A review of Literature on Flyash-Gypsum-Lime Bricks

CIA Project report submitted in partial fulfillment of S.Y. B.Tech. (Semester-I)
In

Structural Engineering

By

Prasad Aher

Snehal Aher

Omkar Dahale

Sanika Bombe

Under the Guidance of
Dr. N. S. Naik

DEPARTMENT OF STRUCTURAL ENGINEERING
SANJIVANI COLLEGE OF ENGINEERING
An Autonomous Institute

(Affiliated to Savitribai Phule Pune University, Pune)

Kopargaon-423603

Year 2023-24 (Semester-I)

SANJIVANI COLLEGE OF ENGINEERING

An Autonomous Institute
(Affiliated to Savitribai Phule Pune University, Pune)

DEPARTMENT OF STRUCTURAL ENGINEERING

CERTIFICATE

This is to certify that

1) Mr. Prasad Aher Registration No. UST22M1003

2) Miss Snehal Aher Registration No. UST22F1004

3) Mr. Omkar Dahale Registration No. UST22M1013

4) Miss Sanika Bombe Registration No. UST22F1010

Have satisfactorily carried out the work and completed the CIA project entitled A review of Literature on Flyash-Gypsum-Lime Bricks under my guidance. This work is being submitted for the partial fulfillment of S.Y. B.Tech. (Semester-I) in Structural Engineering.

Dr. N. S. Naik
Designation **Head of the Department**

DECLARATION

We hereby declare that the CIA Project entitled Use of Fly Ash, Lime and Gypsum in Bricks submitted, as CIA Project is original work.

Place: Kopargaon

Date:

Name	PRN
Prasad Aher	UST22M1003
Snehal Aher	UST22F1004
Omkar Dahale	UST22M1013
Sanika Bombe	UST22F1010

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LIST OF ABBREVIATIONS

FAL-G	Mixture of Fly Ash, Lime and Gypsum
OPC	Ordinary Portland Cement
PPC	Production Planning and control
FA	Fly Ash
RSP	Rourkela Steel Plant
FCM	Fly Ash Composite Materials
CaO	Calcium Oxide
CO2	Carbon Dioxide
SiO2	Silicon Dioxide
MPa	Mega Pascal
Ca	Calcium
Si	Silicon
SO3	Sulphur Trioxide
UCS	University of Southern California
CaSO4	Calcium Sulfate
FGDG	Flue Gas Desulfurization Gypsum
BA	Bottom Ash
NaOH	Sodium Hydroxide

FGD	Flue Gas Desulfurization
IKA	Initial Rate of Absorption
CSH	Calcium Silicate Hydrate
LC3	Limestone Calcined Clay Cement
ACC	Associated Cement Companies
CBR	California Bearing Ratio
PCC	Plain Cement Concrete
CLFBM	Cement Lime Fly Ash Bound Macadam
GGBS	Ground Granulated Blast-Furnace Slag
SEM	Structural Equation Modeling
$CaSO_4.2H_2O$	Gypsum
MCDM	Multi Criteria Decision Making
SFA	Sintered Fly Ash Aggregate
$Al_2(SO_4)_3$	Aluminium Sulphate
SCC	Self-Compacting Concrete
HVFASCC	High Volume Fly Ash Self-Compacting Concrete
EBF	Braced Frames
GP	Ground Plane
RCPT	Rapid Chloride Permeability Tests

ABSTRACT

In Structural Engineering traditionally we are using different materials in the form of building units. Some of the building units which we are commonly using for construction are bricks and concrete blocks Specially for bricks we have to use good plastic clay as primary raw material. This clay is often obtained from prime agricultural land, causing degradation as well as economic loss due to diversion of agricultural land for manufacture of bricks. For burnt clay bricks, burning is required after moulding. For bunt clay bricks coal is used as a fuel for burning of coal produces greenhouse gases as well as it results in significant local air pollution. This burnt clay brick industry in India produces over 200-250 billion clay bricks annually with strong impact on soil erosion and unprocessed emissions.

This dissertation report aims to research the ill effects of using traditional burnt clay bricks on environment needs a proper solution. To avoid the pollution, land degradation due to erosion of top layer of good agricultural land, utilisation of fly ash from thermal power stations, phosphogypsum from fertilizer industry and waste lime if available. All these materials are waste products from various industries and creating problems during their disposal. To make construction of wall easy, economical and eco-friendly with use of hollow interlocking Fal-G bricks. To reduce use of natural sand and cement, where cement is a product which emits 1 tonne of carbon dioxide after production of the tonne of cement. To check the feasibility of Fal-G as an alternative material for production of building materials particularly hollow interlocking bricks. The main constituents of Fal-G consist of three ingredients are i) Fly ash ii) Lime (Cement can be used if good lime is not available) iii) Phosphogypsum.

After getting good results of FaL-G material through testing, it has been decided to use Fal-G masonry for casting of Bricks. It results as best replacement solution for conventional bricks. Also, by reducing cement use and utilization of agricultural waste and thermal power plant waste i.e., Phosphogypsum and Fly Ash respectively, it provides Eco friendly solution, easy and economical construction instead of conventional bricks.

CHAPTER I

Introduction

1.1 Introduction

Material science is a complex composite, arising out of in-built judgment in orienting the characteristics and constituents of various products to serve the human race, and depending on the nature's gift, tapping the same for the applications of human needs. Traditionally people are using burnt clay bricks for construction. It is a clay product which proved its credence since the dawn of civilization. For production of bricks people are using good plastic clay as primary raw material. This clay is often obtained from prime agricultural land, causing land degradation as well as economic loss due to diversion of agricultural land. The nature's kind heartedness is gifting the human kind with its resources of course, has a threshold limit and the utilization of clay has reached such a point in construction. The result is evident through erosion of fertile soil. Soil degradation disturbance in ecology threatening the very rudimentary pillars of welfare.

Masonry brick is one of the oldest and important construction materials around the world. Brick was considered the main ground material in the ancient Egyptian, Roman, and Mesopotamian eras. The compressive strength and durability of the brick upon baking the clay had made it a valuable material that has been used in the construction of every building for thousands of years. The common and traditional processes to make brick includes mixing raw ingredients, grinding brick clogs, drying and baking them to achieve a certain compressive strength, or through using regular portland cement, resulting in the production of concrete blocks. The uncontrolled exploitation of ground soil materials resulted in extensive removal of raw materials and high energy intake. Therefore, there is a need to review the process of production and materials used for brick as a means to decrease environmental risks due to an increase in greenhouse gases. The cementitious bricks are a combination of cement and sand. Cement is also considered to be an anti- environmental substance in which quite a high volume of CO_2 is generated for its production.

A brick is a block or a single unit of a ceramic material used in a masonry construction. Typically, bricks are stacked together or laid as brick work using various kind of mortar to hold the bricks together and make a permanent structure. Asia produces 87% of the total production of bricks. Moreover, India and China are the major consumer countries of the bricks. Bricks are typically produced in common or standard sizes in bulk quantities. They have been regarded as one of the longest, lasting and strongest building material used in 20th century.

The standard size of brick provided by IS: 2212 (1991) is 19cm×9cm x 9cm. Bricks are laid in horizontal courses, sometimes dry and sometimes wet mortar. In some instances, such as adobe (a kind of clay used as a building material) brick is merely dried. More usually it is fired in a kiln of some sort to make a true ceramic. Clay bricks are used in a wide range of buildings from housing to factories, and in a construction of a tunnels, waterways, bridges, etc. Their properties vary according to purpose for which they are intended, but clays have provided the basic material of construction for centuries.

