is to assess the feasibility of fly ash bricks vis-a-vis conventional kiln bricks. Additionally, it also focuses on proposing a fly ash brick variant as an improved version of the commercially available fly ash bricks in Pakistan across the domains of cost, mechanical and material properties.

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CHAPTER 1

INTRODUCTION

1.1 General

Use of fly ash in construction materials is a growing necessity of today's world. With Pakistan being a signatory of the Paris Accord and with the government's 2025 plan in place, it is imperative that the prevalent practice of landfilling fly ash be curtailed (Salik, 2017). While there is the definite improvement with respect to the environmental impact to look forward to fly ash, when used in construction materials, has its own material advantages including improved water absorption and decrease in efflorescence (Gourav & Venkatarama Reddy, 2014).

Use of masonry is still in widespread use in low level construction projects throughout Pakistan. With the advantages that fly ash offers including a decrease in weight of structure (Abbas, Saleem, Kazmi, & Munir, 2017) and specific gravity, fly ash bricks are indeed a revolutionary innovation in masonry structures.

With promising results identified over various literature, although fly ash bricks cost is comparable to conventional clay bricks in Pakistan, they can certainly be adjusted with respect to composition to build products with advantages that outweigh the costs (Gourav & Venkatarama Reddy, 2014).

Among the issues usually experienced in the case of masonry structures, uniformity in brick sizes and dimensional stability across various weather conditions is an issue which fly ash bricks promise to curtail if not eliminate. Not only the bricks' composition is responsible for this improvement but also the method of manufacturing is more systematic and guarantees greater ease in adhering to standard sizing of products. (Ameh, Andrew, & Temitope, 2017)

Efflorescence is another issue that renders masonry structures vulnerable. There is literary evidence regarding this as well where fly ash is known to have assisted in curtailing efflorescence in structures (Abbas, Saleem, Kazmi, & Munir, 2017).

As far water absorption is concerned, fly ash absorbs less water due to its particulate structure (Freidin & Erell, 1995).

With such anticipated results, the study aims at introducing a fly ash brick solution with optimum composition to bring forth the best result that addresses all the concerns.

1.2 Problem Statement

As mentioned above, there are several issues that need to be studied and worked upon to achieve the ideal solution that can be put into practice. The issues of non-uniformity in conventional clay bricks, efflorescence in masonry structures, varied compressive strengths and greater water absorption of clay bricks need a thorough investigation. While composition of available fly ash is influenced by localized factors (primarily the origin of the coal being incinerated in power plants from which fly ash is obtained), there are unique, localized solutions for such problems. This study aims to assess and investigate these issues and provide viable conclusions which are cost effective.

1.3 Objectives of the Study

The main aim of this study is to analyze the feasibility of using fly ash in mechanically compressed bricks (by observing material and mechanical properties) and to suggest suitable / viable option of using flyash bricks.

1.4 Research Scope

Following a comprehensive literature review on fly ash and its use in construction materials and products, the study would analyze samples of both conventional (kiln) clay bricks and fly ash bricks obtained from local brick manufacturers and retailers. For fly ash bricks, one local producer in the Rawalpindi city area was chosen to obtain three different samples of fly ash bricks. These samples would be tested against their mechanical and material properties of compressive strength, water absorption, and specific gravity and compared with clay bricks.

Lastly, three variants of samples differing in their composition of fly ash and cement would be cast and subsequently tested again for the same properties. Proposed fly ash brick samples with the most favorable results regarding both selected parameters (mechanical and material properties and cost-effectiveness) would be presented as the viable outcome of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Being an unwanted material of coal-controlled thermal energy stations that is possibly harmful for the nature, utilization of fly debris in the development business has been urged after some time to diminish waste and carbon impression. In modern coal-fired power plants, with the EPA regulations in the United States regarding capturing of more than 99% of total produced fly ash (Ashraf, 2016), electrostatic precipitators are made use of to capture fly ash before the mixture of gases escapes through the chimney (White, 1977).

Components of fly ash vary as per the source and composition of the coal being burned. However, it majorly consists of aluminum oxide, silicon dioxide, and calcium oxide. Also, based on the lime content, fly ash can be categorized as either Class F – produced from usually high-ranked coals – or Class C – produced from usually low-ranked coals – as per ASTM C618 (Fox, 2017).

The use of fly ash in concrete has several environmental benefits wherein it supplements cementitious materials thereby reducing cement demand, reduces landfilled fly ash, and reduces water demand in concrete mixes. In the case of masonry, fly ash bricks are known to have up to three times the strength of conventional bricks, demonstrate low water absorption, being durable, demanding less mortar consumption, and being environmentally friendly.

2.2 Pakistan Fly Ash

It is simple to make a Fly Ash Brick. A successful brickyard should make standardized bricks of the same quality and promote them at a rate sufficient to cowl prices and make an inexpensive profit. Before beginning a brickyard, it is extremely crucial consequently to research the financial feasibility of the project. Determination of stage of call for brick inside the location (what number of in keeping with month) and competitors from different brick yards are crucial elements having a large bearing on the feasibility of the venture. Thereafter, value estimation, which is primarily based on diverse strategies of manufacturing and output, is done. Factors that affect unit value include:

- Own Cost of site
- Expenditure on Site developments & improvements: fencing, paved regions for manufacturing and stockpiles, roadways, buildings, and pathways.
- Equipment Expense: Concrete mixer, brick making gadget, and miscellaneous equipment
- Services Cost: water and electricity
- Material prices
- Wastage
- Maintenance prices of site and equipment
- Output: Production of bricks in a day
- Labor value etc

In Pakistan, fly ash may be acquired from Lakhra Coal Power Plant which produces about 2 million tons annually (Memon, Memon, & Memon, 2010). This fly ash is improper to be used in concrete attributable to its composition being excessive in gypsum (Aziz, et al., 2010). Raw product for use in Fly Ash Brick is to be withinside the nearby marketplace at an affordable rate. Main manufacturing material additives include Fly Ash Type C, cement, and sand/stone dust. Several providers are in every place and location of Pakistan and can be contacted easily, while cement can be obtained from any recognized agency. A contrast of Pakistan fly ash with ASTM limits for fly ash is given withinside the desk below.

