

**A STUDY OF CONCRETE WITH PARTIAL
REPLACEMENT OF FAL-G BINDERS FOR CEMENT
AND RECYCLED CONCRETE FOR COARSE
AGGREGATE**

Submitted in partial fulfillment of the requirements for the award of
Master of Engineering Degree in Structural Engineering

by

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**DEPARTMENT OF CIVIL ENGINEERING
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **C.R.Ponnusankar (Reg No: 41380012)** who carried out the project entitled “ **A Study on Concrete with Partial Replacement of FAL-G Binders for Cement and Recycled Concrete for Coarse Aggregate**” under our supervision from December 2022 to May 2023.

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05/05/2023

Submitted for Viva voce Examination held on _____

Internal Examiner

External Examiner

DECLARATION

I **C.R.Ponnusankar (41380012)** ,here by declare that the Project Report entitled “**A Study on Concrete with Partial Replacement of FAL-G Binders for Cement and Recycled Concrete for Coarse Aggregate**” ,done under the guidance of **Dr.S.Packialakshmi** is submitted in partial fulfillment of the requirements for the award of Master of Engineering degree in Structural Engineering.

DATE : 05-05-2023

PLACE : Chennai



SIGNATURE OF THE CANDIDATE

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ABSTRACT

In this project Fly ash-Lime-Gypsum (FaL-G) binder has been used as a binder to partially replace OPC and studies have been carried out for physical, mechanical and other relevant properties with recycled concrete as aggregate partially replaced with normal aggregate. As one kind of solid waste produced during demolition of concrete structure

The results will be compared with conventional concrete and 30% of FAL-G binder and 25% recycled concrete as aggregate. FAL-G binder means fly ash-lime-gypsum binder Which are all a sort of waste materials or byproducts produced during manufacturing products and utilities.

So, this concrete is a green concrete which replaces OPC and recycled concrete for aggregate which is a waste produced during demolition of concrete structure. This can help to meet the unavailability of minerals which are a non - renewable resources and gets reduced day by day.

From the results we get we can conclude that adding 25% recycled aggregate in concrete produce similar strength like conventional concrete.

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LIST OF ABBREVIATION

FAL-G	Fly ash - lime - concrete
FRC	Fiber Reinforced concrete
SFRC	Steel Fiber Reinforced Concrete
RCA	Recycled concrete Aggregates
FA	Fine Aggregate
CA	Coarse Aggregate
LP	Lime Powder
RE	Recycled aggregate

CHAPTER 1

1 INTRODUCTION

1.1 GENERAL INTRODUCTION

. Coal combustion residuals (CCRs), commonly referred to as coal ash, fly ash, flue ash, or pulverised fuel ash (in the UK), are fine particles that are produced when coal is burned in boilers. These particles are released into the atmosphere with the flue gases. The ash that accumulates at the bottom of the boiler's combustion chamber is called bottom ash or firebox ash. In modern coal-fired power plants, fly ash is typically collected using electrostatic precipitators or other particle filtration equipment before the flue gases are released through the chimneys. The combination of fly ash and bottom ash is commonly known as coal ash.

.Plaster and mortar have historically been manufactured using lime, which is commonly produced through the burning of limestone. Chemically, lime is composed of calcium oxide (CaO), which is generated through the calcination of calcite (CaCO_3) to eliminate carbon dioxide (CO_2). Lime is also referred to as calx or quicklime, and the latter is particularly hazardous due to its high alkalinity, which can even lead to the dissolution of human tissue.

Gypsum is a soft sulfate mineral consisting of calcium sulfate dihydrate, with the chemical formula $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. It is widely mined, used as fertiliser, and the primary component of numerous plaster, sidewalk or blackboard chalk, and plasterboard products.

. Alabaster, a high-quality, white or lightly tinted variety of gypsum, has been used for sculpting by various cultures throughout history, such as Ancient Egypt, Mesopotamia, Rome, the Byzantine Empire, and Medieval England's Nottingham alabasters. Gypsum is capable of forming transparent selenite crystals. It is generated through the evaporation of minerals and as a byproduct of anhydrite hydration.