The main ingredients of bricks are clay, lime, magnesia, silica, alumina, iron oxide. So, the brick is produced on a larger scale where these ingredients are easily available. In order to satisfy the ever-increasing demand for the energy efficient building construction material there is a need to adopt cost effective, environmentally appropriate technologies and upgrade traditional techniques with available local materials. Hubli K. et al. [2018] discussed probable solution of this problem with using different materials like fly ash, black cotton soil, concrete blocks, agro waste, etc.

FaL-G (Fly ash: Lime: Gypsum) bricks offer a viable, energy efficient and environment friendly alternative. Fal-G technology can be used in plants with an annual brick production capacity from 3 million bricks (tiny sector) to 30 million bricks (mechanized sector). Fal-G bricks and blocks are alternative building materials to the traditional burnt clay bricks and are substitutes to the traditional burnt bricks used for construction. Production process of Fal-G bricks and blocks does not involve sintering. Thus, by substituting the burnt clay bricks, Fal-G bricks and blocks completely eliminates the burning of fossil fuels required in the clay brick production process and ultimately contributes to the reduction of greenhouse gas emissions. Since the FaL-G activity reduces greenhouse gas emissions, it has the potential to benefit from the emerging carbon market. Whereas the current annual production of fly ash worldwide is estimated around 600 million tonnes. The government of India took policies initiative for utilization and disposal of fly ash. In a tropical country like India the burnt clay brick is the most basic building material for construction of houses. It is reported that the requirement of bricks for construction activity amounts to be more than 140 billion number. To fulfil such demand Fal-G interlocking brick may be one of alternative for sustainable construction.

The burnt clay brick industry in India produces over 60 billion clay bricks annually with a strong impact on soil erosion and unprocessed emissions. For production of these bricks about 160 million tons of top soil, making barren 7500 acres of fertile land, with the ongoing activities of housing in developing countries like India, one could imagine the extent of damage to the earth. This is where innovations on alternatives to clay bricks have summoned the research and development work.

1.2 Introduction to Fal-G Technology.

Fal-G technology works with the strength of fly ash, lime and gypsum chemistry. The slow chemistry of fly ash and lime is maneuverer by tapping ettringite phase to its threshold limits through sufficient limit of gypsum. Therefore, Fal-G does not require heavy duty press or autoclave, which is otherwise required in case of only fly ash and lime.

The ingredients of the Fal-G bricks and blocks, fly ash, lime and gypsum are well known minerals that are widely used in industries. All these materials are available in the form of wastes and by-products from industrial activities. In certain areas where by-product lime is not available in adequate quantity, ordinary portland cement (OPC) is used as the source of lime producing the same quality of bricks and blocks. This technology is proved to be environmentally safe and sound.

The use of fly ash as a component of FaL-G mixture is based on its pozzolanic properties. A pozzolan is defined as "A siliceous and aluminous material which chemically reacts with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

The chemistry of fly ash-lime has its antecedents in civil engineering practices for the last two millennia. Most of the Roman constructions have been executed with pozzolana-lime mixes. The formulations in those days were based on empirical judgments in the absence of chemical engineering explanations. But the physical behaviors were judged as the basis to decide the quality of products. After the advent of ordinary portland cement (OPC), the concern to optimise pozzolana-lime chemistry was not felt much. Since the fall of 60s, whilst the confidence on OPC as the durable media has begun waning out, pozzolana-lime chemistry has again gained importance, ordinary portland cement being the source of lime. This is how PPC has emerged as a cement blend. In this background, Fal-G has made its presence felt, proving the factor of innovation in its composition through the optimised role of calcium alumino sulphate mineralogy.

FaL-G is the innovative cementitious binder that has the ability to offer structural concrete with sound microstructure properties. In simple terms, it is an extension of lime-pozzolanic binder by adding specified quantity of gypsum in order to tap the potential of calcium sulpho aluminate hydrates.

The studies on the hydrated phases of Fal G cementitious blend have shown hydrated mineralogy akin to OPC eventually resulting in water impervious matrix. While gypsum is the set- retarder and strength-accelerator in the case of OPC, it is both set accelerator and strength accelerator in the case of Fal-G. Wherever early strengths are required to FaL-G. OPC was added in minute quantities of 10-30%, which was identified as Portland: FaL-G.

1.2.1 What is great about Fal-G?

Sustainable development indicators are statistics that are used to measure social equity, economic growth, institutional capacity, and environmental protection to ascertain the different dimensions and levels of sustainable development.

Bhanumathidas N. and Kalidas N. [2007] discussed that the Fal-G is one of the rare technologies to serve all the indicators of sustainable development such as conservation of natural resources i.e. saves precious topsoil otherwise used for clay bricks, conservation of thermal energy and fossil fuels i.e., saves coal as no sintering is involved as practiced for clay bricks, environment friendly i.e. used the industrial by-products such as fly ash, lime and chemical gypsum, avoiding resultant pollution, employment generation i.e., provides yearlong employment, unlike clay bricks where the production activity is seasonal (November to May), with more scope in rural areas and at last appropriate and eco-friendly technology i.e., renders more durable products for housing and infrastructure applications with longer service life, conserving mineral and fiscal resources to the nation.

1.3 Constituents of FaL-G

The three materials used in the manufacturing of Fal-G are industrial wastes such as fly ash, lime and gypsum.

1.3.1 Fly Ash

Fly ash is a fine, glass powder recovered from the gases of burning coal during the production of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron.

The difference between fly ash and portland cement becomes apparent under a microscope. Fly ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures. That capability is one of the properties making fly ash a desirable admixture for concrete.

Fly ash is one of the residues generated in the combustion of coal, Fly ash is generally captured from the chimneys of coal-fired power plants, whereas bottom ash is removed from the bottom of the furnace. In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release Depending upon the source and makeup of the coal being burned, the components of the fly ash produced vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide. Fly ash is commonly used to supplement portland cement in concrete production, where it can bring both technological and economic benefits, and is increasingly finding use in the synthesis of geopolymers and zeolites was discussed by Chatterjee B. et al. [1999]

Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue. Boiler tubes extract heat from the boiler. cooling the flue gas and causing the molten mineral residue to harden and form ash, Coarse ash particles, referred to as bottom ash or slag, fall to the bottom of the combustion chamber, while the lighter fine ash particles, termed fly ash, remain suspended in the flue gas. Prior to exhausting the flue gas, fly ash is removed by particulate emission control devices, such as electrostatic precipitators or filter fabric baghouses.

In view of the very large amount of fly ash, utilization should be aimed at its large consumption. Coupled with economy rather than only considering the value of utilization in this context, utilization of fly ash in producing useful building components/elements can constitute a major thrust.

There are two types of fly ash which are normally used

a) Class C Fly Ash

Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike class F. self-cementing class C fly ash does not require an activator. Alkali and sulphate (SO4) contents are generally higher in class C fly ashes.

b) Class F Fly Ash

The burning of harder, older anthracite and bituminous coal typically produces class F fly ash. This fly ash is pozzolanic in nature, and contains less than 10% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of class F fly ash requires a cementing agent, such as portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. Alternatively, the addition of a chemical activator such as sodium silicate to a class F fly ash can lead to the formation of a geopolymer.

Figure 1.1 Fly Ash

1.3.2 Lime

Being a Pozzolana, fly ash reacts with lime to produce building components of building units.