Table 2.2: Comparison of Pakistan Fly Ash with ASTM Limits for Fly Ash (Munir, et al., 2016)

Sr. No.	Chemical Constituents (%)	Pakistan Fly Ash (%)	ASTM Limits for Fly Ash (%)
1	SiO_2	20.3-25.2	($SiO_2 + Al_2O_3 + Fe_2O_3$) Min. 50.0
2	Al_2O_3	13.1-15.2	
3	Fe_2O_3	8.2-9.8	
4	CaO	21.2-24.0	No Limit
5	MgO	2.3-3.5	No Limit
6	SO_3	12.5-14.0	Max. 5
7	LOI	13.8-15.2	Max. 6

Incomplete supplanting of concrete with Lakhra fly debris and rice husk ash demonstrated an enhanced compressive (16.14%) and indirect tensile (15.20%) strength while decreasing the sample's slump value (Bheel, et al., 2020).

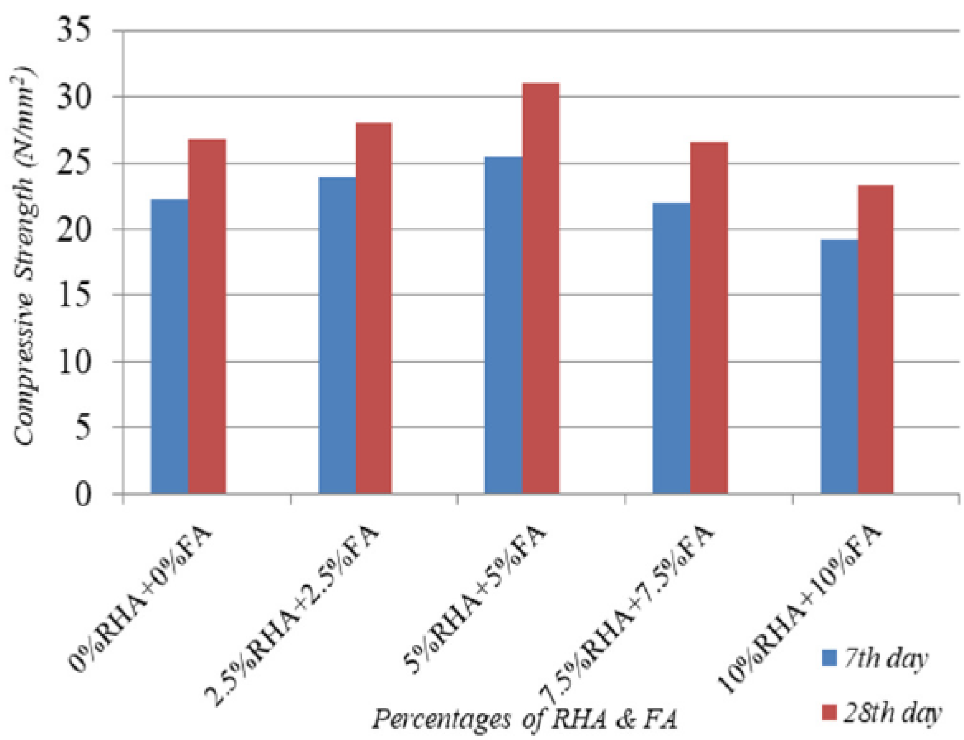

Figure 2.2.1: Compressive Strength of Concrete (Bheel, et al., 2020)

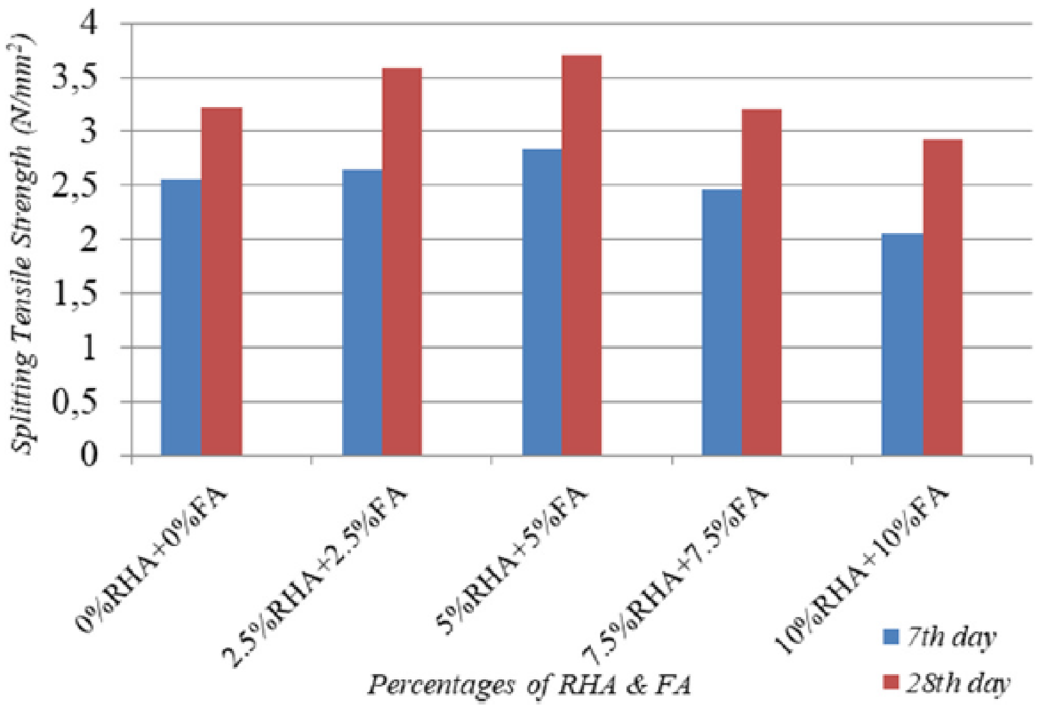

Figure 2.1.2: Split Tensile Strength of Concrete (Bheel, et al., 2020)