By combining these fly ash – lime – gypsum together forms FAL-G binder. This binder usually used to make brick. Because the final strength of the binder takes longer time to attain

Recycled aggregate, obtained by demolition of building and other concrete structures which has certain amount of strong aggregate and concrete parts which can be used as an aggregate for the concrete up to certain ratio.

1.1.1 Fly ash

Coal combustion residuals (CCRs) are residual materials produced by the combustion of coal, which include fine particles of burned fuel and flue gases expelled from coal-fired boilers. These residuals are also known as coal ash, fly ash, flue ash, or pulverised fuel ash (in the UK). Bottom ash, also known as firebox ash, is the ash that accumulates at the bottom of the boiler's combustion chamber. In modern coal-fired power plants, fly ash is commonly collected using electrostatic precipitators or other particle filtration equipment before the flue gases are released through the chimneys. The combination of fly ash and bottom ash is referred to as coal ash.

The composition of fly ash varies greatly depending on the type and composition of the coal being burned. However, all fly ash contains significant amounts of silicon dioxide (SiO_2) in both amorphous and crystalline forms, as well as aluminum oxide (Al_2O_3) and calcium oxide (CaO), which are the primary mineral compounds found in coal-bearing rock strata.

Fly ash can be utilized as a lightweight aggregate (LWA) to recycle one of the largest waste streams in the United States. Fly ash can also have a lot of advantages when used as a LWA, both economically and environmentally.

In addition to its major components, fly ash may contain minor constituents depending on the composition of the coal bed, with trace concentrations (up to hundreds ppm) of substances such as gallium, arsenic, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum,

selenium, strontium, thallium, and vanadium. Furthermore, unburned carbon can also be present in fly ash.

In the past, fly ash was commonly released into the atmosphere, but modern air pollution regulations now require it to be captured using pollution control equipment before being released. Fly ash is typically stored at coal power stations or disposed of in landfills in the United States. However, approximately 43% of fly ash is recycled and utilized as a pozzolan in the production of hydraulic cement or plaster. It can also be used to replace some or all of the Portland cement used in concrete production. Pozzolans help to ensure that concrete and plaster set properly and provide additional resistance to moisture and chemical damage.

If fly ash or bottom ash is produced from the incineration of solid waste to generate power in a waste-to-energy facility, it may contain greater impurities than coal ash. In such cases, the resulting ash is often classified as hazardous waste.

1.1.2 Lime

Lime is an inorganic substance that contains calcium, primarily in the form of oxides and hydroxides, such as calcium oxide and calcium hydroxide. Calcium oxide is also referred to as lime and is found as a byproduct of coal seam fires and altered limestone xenoliths in volcanic ejecta. According to the International Mineralogical Association, lime is a mineral with the chemical formula CaO . The term "lime" is derived from its early use as a mortar in construction.

These materials continue to be utilised extensively as chemical feedstocks, building and engineering materials (including limestone products, cement, concrete, and mortar), as well as for the refinement of sugar. Both in the Old and New Worlds, the usage of lime and the businesses that produce it date to prehistoric times[citation needed]. For the ferrous sulfate-based wastewater treatment process, lime is widely employed.

Limestone and chalk, which are primarily made up of calcium carbonate-based rocks and minerals, are often used to produce these materials. The raw materials are chemically modified and then mechanically processed by chopping,

crushing, or pulverizing. Burnt lime, unslaked lime, or quicklime (calcium oxide), which is highly corrosive, and slaked lime, also referred to as hydrated lime (calcium hydroxide, $\text{Ca}(\text{OH})_2$), which is less corrosive but still highly alkaline, are produced by heating calcium carbonate to temperatures above $900\text{ }^{\circ}\text{C}$ ($1,650\text{ }^{\circ}\text{F}$) in a lime kiln.

The term "lime" in relation to agriculture usually refers to agricultural lime, which is commonly produced by crushing limestone rather than being produced in a lime kiln. If not, it typically refers to slaked lime because the more hazardous version is typically referred to as quicklime or burnt lime.