However, in many regions of India, fly ash and lime are not available in mutual proximity. Due to high transportation charges, the final cost of the fly ash bricks manufactured compares unfavourably to that of burnt clay bricks. Therefore, there is no appreciable demand for these fly ash bricks and hence its use has not been commercialized to the desired extent to overcome this difficulty or problem use of waste lime instead of commercial lime is recommended. Waste lime available as a by-product from paper, fertilizer, petrochemical industries can be used to make building components like bricks of adequate strength. Through the use of waste lime instead of commercial lime an economic alternative to conventional burnt clay bricks will be made available. Lime sludge is a waste material in paper mills, fertilizer and acetylene industries The production of lime sludge is estimated to be 4.5 million tonnes per year. If this waste lime is used for production of building units, then problem of its disposal can be solved efficiently.

If by-product lime is not available in adequate quantity, ordinary Portland cement (O.P.C.) can be used as the source of lime

1.3.3 Gypsum (Phosphogypsum)

Gypsum is the third constituent material of FaL-G. Calcined gypsum is added in small percentage to the mix of lime and fly ash in order to impart strength to the products so that they can be handled easily. Chemically gypsum is a dehydrate of calcium sulphate ($CaSO4.0.5H_2O$) containing about six percentage of water of crystallization and called as calcined gypsum (which is also known as plaster of Paris). To reduce the cost of building units manufactured from Fal-G, instead of pure calcined gypsum, which is expensive, low grade calcined gypsum available as waste from industry can be used gypsum is another industrial waste used in Fal-G which is produced at a rate of 45 million tonnes per year in India fertilizers, phosphoric acid and hydrochloric acid industries produce this waste.

Figure 1.2 Phosphogypsum

1.4 Objectives of Project Work

Objective of this study is to study the literature available related to use of waste material for the preparation of bricks and to search new methodology for future work.

1.5 Presentation of Project Work

Forthcoming sections of this project focuses on the literature review in chapter 2 and chapter 3 describes conclusion of the study

1.6 Summary

In this chapter various constituents of Fal-G as well as the introductory part of clay brick, fly ash brick, FaL-G brick and draw backs or ill effects of using the traditional bricks for construction and the objective of this study is given. In the second chapter literature review is discuss.

CHAPTER 2

Literature Review

2.1 Introduction

A review of literature is carried out to identify the recent developments in the field of hollow interlocking brick, Fal-G masonry and related areas. The literature review is done on a wide variety of topics but only the topics relevant to the objectives of the present study are presented in this chapter. This chapter is broadly divided into four segments.

The first part of this chapter is devoted to the various researches related to the study of history of hollow interlocking bricks and self-alignment of interlocking. The second part deals with the structural properties of both burnt clay and fly ash brick masonry. The third part is devoted to literature available on the study of development of Fal-G bricks. The fourth part deals with working of FaL-G technology.

The use of fly ash in concrete was reported in early eighties. Fly ash is also being successfully used in making various types of bricks. The manufacturing cost is less and they possess better thermal insulation properties compared to conventional bricks. Yet even after a decade of extensive research there are still traces of uncertainties and doubts, casting a shadow over its future prospects.

Several studies have been reported on utilization of fly ash, by addition of lime and gypsum to produce building components such as bricks. Attempts have also been made to extent its use to make plain and reinforced concrete. Following section deals with review of research work done in the past.

2.2 Literature Review

(L.J. Minnick et al., 1974) studied lime fly-ash cementitious mixture with improved hardening and expansion characteristics and stated that a cementitious mixture made of fly ash and lime sulfate material, unlike traditional lime, hardens faster and has improved dimensional stability. This material can be made by adding sulfuric acid solution to quicklime or a separate sulfate compound like gypsum. The cementitious mixture can be used as a subsurface base material, soil stabilization agent, landfill, or in pre-stressed structural members. It can also be used in conjunction with filler material.

(M. Thomas et al., 1992) study on Maximizing Fly Ash Utilization in Concrete. The purpose of this book is to optimize the amount of fly ash used for a particular application by discussing the effects of fly ash on the characteristics of concrete. The ideal quantity of fly ash depends on a number of factors, including the application, the ratios and composition of each element in the concrete mixture, the setting during placement, the building methods, and the exposure circumstances. As a result, the ideal fly ash content will differ from situation to situation. If the project’s early-age strength requirements can be satisfied and sufficient moist-curing can be guaranteed, fly ash levels of up to 50% may be appropriate for the majority of the elements.

(A.Ghosh and C.Subbarao, 1998)studied Fly ash disposal on land is a problem, and recycling is a solution. Stabilizing low lime fly ash with lime and gypsum is effective in controlling hydraulic conductivity and leachate characteristics. Proper proportioning and curing can achieve hydraulic conductivity values of 10 cm/s. Concentrations of contaminants in effluent from mixes with higher lime or gypsum concentrations are below acceptable limits for groundwater.

(P.Ausset et al., 1999) studied to a simulation chamber exposed limestone samples to urban pollution in Europe for 12 months. The results showed that fly-ash emitted by heavy fuel combustion is highly reactive, resulting in crystal growth, particularly gypsum. Gypsum crystals were observed close proximity to fly-ash, anchoring them to the limestone surface. The study also revealed that the roughness of the limestone increases the development of the crust by trapping new particles. The study concluded that fly-ash plays a crucial role in the formation of sulphated black crusts in polluted environments.

(S.K. Malaviya et al., 1999) studied fly ash and came to know that it is an emerging alternative building material. They studied various applications of fly ash as building material such as lime / clay fly ash bricks, portland pozzolana cement, lightweight aggregates replacing the conventional building material to some extent. They concluded that the fly ash disposal can be usefully made if the local entrepreneurs, preferably from nearby thermal power plants, come forward to install brick making plants using fly ash.

(A.Ghosh and C.Subbarao ,2001) studied on examined the physicochemical and microstructural developments of low-lime fly ash modified with lime and gypsum. Results showed new peaks and a compact matrix with longer curing periods. The modified fly ash improved strength, durability, and reduced permeability. The Ca:Si ratio varied depending on the mix proportions and curing period. The modified material has potential for civil engineering construction.

(N. Bhanumathidas et al , 2001) discuss the Indian perspective on fly ash for bricks, cement, and concrete. India generates over 90 million tons of fly ash annually, with a 50% increase in usage over the last decade. However, the country faces high targets of 120 million tons per year in the coming decade, requiring aggressive promotional efforts. Indian fly ashes are one of the best in the world, but confidence in the country is low due to various reasons. The transition in Indian fly ash scenario is discussed in this paper.

(N. Bhanumathidas and N. Kalidas, 2004) studied the dual role of gypsum: Set retarder and strength accelerator. They studied gypsum, a small quantity of SO3 in cement, acts as a set regulator or retarder, maintaining workability and contributing to strength acceleration during early hydration stages and concluded that understanding cement chemistry and hydration chemistry is crucial for judicious gypsum dosage, as improper use can lead to disastrous results.

(Slobodanka Marinković et al , 2004) studied the manufacturing of building products is utilizing fly ash and FGD glycosum as raw materials. This study investigates the recycling of fly ash and FGD gypsum from power stations for building products. A ternary mixture of fly ash, lime, and calcined FGD gypsum was mixed with water to create a new product called FaL-G. The product's compressive strength, volume mass, and water absorption were determined after hardening for 28 days in ambient air. X-ray diffraction analysis revealed gypsum and portlandite as new phases in the hardened sample. The product's compressive strength increased after exposure to heating, cooling, and drying cycles, but decreased in the third case. Exposure to tap water during the drying-wetting cycle resulted in the loss of gypsum and portlandite, as these minerals are water-soluble.