2.3 Fly Ash in Bricks

At the point when fly debris was introduced in traditional mud bricks (0 to 25% by dirt weight), although the bricks fulfilled the base compressive strength prerequisites of the Pakistan Building Code yet there was a decrease in compressive strength with expanding fly debris content when contrasted with ordinary earth bricks. On the other hand, there was a reduction in both weight (up to 18% reduction in weight for 25% fly ash clay bricks) and efflorescence of the fly ash bricks. In the case of water absorption, again there was an increase for fly ash bricks in comparison with conventional compressed earthen bricks (clay bricks). (Abbas, Saleem, Kazmi, & Munir, 2017)

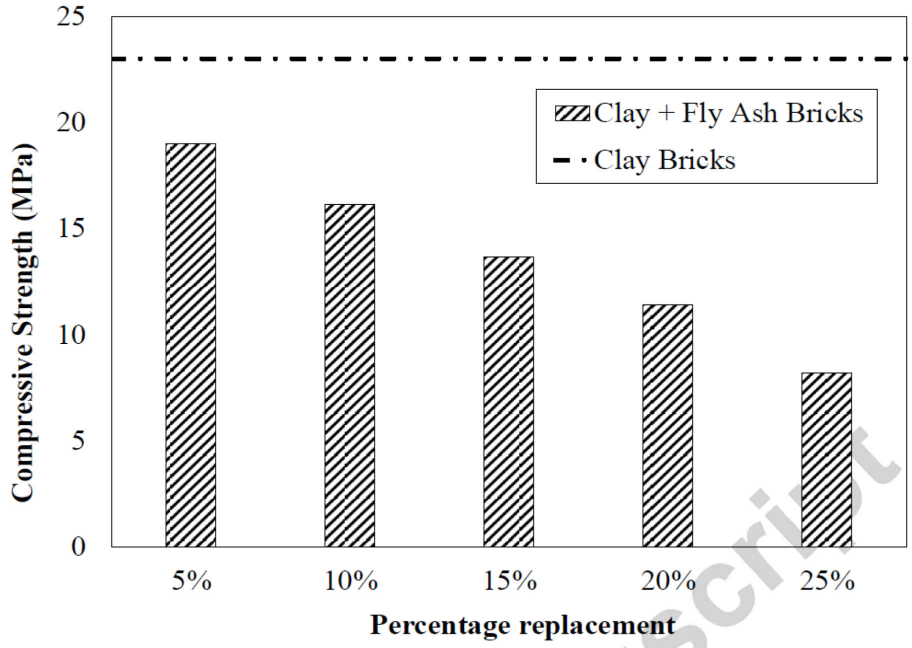

Figure 2.2.1: Compressive Strength of Fly Ash Bricks Against Conventional Clay Bricks (Abbas, Saleem, Kazmi, & Munir, 2017)

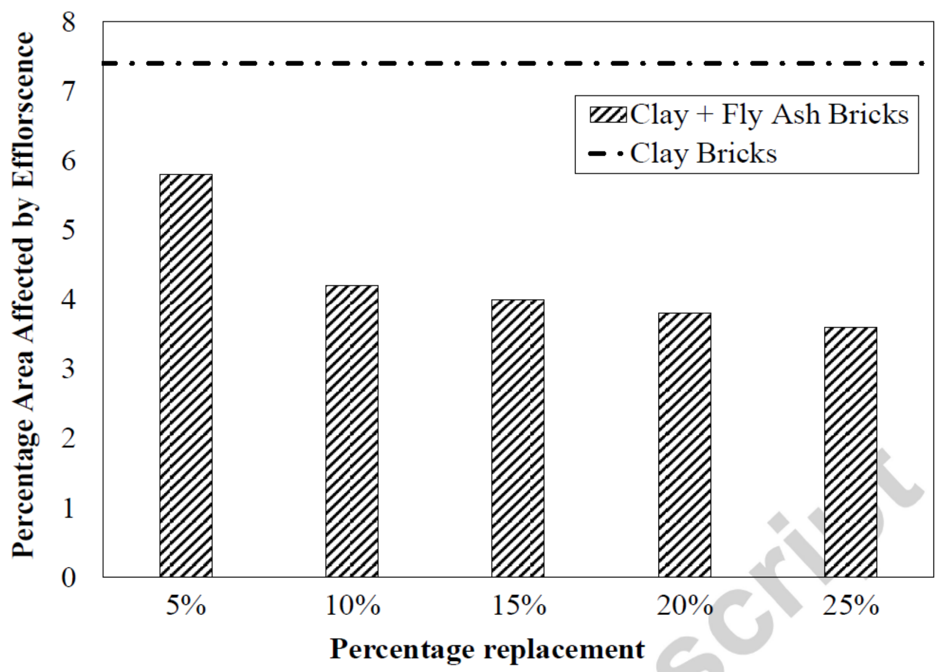

Figure 2.3.2: Efflorescence in Fly Ash Bricks Against Conventional Clay Bricks (Abbas, Saleem, Kazmi, & Munir, 2017)