1.1.3 Gypsum

With the chemical formula $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, gypsum is a soft sulphate mineral made of calcium sulphate dihydrate. It is widely mined, used as fertiliser, and the primary component of numerous plaster, sidewalk or blackboard chalk, and plasterboard products. Many cultures, including Ancient Egypt, Mesopotamia, Rome, the Byzantine Empire, and the Nottingham alabasters of Mediaeval England, have used alabaster, a fine-grained, white or lightly tinted variety of gypsum, for sculpture. Gypsum can also form selenite crystals, which are transparent. It develops as an evaporite mineral and as an anhydrite hydration byproduct.

Gypsum has a hardness value of 2 on the Mohs scale of mineral hardness, based on a scratch hardness comparison. It exhibits retrograde solubility, which means that it becomes less soluble at higher temperatures, unlike most other salts. At $25\text{ }^{\circ}\text{C}$, gypsum is moderately water-soluble, with a solubility of $2.0\text{--}2.5\text{ g/L}$. When heated in the presence of air, gypsum loses water and transforms first into bassanite, also known as "plaster," and then, with further heating, into anhydrous calcium sulphate, or anhydrite. In saline solutions and brines, similar to anhydrite, the concentration of NaCl , or common table salt, has a significant effect on the solubility of gypsum.

Gypsum has a crystal structure composed of layers of calcium ions (Ca^{2+}) and sulphate ions (SO_4^{2-}) that are tightly bonded together. The layers are held together by anion water molecule sheets, which are connected by weaker hydrogen

bonds. This unique structure gives gypsum its characteristic perfect cleavage along the sheets in the 010 plane.

1.1.4 Recycled aggregate

The use of recycled construction and demolition debris in the production of recycled aggregate concrete is an attractive option both ecologically and economically. However, the substitution of natural aggregates with recycled aggregates is challenging due to the lower quality properties of recycled aggregate concrete.

This chapter covers the limited structural uses for recycled aggregate concrete, due to its poor mechanical and durability performance.

Readers will have enough information from the discussions and suggestions in this chapter to effectively use recycled aggregates in concrete, resulting in environmentally beneficial building practises.

Recycled aggregate refers to the use of crushed concrete, asphalt, or other construction materials as a substitute for natural aggregates in fresh concrete or other construction materials, through the recycling of construction and demolition waste. To create recycled aggregate with qualities akin to those of natural aggregates, the waste material must be gathered and crushed.

There are two categories for recycled aggregates: coarse and fine. Large chunks of concrete or masonry are broken down into tiny pieces to create coarse recycled aggregate, which is then utilised as a subbase for roads, parking lots, and building foundations. Fine recycled aggregate can take the place of sand in the creation of fresh concrete or asphalt by crushing smaller fragments of concrete or masonry into smaller particles.

Indeed, the use of recycled aggregate has numerous environmental and economic benefits. For instance, it helps reduce the amount of construction and demolition waste that ends up in landfills, which in turn decreases the need for additional landfill space. Moreover, using recycled aggregate instead of virgin aggregate can help conserve natural resources such as gravel and sand.

Additionally, the transportation and processing of virgin aggregate require a significant amount of energy, which contributes to greenhouse gas emissions. By using recycled aggregate, energy consumption and carbon emissions associated with transportation and processing can be reduced. Recycled aggregate is also more affordable than natural aggregate, making it an attractive option for construction companies and developers.

1.1 Objective

- To determine the physical properties of the recycled concrete aggregate, Fal-g (fly ash-lime-gypsum) binder
- To determine the strength characteristics of developed concrete
- To compare the analytical results and experimental results
- To determine the Scanning Electron Microscopy(SEM)of the concrete to understand the micro structural arrangements.

1.2 scope of the project

The work can be extended for various grades of concrete with various types of aggregates, binders, and admixtures with the optimum volume the performance can be increased.