(A. Basumajumdar et al., 2005) studied the reaction between fly ash and lime and stated that the reaction between fly ash (FA) and lime is used in building bricks, blocks, and aggregates. Different FA ratios were mixed with lime and compacted, treated with water and hydrothermal curing. The decrease in free lime content was measured, correlated to fly ash chemical composition. Mathematical relationships were developed between free lime content and lime binding modulus, and the rate of decrease in free CaO content was compared.

(A. Diouri et al., 2005) studied 12ortland composite cement with minor addition of fly ash stated that the 12ortland plant produces composite cements by intergrinding clinker, gypsum, and limestone with a minor addition of fly ash up to 10%. This reduces natural raw material consumption, saves fuel energy for clinker production, and significantly reduces CO2 emissions. The addition of fly ash acts as a grinding agent, reducing the time needed to achieve the same percentage of particles retained on an 80 μm sieve compared to cement without fly ash.

(A.Ghosh and C.Subbarao , 2006)studied the paper presents leaching test results for class F low lime fly ash stabilized with varying percentages of lime or gypsum. The results show that adding gypsum effectively reduces lime leaching from fly ash stabilized with lime. Factors like lime content, gypsum content, curing period, and flow period affect leaching. A model is also presented to estimate calcium leached from the compacted fly ash.

(A. Ghosh and C. Subbarao, 2006) studied tensile strength bearing ratio and slake durability of Class-F fly ash stabilized with lime and gypsum and stated that the the tensile strength, bearing ratio, and slake durability of a class F fly ash stabilized with lime or gypsum. It highlights the effects of lime content, gypsum content, and curing period on these characteristics. Unconfined compressive strength test results show medium durability at 28 days curing, with enhancement with longer curing periods. Empirical models are proposed to estimate these properties, suggesting the fly ash may be useful in civil engineering construction.

(M.K.Mishra and U.M.Karanam.Rao, 2006) studied developed four fly ash composite materials (FCMs) from fly ash obtained from a captive thermal unit of Rourkela Steel Plant (RSP). The composites showed significant increases in compressive strength after 56 days of curing time. The addition of lime and gypsum significantly contributed to the strength characteristics of the composites, without adverse effects on ground water quality. The fly ash composite has potential as an alternative to sand for backfilling mine voids.

(A. Ghosh and C. Subbarao, 2007) studied strength characteristics of Class F fly ash modified with lime and gypsum and stated that the shear strength characteristics of low lime class F fly ash modified with gypsum or lime. Results show that adding gypsum and lime enhances the fly ash's strength and cohesion, potentially useful in civil engineering construction fields. The study also suggests empirical relationships for design parameters.

(I.Demir and M.S.Baspinar, 2008) studied on The research examined the impact of pozzolan additions on fly ash-lime-gypsum mixture cement, revealing improvements in thermal conductivity, strength, and microstructure. The study found that silica fume replaced fly ash, silica fume improved pozzolanic reactions, perlite decreased bulk density, and simultaneous additions resulted in lower thermal conductivity.

(B Yilmaz and B. Civelekoglu, 2009) studied gypsum: an additive for stabilization of swelling clay soils and stated that the use of gypsum as a stabilizing agent for expansive clay soils, focusing on its potential to reduce ground movements and damage to low-rise buildings. The study found that gypsum can effectively improve the plasticity, swell percent, and strength parameters of treated and untreated samples, indicating its potential as a stabilizing agent for expansive clay soils. The study highlights the importance of considering moisture variations in geotechnical engineering.

Kumar Rakesh (2010) works on Fly ash characteristics for their efficient management and utilization . Mill tailings and fly ash are comparable in terms of their mineralogical composition and particle size. Nonetheless, the literature on using fly ash as a fill material directly isn't very extensive. Physico-chemical and strength properties have been the main focus of investigations into fly ash. Thus, the current study designs and conducts various experiments on the settling rate and hydraulic transportation aspects of fly ash using the literature that is currently available on the subject.

(Moghal A.A and Sivapullaiah P.V , 2010) studied role of gypsum in the strength development of fly ashes with lime and stated that the effect of gypsum on the strength development of two Class F fly ashes with different lime contents after curing them for different periods. The study found that the strength improved markedly up to a specific lime content, and the improvement continued for a longer period. Gypsum accelerates the gain in strength for lime-stabilized fly ashes, particularly during initial curing periods. It also improves the durability of stabilized fly ashes due to repeated cycles of wetting and drying.

(Alam J and Akhtar M.N , 2011) studied on Fly ash, a by-product from coal-based thermal power plants, has become a valuable resource material in India's civil engineering construction industry. Despite its potential for waste disposal and environmental pollution, fly ash has proven its worth over time. It is widely used in brick manufacturing, cement, asbestos-cement products, roads, agricultural crops, wastelands, and zeolites. Future applications may include heavy metal recovery, reclamation of wasteland, and floriculture. The future challenges lie in sound management of fly ash disposal and deposition technologies.

(P. Chindaprasirt et al., 2011) studied utilization of fly ash blends from pulverized coal and fluidized bed combustions in geopolymeric materials and stated that the use of fluidized bed combustion (FBC) fly ash as a geopolymer source, overcoming its low reactivity and high CaO and CaSO4 content, resulting in a high strength of 30.0 Mpa.

(A.Ghosh and C.Subbarao, 2011) studied on paper presents the deformation modulus of fly ash modified with lime alone or in combination with gypsum at different strain levels. The results show that with lime and gypsum, class F fly ash achieved a deformation modulus of 190 Mpa in the UCS test and up to 300 Mpa in the triaxial test under 0.4 Mpa pressure.

(S.P.Guleria and R.K.Dutta, 2011) studied on investigates the impact of treated tire chips on the unconfined compressive strength of a reference mix containing fly ash, lime, and gypsum. The results show that the unconfined compressive strength can be significantly improved by treating with carbon tetrachloride and sodium hydroxide. The increase in strength was highest with carbon tetrachloride treatment and was highest when cured in a water-filled container. However, the strength decreased with increased tire chip content.

(M.R.Alejandro et al., 2011) studied effect of fly ash and hemihydrate gypsum on the properties of unfired compressed clay bricks and stated that the impact of fly ash type F and hemihydrate gypsum on the mechanical and thermal properties of unfired compressed clay bricks, highlighting their potential for energy conservation.

(B.V.V Reddy and K.Gourav, 2011) studied on Lime-fly ash mixtures are used to manufacture fly ash bricks for load-bearing masonry. Lime-pozzolana reactions occur slowly under ambient temperature, requiring long curing durations. This study investigates the strength development in lime-fly ash compacts through low temperature steam curing and gypsum addition. Results show that strength increases with density, irrespective of lime content, curing type, and moulding water content. The optimum lime-fly ash ratio yields maximum strength at 0.75, and 24 hours of steam curing at 80C is sufficient for nearly possible maximum strength

(P.V.Sivapullaiah and M.A.Abaig, 2011)studied on Fly ash has potential for waste containment facilities as a base liners. However, its permeability ranges may not meet basic requirements. To reduce hydraulic conductivity, lime content up to 10% is added to fly ashes, and gypsum is investigated for further improvement. The addition of gypsum reduces hydraulic conductivity, increasing with lime content and curing period. This reduction in conductivity reduces the leachability of trace elements in fly ash, enhancing its potential as a liner material.