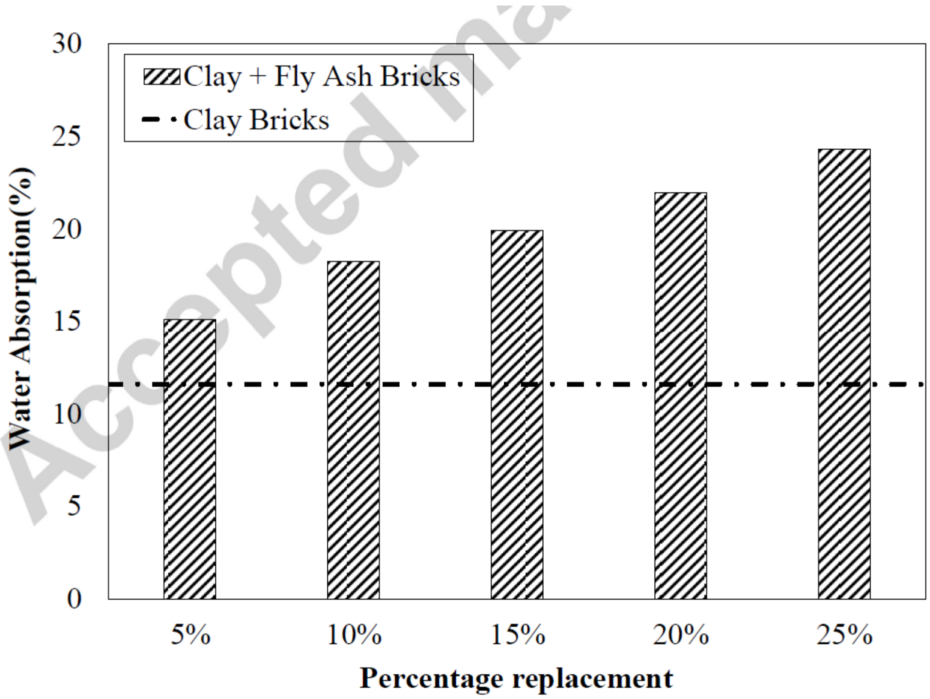

Figure 2.3.3: Water Absorption in Fly Ash Bricks Against Conventional Clay Bricks (Abbas, Saleem, Kazmi, & Munir, 2017)

Fly ash-lime and fly ash-lime-gypsum mechanically compressed bricks were investigated in differing lime concentrations and presence or absence of gypsum. The results showed that it is possible to achieve 8 – 10 MPa compressive strength in saturated state, low water absorption and good dimensional stability (0.01 – 0.04 linear expansion on saturation and less than 2% weight loss) with fly ash bricks. Furthermore, flexure bond strength was high for fly ash bricks when compared with kiln clay brick masonry. The investigation reasoned that there is an extension for choosing ideal blend proportions of fly debris, sand, lime and different added substances to get a particular planned strength for the brick. (Gourav & Venkatarama Reddy, 2014)

Table 2.3.1: Brick Designation (Gourav & Venkatarama Reddy, 2014)

TABLE 1

DETAILS OF FLY ASH BRICK PROPORTIONS AND THEIR DESIGNATIONS BRICK SIZE (MM): 230 X 108 X 75

Proportions (by weight)		Brick designation
Lime	Gypsum	
10.5%	-----	FAL10
10.5%	2.0%	FALG10
17.5%	-----	FAL17
17.5%	2.0%	FALG17

Table 2.3.2: Brick Designation (Gourav & Venkatarama Reddy, 2014)

TABLE 3

CHARACTERISTICS OF FLY ASH BRICKS STANDARD DEVIATION VALUES IN PARENTHESIS; DRY DENSITY OF BRICKS: 16.28 – 16.81 kN/m^3

Details of the property	FAL10	FALG10	FAL17	FALG17
Wet compressive strength (MPa)	4.9 (0.22)	7.8 (0.36)	7.8 (0.94)	9.5 (0.62)
Dry compressive strength (MPa)	9.3 (0.97)	14.5 (0.90)	15.8 (0.87)	16.9 (0.53)
Wet to dry compressive strength ratio	0.53	0.54	0.49	0.56
Initial Rate of Absorption (kg/m^2/min.)	1.2 (0.28)	1.17 (0.10)	0.58 (0.13)	0.56 (0.14)
Water absorption (%)	13.30 (0.23)	14.21 (0.42)	14.04 (0.25)	15.55 (0.33)
Linear Expansion on saturation (%)	0.01 (0.003)	0.03 (0.009)	0.030 (0.003)	0.039 (0.003)
Weight loss after durability test (%)	1.24 (0.26)	1.89 (0.40)	0.30 (0.14)	1.45 (0.66)

2.4 Fly Ash Brick Production

Fly ash bricks are mechanically compressed using a fly ash brick machine. In commercial production, the machines are fully automated and do not require any human input. Comprising of mixers, the appropriate proportion of mixture is fed to pre-set molds which are mechanically pressed to shape the bricks. These are then stacked and cured. (Ameh, Andrew, & Temitope, 2017)

Figure 2.4.1: Fully Automated Mechanically Pressed Brick Machine (Ameh, Andrew, & Temitope, 2017)

LAND & BUILDING REQUIREMENTS

Selection of Site. In choosing a favorable site, bear in mind the location, get entry to, slope, and space required. The following must be taken into consideration:

Location

- Transportation of raw materials
- Market available for bricks
- Availability of local labor
- Security of the vicinity
- Availability of services, i.e., roads, water, electricity, sewerage, etc.

Access The production place should be reachable for vehicles giving over aggregates and cement and amassing finished bricks.

Ground slope Ideally, the production site has to be plain. Steep slopes make dealing with and manufacturing difficult. Working on a lofty slant is costly.

Size The production site to be large sufficient for combination stockpiles, cement storage, manufacturing (slab or desk-bound device) brick stacking, workers facilities, a field office in location and easy entry. With all arrangements, one acre of land could be adequate for the task.

Figure 2.4.2: Semi Automated Mechanically Pressed Brick Machine

Setting up the Production Place. The production place to have provision for stockpiling aggregates and storing cement, a manufacturing vicinity, workers facilities, a workplace, or a field office.