The present study is aimed to utilize waste and industrial by product to partially replace the conventional concrete materials. The reduced consumption of cement will prove a great way in reducing the greenhouse gas emission while manufacturing the cement in the industries. Further utilization of recycled concrete will reduce the consumption of scarce natural coarse aggregate / conventional coarse aggregate. Currently the research on partially replacement of conventional concrete materials by using industrial byproducts or waste materials which are greatly affecting the environment due to their improper disposals is considered as socially impacted studies.

1.3 Need for project

- To reduce the waste dumping of concrete waste on the ground.
- To minimize the usage of cement by adding FAL-G (fly ash-lime-Gypsum) binder...
- To provide effective conservation and utilization of natural resources
- To make a perfect use of the industrial byproduct to save natural resources

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Literatures

Elango and Revathi (2017) investigated the properties of Studies on the physical, mechanical, and other pertinent properties of fly ash-lime-gypsum (FaL-G) binder with various sizes of coarse aggregates have been conducted. The outcomes are contrasted with permeable concrete prepared with OPC binder. The test findings are shown and thoroughly described.

Carmine Lima, et al., (2013) investigated the 'natural' components (i.e., aggregates, cement, water, and fibres) could be partially replaced with recycled ones in order to reduce the demand for raw resources and the amount of waste that needs to be disposed of in landfills. However, it is still regarded as a work in progress to establish solid correlations between the primary physical and mechanical characteristics of concrete made with the aforementioned recycled constituents.

Rui Vasco Silva, et al., (2014) investigated concrete's modulus of elasticity after adding recycled aggregates made from processed building and demolition debris. It identifies various factors that can affect the use of recycled aggregates, including replacement level, size, and origin. It also discusses mixing techniques, how the finished concrete is exposed to various environmental factors, the use of chemical admixtures and additions, and how the modulus of elasticity changes over time. In order to comprehend the loss of elasticity modulus based on the calibre and quantity of recycled aggregates, a statistical analysis of the gathered data is also presented. It is proposed in this chapter that there is also a correlation between compressive strength and modulus of elasticity, which is consistent with current specifications for traditional structural concrete.

George Dimitriou, et al., (2017) investigated the impact of RCA on concrete and a method for improving RCA's qualities by minimising the amount of mortar that

is attached and, consequently, the characteristics of Recycled Aggregate Concrete (RAC). Mineral admixtures were employed in place of cement in several applications. Fly ash and silica fume were employed as mineral admixtures, along with three different types of coarse RCA.

Kho Pin Verian, et al., (2018) investigated The use of recycled concrete aggregate (RCA) in concrete mixtures presents a potential solution for reducing the need for new aggregate quarries and decreasing the amount of construction debris that ends up in landfills. This approach offers environmental benefits by reducing waste and conserving natural resources. However, replacing natural aggregate (NA) with RCA can be challenging due to the inferior properties of recycled aggregate concrete, as discussed in previous sections. Despite these challenges, the potential environmental benefits of using RCA in concrete make it a worthwhile consideration for sustainable construction practices. Concrete's strength and durability are influenced by the characteristics of RCA, including as its specific gravity, absorption, and the quantity of contaminants it contains.

Guoliang Bai, et al., (2020) investigated the old mortar that is linked to recycled aggregate (RA) is what causes the differences in characteristics between RA and natural aggregate (NA). The quantitative correlations between the amount of old attached mortar and the effectiveness of RA at the material level were depicted in this review. The study analyzed how the replacement ratio of recycled aggregate (RA) affects the mechanical properties of concrete at the component level.

Hui Guo, et al., (2018) investigated the continual rise in construction wastes has made recycling used concrete an essential concern on a global scale. Additionally, the need to find sustainable resources to replace natural resources in the production of concrete is driven by the expanding global construction industry. Many studies on the use of recycled aggregate (RA) derived from construction and demolition wastes to produce concrete products have been conducted in the last few decades. This essay discusses previous studies that investigated the effect of using RA on concrete durability. The amount of mortar adhered to the RA and the quality of the original concrete mainly affect the properties of the final concrete. As the RA

content and water-to-cement ratio (w/c) increase, the durability of the concrete decreases.