(B.V.V. Reddy and K. Gourav, 2011) studied strength of lime–fly ash compacts using different curing techniques and gypsum additives and stated that the strength development of lime-fly ash compacts using low temperature steam curing and gypsum additives. Results show that strength increases with density, irrespective of lime content, curing type, and moulding water content. The optimal lime-fly ash ratio yields maximum strength at 0.75, and 24 hours of steam curing at 80°C is sufficient. Using gypsum additive, lime-fly ash bricks can achieve strength over 10 Mpa at 28 days of normal wet burlap curing.

Dinil Pushpalal (2012) studied on examination of mongolian fly ash's adequacy for creating bricks for an eco-friendly future. The purpose of this study is to identify potential applications for Mongolian fly ash in brick production. One of the most essential building materials in Mongolia is brick. Brickmaking is a conventional, energy-intensive industry that uses a lot of subpar coal. Brick manufacturing is a very informal and unorganized industry in many countries, run by small private business owners who invest a small amount of capital to launch their venture. The main environmental issue with brick production is the smoke from burning coal. Although the amount of coal used depends greatly on the type of kiln, the burning process usually uses 100 g of coal for each brick.

(S.P Guleria and R.K.Dutta, 2012) study analyzed the optimum reference mix containing fly ash, lime, and gypsum for road sub bases. Results showed that adding gypsum did not affect dry unit weight or moisture content. The mix was mixed with dry/wet tire chips, revealing that tire chip content, curing period, and curing method significantly influenced the strength, energy absorption capacity, and cracking pattern.

(S.P Guleria and and R.K Dutta. 2012) studied effect of addition of tire chips on the unconfined compressive strength of flyash-lime-gypsum mixture and stated that the optimum reference mix of fly ash, lime, and gypsum for road sub bases. Results showed that tire chip content, curing period, and method significantly influence the mix's unconfined compressive strength, energy absorption capacity, and cracking pattern. Wet tire chips could be an eco-friendly material.

(J.M.Khatib et al., 2012) studied on research investigates the use of flue gas desulphurisation (FGD) in construction applications. It examines the porosity and pore size distribution of cement paste containing varying amounts of fly ash-gypsum blends as partial replacement of cement. Results show that increasing gypsum increases pore volume and pore structure, and unless the right amount is introduced, the total pore volume increases.

(N. Vamsi Mohan et al, 2012) studied the performance of rice husk ash bricks. The study investigates the use of rice husk ash for brick preparation, focusing on compressive strength, water absorption, and size and shape. The optimal proportion for (RH A + Clay) bricks was 30% RHA and 70% clay, with full replacement of clay resulting in higher strength after 28 days.

(P.V.Sivapullaiah and M.A.A.Baig., 2012) studied examines lime leachability in fly ashes under continuous leaching conditions. The study found that the ratio of lime leached to total lime added decreases with increased lime content, and significantly reduces in the presence of gypsum due to the formation of calcium silicate hydrate. The study also found a correlation between lime leachability ratio and geotechnical properties like soaked unconfined compressive strength, compressibility, and hydraulic conductivity.

(M.N. Akhtar et al., 2013) does the study of fibre reinforced fly ash lime stone dust bricks with glass powder and stated that the use of fly ash as a material for making fly ash reinforced bricks, revealing that compressive strength increases linearly with sand and plastic fiber combination, reaching maximum strength at 25%.

(Alaa .A. Shakir et al, 2013) discusses the development of bricks from waste material. Alaa.A.Shakir et al The increasing demand for building materials in the last decade has led to a chronic shortage of materials. Civil engineers are challenged to convert waste into useful building materials. Recycling waste can help conserve natural resources, improve population health, and reduce waste disposal costs. This paper reviews waste material recycling in brick production, providing potential and sustainable solutions.

(T. Banu et al., 2013) studied the fly ash-sand-lime bricks with gypsum addition. The study investigates the production of light weight structural bricks using coal fly ash from Barapukuria Thermal Power Plant. The optimum mix of fly ash, sand, hydrated lime, and gypsum was found, with the bricks exhibiting good quality under various brick forming pressures and concluded that fly ash-sand-limegypsum unfired bricks have the optimum composition of fly-ash (55%), sand (30%), lime (15%), and gypsum (14%). The bricks exhibit properties like no shrinkage, unit volume weight, initial rate of absorption (IRA), absorption capacity, apparent porosity, open pore volume, and maximum strength.

(G. Saravanan et al , 2013) discusses the current state of the art in the use of flyash-based geopolymer concrete. Concrete usage is second only to water worldwide, with Portland Cement (OPC) being the primary binder. However, the production of OPC releases 600 kg of carbon dioxide and requires only a third of the energy required to produce it. The abundant availability of fly ash offers an alternative, using fly ash and aggregates mixed with alkaline liquids like Sodium Silicate and Sodium Hydroxide. The United Nations' Intergovernmental Panel on Climate Change (IPCC) report on global warming emphasized the importance of unintentional CO2 emissions. Disposal of fly ash saves land and reduces cement consumption, reducing CO2 emissions. Researchers have been working on geopolymer cement and concrete for ten years, and 102 papers have been reviewed on its ingredients and technology.

(S.P.Guleria and R.K.Dutta, 2013) studied on investigates the behavior of fly ash-lime-gypsum composite mixed with treated tire chips. The tire chip content was varied from 5% to 15% and curing periods ranged from 7 to 180 days. The results show that the stress-strain behavior, strength characteristics, initial tangent modulus, ultimate strength, and secant modulus of the composite are influenced by various factors. The material has potential applications in road pavements with light traffic. The study concludes that this composite could be a promising alternative.

(M. Sadique et al., 2013) studied mechano-chemical activation of high-Ca fly ash by cement free blending and gypsum aided grinding and stated that the pozzolanic reactivity of calcium-rich fly ash blended with alkali sulphate and silica fume in a cement-free system, revealing its potential as a new cementitious material.

(Zifang XU. Et al., 2013) studied experimental study on hydration mechanism of lime-gypsum fly ash cement paste and stated that fly ash lime gypsum cement paste's setting time, hydration heat, and compressive strength using various techniques. Results show weak early hydrating capacity, but long-term durability, with increased fly ash replacement.

(R. Kumar et al., 2014) studied the properties of light weight fly ash bricks and stated the behavior of fly ash bricks by varying the proportions of fly ash, cement, lime, gypsum, and sand. Three types of bricks were designed with varying cement percentages, and various tests were conducted to compare them with conventional bricks. The study found that fly ash bricks with 5% cement had a 40% higher compressive strength than class I conventional bricks.

(S. Maity et al., 2014) studied pilot scale manufacture of limestone calcined clay cement and stated that a new type of ternary blend cement, containing 50% clinker, 30% calcined clay, 15% crushed limestone, and 5% gypsum (LC3), was pilot produced in India. The raw materials were readily available, and the cement was calcined in static kilns. The blends were tested in a laboratory, and building materials were produced using the cement, demonstrating its viability and robustness.

Naik N.S et al. (2014) works on the Power and Sturdiness of Gypsum, Fly Ash, and Cement Bricks. India's traditional building material for homes is burned clay brick, which is utilized both in rural and urban areas. These bricks are made from high-quality plastic clay that is harvested from agricultural land. Overuse of this clay on agricultural land causes loss of healthy, fertile soil and redirects agricultural land to brick production. Bricks had to be burned with coal in order to be manufactured. The study revealed that fly ash bricks are a viable substitute for traditional bricks that can be utilized in their place.