- **Aggregate stockpiles** Aggregates need to be stockpiled in one of these manners that they do now have no contact with soil, leaves, extraordinary aggregates are saved separately, and rainwater can deplete away. Ideally, aggregates have to be stockpiled on a concrete slab. On the off chance that this isn't constantly done, the layer of aggregates in contact with the dirt needs to now presently don't be utilized for assembling. Aggregates need to now no longer be stockpiled beneath trees. Partitions have to be erected among extraordinary sorts of combinations. Stockpiles have to be on a mild slope so that rainwater does not get trapped between the aggregates voids.

Figure 2.4.3: Stacking of Sand and Flyash

- **Cement stacking**. The best manner to stack cement is in a silo. For limited scope brick yards, cement is transported in bags. Cement in bags need to rather be saved in a climate-proof room. Packs must be piled up on a plastic covering or on eagerly divided wood strips all together that they do now at this point do not absorb moisture of the ground. The storeroom must be big enough to keep as a base seven days convey of cement. If it isn't generally achievable to offer a storeroom, cement in packs must be saved in stacks raised over the floor and totally secured with canvases.
- **Production vicinity**. The total space required depends upon the methodology of assembling bricks. A work area-bound gadget, which structures bricks on beds, wants a tiny area with a region around it for administrators. A versatile "egg-laying" gadget wants a tremendous piece on which bricks are made. Subtleties of one of these pieces are referenced beneath.
  - **Area**: A flat concrete slab, sufficient for a minimum requisite of one day's manufacturing,. To limit breakages in extreme weather conditions, it's far

advocated to increase the cement content material of the combination or the curing time earlier than shifting the bricks.

- **Slope**: Normally brick manufacturing is done withinside the open, and the concrete slab must have an insignificant slant of one in hundred to ensure the water drain out properly.
- **Thickness**: Enormous assembling machines require an insignificant piece thickness of 150mm.
- **Joints**: To save out-of-control cracking, the slab must be divided into square panels. The 1/2 of circular keyway forestalls differential settlement of abutting chunks. Most joint dispersing depends upon the thickness of the piece and should now presently don't surpass six meter for slab thicknesses of one hundred and fifty or two hundred mm.
- **Stacking vicinity**: A vicinity sufficient enough to stack at least a week’s manufacturing is required for drying and curing bricks. Paving this vicinity is no longer as much important. To keep away from muddy conditions, a layer of concrete stone, approximately a hundred mm thick, is sufficient.

Figure 2.4.4: Fly Ash Bricks

- **Office and Staff facilities**: These encompass toilets, rooms, etc. A workplace must be made for all.

Land and Building necessities are listed down in the table:

Table 2.4.1: Estimated Area & Cost required

Details	Size/Area (Sq. Ft.)	Civil Works /Construction Cost/Sq. Ft.	Total Construction Cost
Management Building	1000	2000	2000000
Production & Stacking Area	5000	1800	9000000
Cement Store	5000	1200	6000000
Water Tank	2000	800	1600000
Cafeteria & Staff Facilities	500	2000	1000000
Pavement / Driveway	4000	150	600000
Ground	69650	05	348250
Total Construction Cost			20548250

The facility will be in every industrial zone in Pakistan's major cities. The reason for the choice is the availability of utilities i.e. water, electricity, and skilled labor, but the relatively low land cost and good transportation options also explain your choice.

2.5 Testing of Bricks

2.5.1 Compressive Strength Test

As per ASTM C 67, test specimens should be oven-dried prior to testing as the amount of moisture in brick is inversely proportional to its apparent strength. Capping of specimens is advised to counter for surface irregularities of specimens. During testing, it is to be ensured that the load acting upon the specimens is centered over the specimen to avoid any eccentricity resulting in dubious readings. Apart from the speed of testing specified by ASTM C 67, the code likewise determines that in the wake of stacking to one-portion of the most extreme burden, the rate ought to be changed with the end goal that the test is finished in at least one moment and not over two minutes.

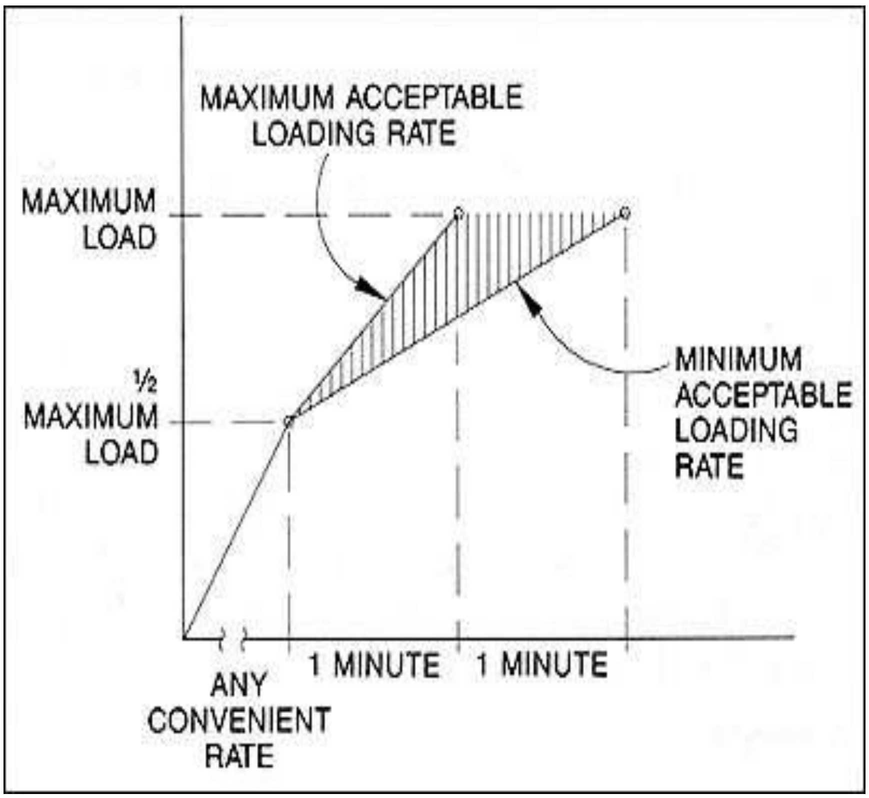

Figure 2.5.1: Compressive Testing Loading Rate (ASTM International, 2020)