Jianzhuang Xiao, et al., (2002) investigated Experimental research has been conducted to evaluate the compressive strength and stress-strain behavior of recycled aggregate concrete (RAC) by replacing natural coarse aggregate (NCA) with different percentages of recycled coarse aggregate (RCA). Different RCA replacement percentages of 0%, 30%, 50%, 70%, and 100% were used to fabricate and test concrete specimens. In the experiments, uniaxial compression loading is used. The analysis focuses on the failure behavior and the impact of RCA content on the compressive strength, elastic modulus, peak stress, and ultimate stress of RAC. This statement suggests that the analytical formulas for the stress-strain relationship and peak strain of RAC can be used directly in various contexts, including theoretical and numerical analysis and the engineering design of structures made of RAC.

Etxeberria, et al., (2007) investigated Four different recycled aggregate concretes were produced using recycled coarse aggregates made from shattered concrete with replacement ratios of 0%, 25%, 50%, and 100%. The four concretes' mix ratios were created to produce the same compressive strengths. The recycled aggregates used in the study were kept moist but not completely saturated to control their fresh concrete characteristics, achieve an effective water-cement (w/c) ratio, and reduce the strength variability. Additionally, the study confirmed the demand for producing recycled aggregate concrete with low-medium compressive strength due to the high volume of cement required.

Casuccio, et al., (2008) investigated The study includes three concrete series, each having a different level of compressive strength. Each series comprises two RAC samples made with two types of coarse aggregates obtained by crushing regular and high strength concrete, along with a reference concrete made from naturally crushed stone. Both uniaxial compression testing on ordinary cylinders and flexural tests on notched beams were conducted. In order to calculate the quantity of shattered aggregates, the features of the fracture surfaces were also examined.

When compared to concrete made with natural coarse aggregates, recycled aggregate concrete (RAC) generally exhibits lower strengths (around 1-15%) and a lower modulus of elasticity (around 13-18%) when compared to conventional concrete made with natural aggregates. Moreover, RAC also exhibits notable reductions in the energy of fracture (around 27-45%), which affects the size of the fracture zone.

Padmini, et al., (2009) investigated The study focused on the properties of recycled aggregates obtained from parent concrete of three different strengths, with each parent concrete using the three largest possible aggregate sizes. The study examines the physical and mechanical properties of fresh granite aggregate in comparison to recycled aggregates obtained from parent concrete of varying strengths. The recycled aggregates were then used to create three different strengths of recycled aggregate concrete (RAC), which were subsequently investigated for their mechanical properties. For RAC, a typical relationship between the ratio of water to cement, compressive strength, ratio of aggregate to cement, and cement content has been developed, and it has been compared to the relationship for PC. Compared to PC, RAC can achieve a given compressive strength with a relatively lower water-cement ratio.

Antonio Eduardo Bezerra Cabral, et al., (2010) investigated the use of recycled aggregates in the creation of concrete is hampered by the variety in composition of construction and demolition (C&D) debris that has been found. A study was conducted to advance the field, altering the water-to-cement ratio and the percentage of recycled aggregates used in place of natural aggregates. Samples of the primary Brazilian C&D waste sources—concrete, mortar, red ceramic bricks, and tiles—were employed in the experimental programme. The elastic modulus and compressive strength of concrete results underwent statistical analysis and modelling. The study demonstrates that recycled coarse aggregate had a greater impact on both concrete qualities than recycled fine aggregate.

Thomas, et al., (2013) investigated because of their inherent porosity, concretes built from recycled aggregate are less durable. These variations become

less noticeable for low w/c ratios since the new, better cement paste's reduced porosity is the main determining factor in this situation. Based on the findings of the study, it was observed that the mechanical characteristics of recycled aggregate concrete (RAC) were negatively impacted when a high water-cement (w/c) ratio was used. The study suggests recommendable combinations of recycled aggregates that can be used in hostile situations. Additionally, an experimental model based on the compressive strength of RAC was proposed.