(V. Sahu and V. Gayathri, 2014) studied the use of fly ash and lime sludge as partial replacement of cement in mortar and explores that the increasing demand for drinking water and power in India has led to the generation of water treatment plant residue and thermal power plant by-products like fly ash. This study explores the use of fly ash and water softening sludge in mortar, using two types of mortar with four binder combinations. The study discusses the effect of various combinations on strength and outlines the composition of the composite material, preparation method, testing procedure, and results

Asokan Pappu (2015) studied on Advances in Fortified Glossy Finish Polymer Composites with Coal Ash Particulates Lately .This paper presents a recent study on the recycling of coal ash for the production of glossy finish composites that meet required specifications. Coal ash particles can be used in the formulation of these composites either with or without fiber reinforcement in a polymeric system, as fillers, additives, and surface-finishing agents. With roughly 50% coal ash and epoxy resin, the composites show tensile strength and modulus of 30.45 ,3.52 MPa and 4.7 0.0476 GPa, respectively, and a lower tensile elongation of 0.7 0.0912%. The created composites are: (i) more resilient than plastic and wood; (ii) self-extinguishing in the event of fire; (iv) more economical and maintenance-free.

(P. Valdez ,et al 2015) impact of CO2 curing in activated fly ash- cement masonary units in portland. The strength requirements of the Mexican standard specification are met by concrete masonry blocks made with ternary blended cementitious mixtures and cement dosages that are 40% lower than those of typical mixtures. Lime was added, which helped the masonry units' compressive strength to be restored. Compressive strength increased for both reference masonry units and masonry units made with binary and ternary cementitious systems as a result of CO2 curing. In terms of sustainability, the use of steam and CO2 curing together during the production of concrete masonry represents a technologically advanced method of sequestering CO2 without negatively affecting compressive strength.

Senthil Kumar studied on properties of geopolymer eco bricks (2015),The goal of the current study is to examine the durability and behavior of fly ash-based geopolymer eco bricks. Bricks measuring 200 x 200 x 400 mm were used. Fly ash was added to river sand and eco-sand (silica sand) in bricks at a weight ratio of 1:2.5. The alkaline activators in question were sodium fume solution. NaOH solution is the binder solution, with a 1:2.5 ratio. Based on the literature that was available, the ideal water-to-binder ratio of 0.416 was chosen. The ratio of solution (NaOH and water) to fly ash is known as the "water/binder ratio." In this study, bricks will be cured in the ambient environment.

8 (Shruti Mutkekar et al, 2015) studied the Flyash is being explored as a sustainable alternative building material for low-cost housing. Shruti Mutkekar et al This paper explores the use of

flyash as a sustainable and low-cost alternative to traditional building materials like burnt clay brick, cement, and steel in developing countries, offering advantages where traditional materials are costly and environmentally harmful.

(V. Chakradhar et al., 2016) studied fly ash in hydraulic barriers in landfills and stated that the potential of fly ash as a reactive material for landfill liners, examining its behavior and potential reduction in hydraulic conductivity with additives.

(M. Gunasekaran et al., 2016) studied development of light weight concrete by using autoclaved aerated concrete and stated that the use of autoclaved aerated concrete, a lightweight, versatile material, replacing natural sand with fly ash, and analyzing its properties for 24-hour steam curing.

(K. Archaneswar Kumar et al, 2016) conducted an experimental investigation on the presence of fly ash and lime sludge in cement mortar. A study investigates the impact of lime sludge and fly ash on cement mortar. Lime sludge, a by-product of water treatment plants and coal thermal power plants, is a significant cost in water treatment. The research demonstrates the potential of using fly ash and lime sludge as partial replacements in cement mortar. The study found that compressive strength decreases as the percentage of lime sludge increases in cement mortar compared to controlled concrete. This suggests that using fly ash and lime sludge together as partial replacements could be a sustainable solution for waste management.

(V.Kaushal and S.P Guleria, 2016) studied on investigates a composite mix of fly ash-lime-gypsum reinforced with jute fibres. The fly ash was sourced from ACC Cement Plant, and jute fibres were added in proportions of 5% to 10%. Split tensile tests were conducted for 28 days, and X-Ray Diffraction analysis revealed that the composite material increased with jute fibers. The study also found that the tensile strength increased with the addition of jute fibers, and the intensity of jute fibers increased with the curing method.

(P. Velumani et al, 2016) studied an Original Method for Assessing the Performance of Fly Ash Bricks with Sludge Incorporated .India's economy, which is renowned for its industries and agriculture, saw a new chapter in its growth during the Industrial Revolution. One of the important sectors, the textile industry, has grown significantly both in Tamil Nadu and across India. In order to enhance large-scale textile production, the Indian government has allocated seven hundred crore rupees for the development of textiles in its twelfth five-year plan, which runs from 2012 to 2017. The largest production operations require that effluents be treated either individually or collaboratively by companies. It seems that large amounts of sludge are produced during the treatment of textile effluents. This presents a problem for getting rid of it.

(P. L. Naktode et al., 2016) studied optimization of lime-fly ash mix and stated that high-grade cements have disadvantages like shrinkage, brittleness, leakage, porosity, and less durability. To address these issues, a combination of old and new technologies is needed, such as pozzolanic material and fly ash.

(V. Sahu et al., 2016) studied effect of lime and gypsum on engineering properties of Badarpur fly ash and stated that the performance of Badarpur fly ash stabilized with lime and gypsum, revealing the highest strength mix. The composite exhibited improved strength over time, making it suitable for road construction.

(A. Shetkar et al., 2016) does experimental studies on fly ash based lime bricks and stated that fly ash bricks, lighter and stronger than common clay bricks, can be used in building construction due to their environmental benefits. This paper discusses the technology of making FaL-G mortar compressed bricks using low-calcium dry fly ash, using quarry dust and sand as sustainable materials.

(Sudharsan N, Palanisamy T , 2016) The feasibility of utilising leftover glass powder in fly ash bricks was investigated experimentally by scientists N. Sudharsan and T. Palanisamy. Fly ash is substituted with glass powder in this investigation. Bricks made of fly ash were cast in two varieties. The ready-made bricks are dried at room temperature for 28 days after being cured for 7 days. The results of the test demonstrate the brick's compressive strength after boron and soda were replaced by 20%.The study revealed that the amount of glass garbage that is dumped on the ground in order to shield the environment from dangerous

(Nitin et al., 2017) investigated on fly ash-lime-gypsum mix mixed with stone dust and stated that the potential of using stone quarry dust and fly-ash bye-products to enhance the strength of composite materials, addressing environmental issues like air pollution and health hazards.

Vinayak Kaushal and S. P. Guleria (2016) studied the Investigation into tensile strength and mineralogical behavior of fly ash-lime-gypsum composite reinforced with jute fibres. According to the study, adding jute fibers to the fly ash, lime, and gypsum composite mix improved its split tensile strength test results. When utilizing the burlap curing method as opposed to the self-curing method, a noticeable increase in split tensile strength was noted. Furthermore, after 28 days of curing in the flyash, lime, and gypsum mix, the addition of 8% of 20mm size jute fibers increased the split tensile strength the highest. The derived composite material may find application in the building sector as a building material. In this sense, waste materials will also be used in an environmentally friendly way.