The compressive strength is determined when the maximum compressive load is divided by the gross cross-sectional area of the specimen. (The Brick Industry Association, 2001)

Figure 2.5.1(a): Universal Testing Machine

2.5.2 Water Absorption Test

After oven drying the brick specimens until they achieve constant mass, are allowed to cool down at room temperature and their weight (M1) obtained. The dried specimens are then immersed completely for 24 hours in clean water at code specified temperature of 27±2^{o}C. The specimens are then removed, excess water wiped and weighed (M2). (The Constructor, 2017)

Water absorption as percentage by mass is given by:

$$W = \frac{M_2 - M_1}{M_1} \times 100$$

Equation 2.5.2: Water Absorption

Figure 2.5.2: Water Absorption Test

2.5.3 Specific Gravity Test

The sample is immersed in water within a basket and the entrapped air is removed. The immersion continues for 24 hours whence the weight of the sample and basket are recorded as W_1g. The empty basket suspended in water is then weighed as W_2g. The specimen is then surface dried for at least 10 minutes and then weighed as W_3g. The sample is then oven dried and weighed as W_4g. (The Constructor, 2018)

While specific gravity is calculated as:

$$\frac{W_4}{W_4 - (W_1 - W_2)}$$

Equation 2.5.3: Apparent Specific Gravity

Figure 2.5.3: Apparatus for Measuring Specific Gravity

Figure 2.5.4: Apparatus for Measuring Specific Gravity

Figure 2.5.5: Apparatus for Measuring Specific Gravity

CHAPTER 3

STRATEGY & TEST SETUP

3.1 Methodology

Following a detailed literature review, the following methodology was devised for the study.

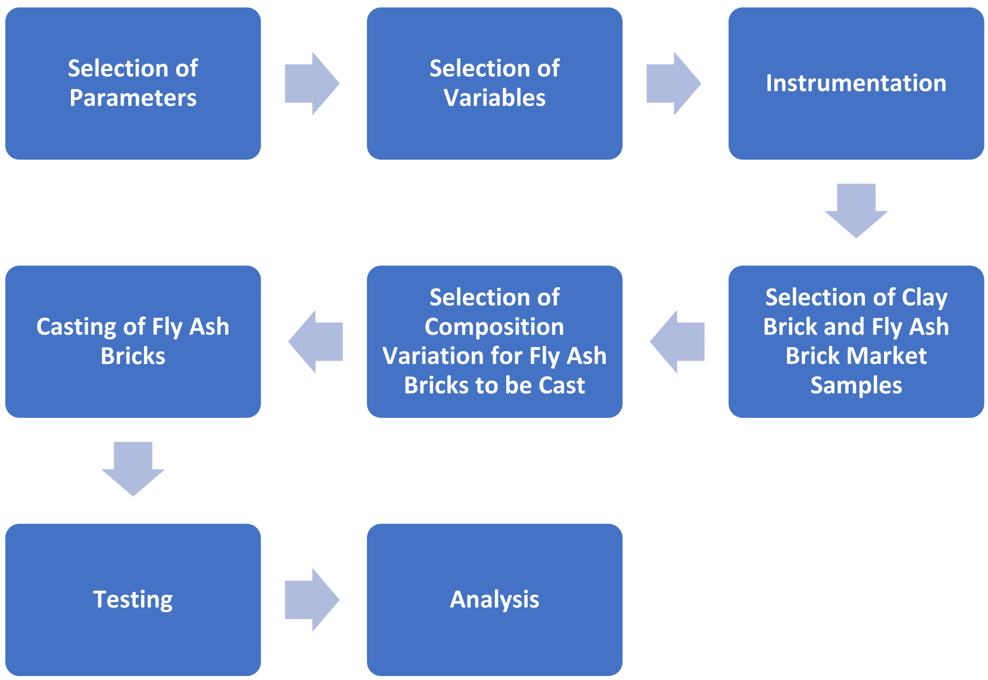

Figure 3.1: Research Methodology

3.1.1 Selection of Parameters

The following parameters were selected to be studied in this investigation:

- **Compressive Strength:** The maximum compressing load a brick can take before failure.
- **Water Absorption:** The amount of water absorbed by a brick after a 24-hour immersion.
- **Specific Gravity:** Relative density of bricks with that of water.

3.1.2 Selection of Variables

To investigate the said parameters, the following variables were chosen to be studied:

- Brick Type (Conventional Kiln Clay Brick or Mechanically Pressed Fly Ash Brick)
- Amount of Fly Ash in Bricks (for comparison within Fly Ash Bricks)

3.1.3 Instrumentation

Compressive strength test of bricks was done with the help of universal testing machine.

Figure 3.1.3: Universal Testing Machine

Water absorption and specific gravity tests were carried out using standard testing equipment.

3.1.4 Material Selection

In the case of proposed fly ash brick samples cast, all material was acquired from the local market that was readily available. With a set mix ratio of 1:2:4 of 50% fly ash – 50%cement mixture, stone dust and sand respectively, the proportion of fly ash and cement was varied to arrive at 3 different proposed sample types (variants). 3 samples of each variation were cast and tested.

3.1.5 Composition of Samples

All brick samples (acquired and cast) underwent testing to determine their composition.

3.1.6 Selected Market Samples

The following brick variants were selected. Testing was conducted on 3 samples of each brick variant.