Silva, et al., (2015) investigated this study compared the estimated and actual measured values of the tensile strength of recycled aggregate concrete over time, using the Eurocode 2 method. The results showed little correlation between the estimated and actual values, leading to the proposal of new coefficients. The study also presented the relationship between tensile and compressive strengths in accordance with Eurocode 2. The findings suggested that recycled concrete showed a similar connection to natural aggregate concrete, regardless of the replacement level, type, and quality of the recycled aggregate used.

Somayeh Lotfi, et al., (2015) the significance of cement type, w/c ratio, and RA substitution to RAC characteristics. Two series of reference concrete were produced with different strength classes of C25/30 and C45/55, using natural coarse aggregates (both rounded and crushed) and natural sand. According to the results, the RAC series of concrete was created by replacing portions of natural aggregate with 0%, 20%, 50%, and 100% RA. The characteristics of RAC are significantly influenced by the mix design and the type of cement used. However, the impact of RA substitution on the performance of RAC is only slightly and controllably affected, even at high replacement levels. This outcome provides strong evidence that employing RA is feasible.

Vivian, et al., (2008) links between DC characteristics and their RA's qualities and the RAC's strength by using regression analysis. Examined are ten samples that were taken from demolition sites. The findings reveal a significant association between the DC samples, RA, and RAC features. It should be emphasised that RA and RAC will both be of worse quality as a result of poor DC.

The DC features and the RA attributes are also used to predict the RAC strength. The RAC performance from DC and RA can be calculated from there. The first stage of concrete demolition is also a good time to define the RAC design specifications. Additionally, suggestions are made to enhance future concreting procedures.

Marinkovic', et al., (2010) investigates the life cycle assessment (LCA) considers the transportation involved in the extraction of raw materials and manufacturing of materials. It utilizes regional life cycle inventory (LCI) data and takes into account typical conditions in Serbia. The environmental impact of aggregate and cement manufacturing phases is slightly higher for RAC compared to NAC, as per the findings of this case study. However, the overall environmental impact depends on several factors, such as the distance traveled by the natural and recycled aggregates and the mode of transportation used. For the particular case study, the maximum natural aggregate transport lengths are determined, above which the environmental implications of RAC can be comparable to or even less severe than those of NAC.

Xiao and Zhang (2006) investigated the connections between recycled aggregate concrete's (RAC) mechanical qualities. An experimental database regarding the key mechanical properties of RAC is created on the basis of a significant number of experimental findings that were published globally in literature from 1985 to 2004. In particular, the relationships between the elastic modulus, splitting tensile strength, flexural strength, density, and compressive strength are explored and thoroughly described. It is discovered that the mechanical characteristics of RAC may interact in ways that are very different from those of regular concrete. Based on statistical regression analysis using the least squares method, some enhanced novel equations are suggested for the prediction of the relationships between the mechanical properties of RAC.

Ettxeberria, et al., (2007) investigated if recycled aggregate concrete can be used as a structural material. The experimental investigation focused on the shear behaviour and strength of beams constructed using recycled aggregate concrete. Four concrete mixtures with various recycled coarse aggregate content percentages

(0%, 25%, 50%, and 100%), three distinct transverse reinforcement systems, and twelve beam specimens with the same compression strength were cast and tested till failure. Using a numerical model based on the modified compression field theory and simpler models like those proposed by Cladera and Mari, the Canadian standard CSA, and the Eurocode-2, analytical predictions of the experimental data were made.

Tushar R Sonawane, et al., investigated the fundamental characteristics of recycled fine aggregate and recycled coarse aggregate, as well as how these characteristics compare to those of native aggregates. All aggregate qualities undergo fundamental alterations, and their implications for concrete work are thoroughly examined. The properties of concrete made with recycled aggregate are also determined in the study. It explains the basic properties of concrete, such as compressive strength, flexural strength, workability, and so on, for different combinations of recycled aggregate and natural aggregate. Here are the legal requirements for recycled aggregate concrete in different nations along with their implications for construction work. The general state of recycled aggregate in India, as well as its future requirements and effective application, are covered here.