Hanifi Binici and Orhan Aksogan (2017) studied on Manufacturing of insulation material from fly ash, pumice, perlite, barite, cement, and gypsum as well as fibers from onion and peanut shells. This study investigates the suitability of peanut shell fibers, onion skin, fly ash, pumice, perlite, barite, cement, and gypsum as insulators. The produced samples' apparent specific gravities, flexural and compressive strengths, and rates of water absorption were all measured. Additionally, values for radioactive relative permeability, thermal conductivity, and the ultrasonic sound penetration coefficient were examined. Because of its increased thermal conductivity, this composite can therefore be used in a variety of settings. It is particularly useful as a coating material in offices where radiation exposure is frequent.

(V.Sahu et al., 2017)studied on explores the use of industrial waste materials like fly ash and lime sludge in Civil Engineering construction applications. The composite, stabilized with lime and gypsum, was tested for strength, durability, and resistance to heavy metal leaching. The composite was found to be durable and suitable for base course layer materials in flexible pavements. The study suggests a reliability-based approach for pavement design and reduces environmental hazards caused by waste disposal.

Arun Reddy Thumma (2017) investigate the most expensive binding substance is commonly acknowledged to be cement. Because gypsum performs well in terms of compressive strength, the study indicates that it may be utilised as a cement substitute. With the casting and 28-day testing of the specimens, the current work seeks to understand the strength characteristics. The study revealed that strength rise in proportion to the lime concentration; however, the strength increases more from 5% to 10% and less.

(Anurag Saraogi et al, 2018) The construction of a building using fly ash is a common method. The study aims to investigate the strength and economy of fly ash bricks compared to cement.

Experiments will be conducted to understand the properties of sand bricks and fly ash mortar, as well as the effect of different binding material percentages on mortar components.

(K. Sherin et al , 2018) discusses the advantages and disadvantages of autoclaved aerated concrete. Lightweight concrete blocks, with foaming agents, offer higher strength, better tensile strain carrying capacity, lower thermal expansion, and better heat and sound insulation. Autoclaved Aerated Concrete (AAC) blocks are a green building material in India, used as a substitute for traditional red clay bricks in residential, commercial, and industrial construction. AAC blocks are eco-friendly, manufactured using 60-65% fly ash, and require less surface treatment.

Raghunathan et al. (2018)observed A Fundamental Investigation of Fly Ash Lime Gypsum Composite Using Sodium Silicate and Sodium Carbonate as Admixtures We have investigated the characteristics of Fly Ash-Lime-Gypsum (FAL-G) composite in this article, with additions of sodium silicate and carbonate at different percentages (1%, 3%, 5%, 7%, and 9%). Liquid 30%, fly ash 65%, and gypsum 5% make up FAL-G’s components. The study revealed that Sodium carbonate performs exceptionally well as an additive to FAL-G, according to the observations.

(S.V. Giri Babu et al , 2018) studied on the manufacturing process of eco-friendly brick. Bricks, the oldest building material in the construction industry, have become a popular masonry unit due to their increasing demand. India, the second-largest brick manufacturer globally, produces over 250 billion bricks annually using traditional methods. However, these methods consume a significant amount of fertile soil and coal, leading to environmental concerns. Alternatives like recycling waste materials like fly ash, marble sludge, granite sludge, stone sludge, ceramic sludge, plastic, coal, and wheat husk can be used instead of fertile clay. This paper reviews the potential and sustainable use of waste materials in brick manufacturing.

Yuanyuan et al. (2018) study on The Process of Cement and Fly Ash Solidification in Contaminated Soil. The study material was determined to be man-made contaminated soil, which was then solidified using a curing agent—a cement and fly ash mixture. The soil will result in exposed overhead structures upon compression and have reduced strength and stability if a curing agent is not added. The study revealed that its strength is also significantly increased, but the manner in which the original soil particles are connected to the fly ash-cement curing agent changes. In addition, the effects of various curing agents on the soil differ.

Deshpande et al. (2019) studied the possibility of use of lime and gypsum in fly ash bricks. The study revealed that the bricks prepared using fly ash, lime and gypsum are not only economical but have good compressive strength and environmental friendly

(C. Ju et al., 2019) studied cement-lime-fly ash bound macadam pavement base material with enhanced early-age strength and suppressed drying shrinkage via incorporation of slag and gypsum a new pavement base material, CLFBM, incorporating Portland cement, dihydrate gypsum, and GGBS. The mix proportion was optimized for better mechanical properties and lowest drying shrinkage. The study found that the optimal mix proportion was Portland cement: dihydrate gypsum: lime: fly ash: GGBS: gravels. SEM results confirmed the formation of ettringite and C-S-H gels, enhancing early-age strength and suppressing drying shrinkage.

Md. Ruhul Amin et al. (2019) performed experiment on stresses in Fly Ash Brick with Various Lime, Cement, Gypsum, Sand and Stone Dust Ratios. The weight and kind of bricks used in a structure determine its dead load. These days, flyash bricks are more common because they are stronger and weigh 28% less than clay bricks. The strength is twenty-five percent greater than ordinary bricks. The study revealed that the strength of fly ash bricks using various material proportions, as well as to increase compressive stress and ascertain the bricks' stability and durability.

Aadil Yousuf et al. (2020) investigate on a overview of the Production and Use of Fly Ash in India Fly ash, which is mostly obtained from coal-based power plants, is the fine particulate residue left over after burning pulverized coal. This paper provides a brief overview of the composition, production, and utilization with particular emphasis on India. Additionally, a number of options for the efficient use of fly ash in the construction, agricultural, and geotechnical engineering sectors have been presented.

Shrihari et al. (2020) conducted experiment on lime and silica fume are added to high volume fly ash self-compacting concrete. By substituting a larger percentage of fly ash—a free and readily available material—for cement, it is hoped to create low-cost SCC. In addition, fly ash and micro silica, which is essentially condensed silica fume, can be utilized simultaneously to produce higher grade HVFASCC and improve the material's strength characteristics. When we use less cement, there is less calcium hydroxide available, necessitating the external addition of hydrated lime, which is available as an additive to meet the calcium hydroxide needs of the reactive silica in fly ash.

Nina Morozova and Galina Kuznetsova (2020) works on A quick-extinguishing lime addition for autoclaved aerated concrete. Aerated concrete production will quickly extinguish lime if it is scheduled to occur concurrently with silicate brick manufacturing. The research also demonstrates that autoclaved concrete has a stronger consistency and a shorter cement setting time. In order to increase the application of quick-extinguishing lime, decrease the water requirement of the mixture without compromising mobility, and boost the final product's strength, a complex additive based on the waste of silicate brick, plasticizer, and gypsum stone has been proposed.

(A.A.B. Moghal et al., 2020) studied on investigates the use of fly ashes for civil engineering applications, focusing on improving geotechnical properties. A multi-criteria approach was used to select the right mix of lime and gypsum for specific applications. The study found that combining lime dosage with gypsum is essential for pavement and liner applications. The MCDM model, based on PROMETHEE and GAIA, was used to identify fly ash types and the appropriate mix of lime and gypsum.

Dr. Ashad Ullah Qureshi (2020) compressive strength of fly ash by using lime gypsum and quarry dust. The masonry structure is dependent on properties like bricks unit and mortal separate and together as unit. The study revealed that mean value of material properties underestimates the structure capacity.

Ray et al. (2020) conduct investigation to enhance this subgrade material by adding fly ash as the primary additive. Two broad sets of samples were combined, one consisting of a mixture of moorum, silver sand, fly ash mix, and stabilizer and the other of a mixture of moorum, silver sand, and soil mix without fly ash and stabilizer. To look into the effects of adding these stabilizers and determine if it enhances pavement subgrade material performance Both kinds of soil samples have undergone Proctor, CBR, and UCS testing. The study revealed that a high correlation coefficient means that the CBR value can be accurately predicted using the findings of the UCS test.