- Clay Bricks A
- Clay Bricks B
- Clay Bricks C
- Clay Bricks D
- Clay Bricks E
- Fly Ash Bricks SSC

3.1.7 Cast Fly Ash Brick Samples

The following 3 variants of fly ash bricks were cast. Testing was conducted on 3 samples of each brick variant:

- 35% FA, 20% Cement
- 40% FA, 15% Cement
- 45% FA, 10% Cement

Figure 3.1.7: Fly Ash

3.1.8 Nomenclature

The following nomenclature was adopted to identify the different brick samples:

- CB-A: Clay Bricks A
- CB-B: Clay Bricks B
- CB-C: Clay Bricks C
- CB-D: Clay Bricks D
- CB-E: Clay Bricks E
- FB-SSC: Fly Ash Bricks SSC
- FB-X: Cast Fly Ash Brick 35% Fly Ash, 20% Cement
- FB-Y: Cast Fly Ash Brick 40% Fly Ash, 15% Cement
- FB-Z: Cast Fly Ash Brick 45% Fly Ash, 10% Cement

3.1.9 Fly Ash Brick Casting

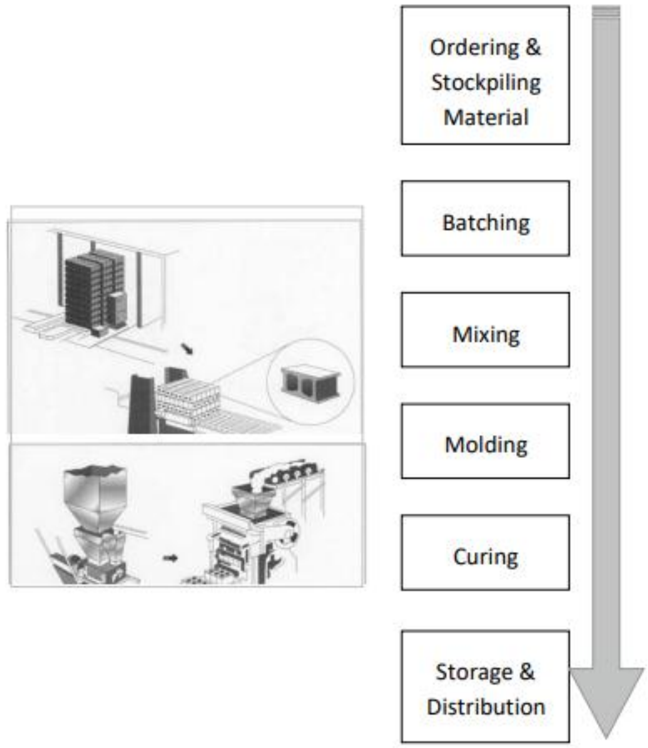

Figure 3.1.9: Production Process Flow

- **The Manufacturing Process**

The manufacturing of bricks includes 4 fundamental processes: blending, molding, curing, and cubing. A Single production plant produces Fly Ash bricks, flat paver stones, and ornamental landscaping portions which includes garden edging, etc. The following steps are typically used to fabricate bricks:

- **Mixing** The sand is saved out of entryways in heaps and is moved into carport boxes withinside the plant through a mechanical transport line as they are required. The Portland cement and Fly Ash are kept in large silos to prevent dampness. As a manufacturing cycle begins, the predetermined quantity of sand, Fly Ash, and cement are moved through gravity or through mechanical ways to a weigh batcher, which estimates the correct quantity of each material. The dry substances at that point course a desk-bound blender wherein they are blended on the whole for various minutes.

There are types of blenders normally utilized. One kind, known as a planetary or dish blender, takes after a shallow container with a top. Blending forefronts are related to a vertical rotating shaft in the blender.

Figure 3.1.10: Mixer for mixing of proptionate material

The second kind is known as a horizontal drum mixer. It takes after a espresso can developed to become on its aspect and has mixing sharp edges associated with a level pivoting shaft in the blender. After the dry substances are combined, a small quantity of water is introduced to the mixer. The concrete is then blended for 6 to 8 minutes.

- **Molding**. Once the weight of concrete is very well blended, it's far unloaded into a willing pail transport and shipped to an all-inclusive hopper. The mixing cycle begins again for the resulting load. From the hopper, the material is passed on to second hopper on the apex of the block contraption at a deliberate go with the floating rate. In the brick contraption, aggregate is constrained descending Pre-Feasibility Study FLY ASH BRICK Manufacturing into molds. The molds envelop an external buildup compartment containing various mold liners. The liners decide the external form of the brick and the internal form of the brick cavities. 12 bricks are made at a time. When the molds are full, the material is compacted through the load of the top mildew head coming down on the mold cavities. This compaction can be enhanced through the air or pressure-driven strain chambers showing up on the form head. Most block machines also utilize a fast explosion of mechanical vibration to likewise helpful asset compaction. The compacted bricks are driven done for of the molds onto a level metal bed. The pallet and bricks are driven out of the gadget and onto a sequence conveyor. The bricks then skip beneath a rotating brush which gets rid of free cloth from the pinnacle of the bricks.

Figure 3.1.11: Brick molder

- **Curing.** The newly formed bricks are shifted to an automatic stacker or loader which transfer them to a curing rack. Curing is performed manually by making use of water or soaked in water. After soaking, the bricks are dried. For five to ten hours brick are dipped in water.

CHAPTER 4

RESULTS & ANALYSIS

4.1 Results

The accompanying outcomes were acquired from the testing:

Table 4.1: Compressive Strength Comparison

Compressive Strength Comparison			
Sr. No.	**Brick Designation**	**Area (in^2)**	**Compressive Strength (Psi)**
1.	CB-A	35.9	685
	“	36.1	623
	“	36.9	790
2.	CB-B	38.2	2600
	“	38.5	2533
	“	37.6	2151

3.	CB-C	37.2	1210
	“	36.9	970
	“	36.4	990
4.	CB-D	36.0	1914
	“	35.8	2530
	“	36.6	2125
5.	CB-E	36.2	1099
	“	37.1	1245
	“	36.8	1305
6.	FB-SSC	35.4	1655
	“	35.4	1370
	“	35.4	1552

Table 4.2: Water Absorption Comparison

Water Absorption Comparison			
Sr. No.	**Brick Designation**	**Area (in^2)**	**Water absorption %**
1.	CB-A	35.9	17.4
	"	36.1	16.1
	"	36.9	16.3
2.	CB-B	38.2	16.58
	"	38.5	15.4
	"	37.6	16.12
3.	CB-C	37.2	19.23
	"	36.9	19.6
	"	36.4	18.88
4.	CB-D	36.0	21.2

	“	35.8	21.9
	“	36.6	22.3
5.	CB-E	36.2	19.54
	“	37.1	19.7
	“	36.8	18.89
6.	FB-SSC	35.4	7.06
	“	35.4	6.55
	“	35.4	6.50

Table 4.3: Specific Gravity Comparison

Specific Gravity Comparison			
Sr. No.	**Brick Designation**	**Area (in^2)**	**Specific Gravity**
1.	CB-A	35.9	1.66
	“	36.1	1.63
	“	36.9	1.54
2.	CB-B	38.2	1.88
	“	38.5	1.86
	“	37.6	1.77
3.	CB-C	37.2	1.82
	“	36.9	1.79
	“	36.4	1.76
4.	CB-D	36.0	1.92

	“	35.8	1.77
	“	36.6	1.87
5.	CB-E	36.2	1.90
	“	37.1	1.96
	“	36.8	1.77
6.	FB-SSC	35.4	2.27
	“	35.4	2.26
	“	35.4	2.15

Price Comparison

Table 4.4: Price Comparison

Sr. No.	Brick Designation	Price Rs/Brick
1.	CB-A	8.00
2.	CB-B	15.50
3.	CB-C	10.50
4.	CB-D	14.00
5.	CB-E	12.00
6.	FB-SSC	10.00

Casted Samples Results

Table 4.5: Casted Samples Results

S No.	Brick Designation	Sample No.	Compressive strength psi	Water Absorption %	Specific Gravity	Price Rs/Brick
1.	FB-X	1	2140	8.10	2.11	10-11
		2	2025	7.06	2.08	
		3	1963	7.45	1.97	
2.	FB-Y	1	1870	7.12	1.94	9-10
		2	1922	7.04	1.83	
		3	1784	6.55	2.01	
.3.	FB-Z	1	1754	6.99	1.95	8-9
		2	1592	6.22	1.80	
		3	1647	6.47	1.79	

4.1.1 Assessment of Parameters

Five clay brick variants (CB-A, CB-B, CB-C, CB-D, CB-E) along with the commercially available fly ash brick (FB-SSC) were tested on the parameters of compressive strength, specific gravity, and water absorption. Moreover, the price of each brick was also estimated. Thereafter, three variants of fly ash bricks were prepared, mainly by changing the proportion of fly ash and cement, and tested against the same parameters. Details of the varying proportions for each variant are as follows:

- FB-X: Cast Fly Ash Brick 35% Fly Ash, 20% Cement
- FB-Y: Cast Fly Ash Brick 40% Fly Ash, 15% Cement
- FB-Z: Cast Fly Ash Brick 45% Fly Ash, 10% Cement

It was observed that with the increase in the flyash and reduction of cement, compressive strength was reduced due to decrease in cement content, moisture content also gets a slight reduction due to flyash being non porous and there is a decrease in specific gravity as well as flyash being light weight resulted in reduction iof weight.

4.1.2 Conclusions

Following conclusions are made:

Compressive Strength

As per (ASTM C62), the minimum compressive strength required for a brick is 1500 psi. Some of the available samples did not fulfill this criterion. However, compressive strengths of the three fly ash variants that were prepared did satisfy this minimum criterion.

Water Absorption

Recommended water absorption of the fly ash brick is between 6-12%. Water absorption in clay bricks was found to be way more than desired (15-22%). However, this criterion was satisfied both by the commercially available FB-SSC fly ash brick and the three fly ash brick variants that were prepared.

Specific Gravity

Less specific gravity for bricks, without compromising on other parameters, is always preferable for the structure. Upon testing, the Specific Gravity of the clay bricks was found to be between 1.54 – 1.9. Whereas for the commercially available FB-SSC fly ash brick it was 2.15 – 2.27. However, in the three fly ash variants that were prepared, their specific gravity was found to be less than that of SSC brick.

Comparison

One of the fly ash brick variants that was prepared with 45% fly ash and 10% cement, was observed to satisfy the following criteria:

- Compressive Strength: 1640 – 1750 psi
- Water Absorption: 6.22 – 6.99%
- Specific Gravity: 1.75 – 1.95

All the above-mentioned criteria have been fulfilled by FB-Z Cast Fly Ash Brick, especially specific gravity which was not being fulfilled by the commercially available FB-SSC brick in Rawalpindi. Additionally, its price range was already reduced in comparison to the other bricks

4.1.3 Recommendations

Therefore, FB-Z Cast Fly Ash Brick with improved specific gravity and price in addition to satisfying other parameters is recommended to be used in

- Load bearing walls
- Non-load bearing walls
- Can be utilized in Army projects where we generally require cost effective material
- Boundary walls
- Construction of high rise buildings e.g Marquees

4.1.4 Way forward

There is always a room for improvement and as far as flyash bricks are concerned,following measures can be taken:

- A more cost effective composition can be prepared by varying proportions of fly ash and cement
- Improved version of flyash brick can be prepared as far as mechanical properties are concerned
- Polymer added flyash brick can be prepared to get better results as far as its mechanical properties are concerned

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