(S.D Khadkaa et al., 2020) studied on This study investigates the effectiveness of two geopolymers synthesized from aluminosilicate sources, fly ash and metakaolin, in stabilizing shrink-swell behavior in high sulfate expansive soil. The geopolymers were modified with lime and gypsum to reduce swell potential and prevent ettringite formation. The study found that the concentration of additives incorporated into the geopolymer affects the behavior of the synthesized geopolymer. Gypsum modified geopolymer was more effective in controlling swelling and reducing swell.

(T. Wang et al., 2020) studied development of green binder systems based on flue gas desulfurization gypsum and fly ash incorporating slag or steel slag powders and stated that the use of flue gas desulfurization gypsum and fly ash as green binder materials. It examines the effects of mineral additions, chemical additives, and optimal mixes on mechanical strengths. The results show that mineral additions improve compressive strengths, and the SFA system with $Al2(SO4)3$ may compensate for shrinkage.

(B N Mohapatra et al , 2021) studied impact of clinker's bogue potential phases on the mechanical strength of fly ash-based limestone. The demand for cement is expected to rise from its current level of production of over 4.2 billion tons to approximately 4.8 billion tons by 2030 and 6.0 billion tons annually by 2050 due to infrastructural requirements and continuous population growth [1]. Sustainable development also calls for the prudent use of natural resources, particularly limestone, and the reduction of carbon and energy footprints. Consequently, in an effort to reduce the environmental impact of cement production, the cement industries have been using fly ash, granulated blast furnace slag, limestone, and other alternative cementitious materials in place of Portland cement over the years.

(N.Gahukar et al., 2021) studied stabilization of lime and fly ash mortor with the help of additives and stated that the stabilization of lime and fly ash mortar for modern construction, aiming to reduce flaws and achieve strong, usable mortar for modern structures.

(Harsimranjit Singh, et al 2021) , study the An Experimental Study of Bricks Made with Different Mineral Additives, To meet the demands of an expanding population in the residential and commercial sectors, a large quantity of bricks is needed. Traditional bricks are used at a very high rate due to general development and industrial development. The conventional bricks are ,It is almost at the end of its useful life because it is mostly composed of clay. The urgent need is to standardize its broad, use, and find its auxiliary one.

(J. James et al., 2021) studied lime activated fly ash phosphogypsum blend as a low cost alternative binder and stated that the use of a blended binder made from phosphogypsum and fly ash in combination with lime. The mixture was tested in three proportions, and the minimum lime content was determined. The resulting blends were cast into cubes and cured for seven days. The strength of the resulting masonry prisms was evaluated, and the optimal proportion was found to be 5% lime mixed with fly ash:phosphogypsum. The X-ray diffraction analysis revealed the formation of calcium silicate hydrate minerals and ettringite.

Lalith Kumar and Manpreet Saini (2022) studied initial research on creating lightweight concrete blocks with rice husk ash brick is the most often used building material. Finding workable solutions for sustainable construction is made easier by comparing the price, energy usage, and carbon emission factors of conventional and non-conventional materials. An environmentally friendly option for building construction is the Autoclaved Aerated Concrete (AAC) block. It can weigh only 25% of the weight of conventional building materials. AAC is composed of easily obtainable basic ingredients such as sand, cement, lime, fly ash, gypsum, and aluminum powder, along with water.

(B.S.Sidhu et al., 2022) studied the use of flyash-lime-gypsum (FaLG) bricks in the storage facilities for low level nuclear waste. They studied In this new method, the calculations of G.P fitting parameters are not required and concluded that EBFs of FaLG samples have been calculated for energy range.

Khan Shahzad and Uzair Amjad (2022) studied on mechanical properties evaluation of simbri fly ash bricks .The basic building materials in Pakistan are regular clay bricks. In addition to destroying rich and fertile land during the burning process, these bricks pollute the air when they are constructed. By using fly ash and bottom ash with cement, bricks can be made at a lower cost and in some ways address environmental and ecological issues. This study aimed to assess the basic mechanical characteristics of fly ash bricks made in the area. In order to do this, the diagonal shear strength of SIMBRI was tested on five brick prism samples, each measuring four feet by four feet. Three samples of fly ash bricks, each measuring eighteen inches by eighteen inches, were evaluated and their compressive strength was tested.

Somnath Maurya and Kuldeep Kumar(2022) studied on ,Fly Ash in construction as an alternative resource. The waste product produced when coal is burned in furnaces is called fly ash. Given that India has some of the world's largest coal reserves, the availability of fly ash is significant there. Indian coal has a low calorific value and a high ash content. In India, approximately 73% of power plants are thermal in nature, and 90% of those are coal-fired. Fly ash was considered waste worldwide until a decade ago, but it is now recognized as a potential environmental protector. These plants produce a significant amount of fly ash, which can potentially be recycled with other building materials.

(B.N.Mohapatra et al., 2023) studied on investigates the use of Portland composite cement (PCC) in concrete mix design. Three compositions were prepared by inter-grinding clinker, gypsum, flyash, and limestone. The study found that with limited limestone addition, early and later age compressive strength increased marginally. However, the durability aspect was influenced by limestone addition. The study also found that the dilution effect of limestone dominates over other physical effects, leading to an overall increase in effective water-cement ratio. The carbonation depth and sulphate resistance of PCC blends were found to be lower than control mixes.

Narain Sunita and Vinay Trivedi (2023) works on available limestone for flue gas desulfurization and the use of gypsum. Flue gas desulphurization (FGD) systems will be installed in a significant number of India’s coal-based thermal power plants by 2022 in order to comply with newly announced government emission standards from 2015. A crucial component of most FGD systems designed to reduce sulfur dioxide (SO2) emissions is limestone. The study revealed that the use of FGD gypsum, a by-product of FGD, as well as the availability of limestone for FGD.

CHAPTER 3

CONCLUSION

3.1 Conclusion

After studying the literature available, following conclusions can be drawn.

- There are so many ill effects of using conventional burnt clay bricks on the environment.
- The environmental pollution due to traditional burnt clay bricks can be checked through using alternative for the bricks.
- A good alternative for the burnt clay bricks is fly ash bricks.
- Gypsum can be used along with fly ash for bricks as it is a waste material from fertilizer industry, its use can control the untreated disposal of gypsum.
- There is a scope to use lime along with fly ash for the manufacturing of bricks.
- Fal-G bricks plants can be established in the vicinity of the thermal power plants and it will result in employment to the local labour.

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ACKWNOWLEDGEMENT

We would like to express our heartfelt gratitude to the following individuals and entities whose support and inspiration have been instrumental in bringing this project on A review of Literature on Flyash-Gypsum-Lime Bricks to fruition: -

Special thanks to Dr. N.S. Naik for their collaborative spirit and unwavering commitment to our shared vision. Their diverse perspectives and contributions have added depth and nuance to the topic fly ash, lime and gypsum as an alternative for clay bricks

We extend our appreciation to Sanjivani Collage of Engineering, Kopargoan for providing resources, research facilities, and a supportive environment that enabled the development of this project.

This endeavour would not have been possible without the collective efforts and encouragement of these remarkable individuals and organizations. We are truly grateful for their support in promoting a deeper understanding of fly ash, lime and gypsum as an alternative for clay bricks