2.2 Literature summery

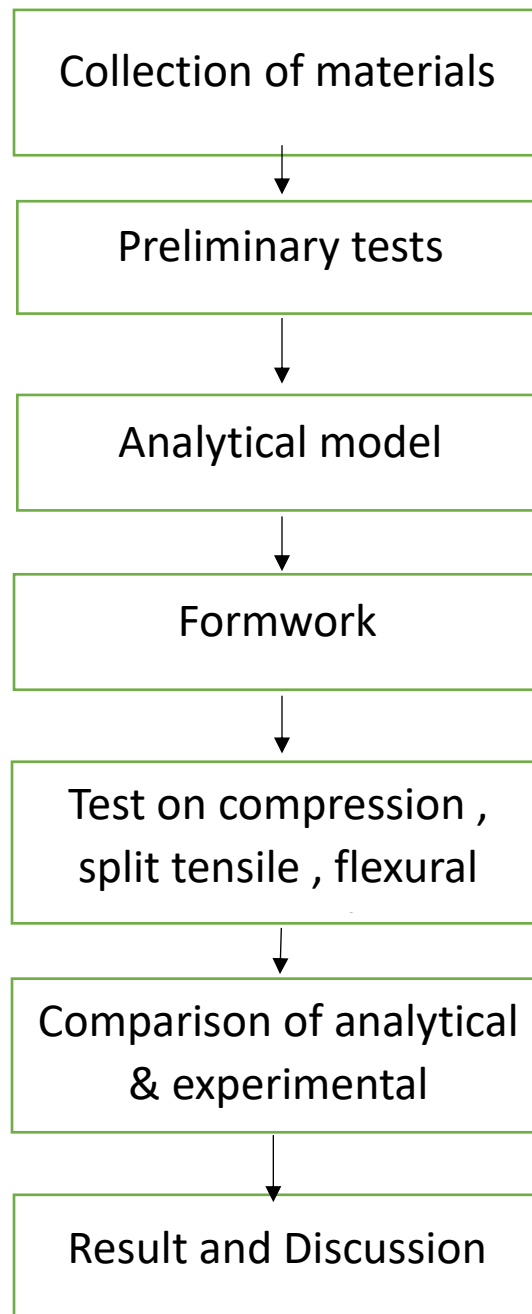
- The road base materials stabilized with lime-fly ash-phosphor gypsum binder showed higher strength compared to road base materials stabilized with ordinary lime, cement, and lime-fly ash. The granular soils stabilized with this binder also exhibited higher later strength compared to those stabilized with lime-fly ash or cement. The binder showed higher early strength and steady strength development.
- Discarded materials like concrete rubble are often disposed of in landfills, leading to negative environmental impacts. A viable solution to this issue is to recycle these materials and incorporate them into new concrete mixes as coarse aggregates.

- To evaluate the mechanical properties and durability characteristics of recycled concrete aggregate.
- The focus of this study is to investigate a cement-free mortar that has been developed as a sustainable building material with several positive effects, including the absence of carbon dioxide emissions and desirable mechanical properties.

CHAPTER 3

3.0 METHODOLOGY

3.1 FLOW CHART



CHAPTER 4

MATERIALS AND EXPERIMENTAL INVESTIGATION

4.1 Materials

4.1.1 OPC cement

It is one of the Portland cement varieties that is most frequently utilised. Joseph Aspdin gave Portland Cement its name in 1824 because of how similar its colour was to Portland stone and how it behaved after hardening. When combined with water, Portland Cement, a fine powder, acts as a binder to hold particles together in concrete. White-grey limestone from Portland Island in Dorset is used to make this cement. Because Portland Cement is naturally caustic, it may result in chemical burns.

4.1.2 fly ash

Fly ash is a powdery substance that is produced as a byproduct of coal-fired power plants. It is composed mostly of small, spherical, glassy particles and exhibits pozzolanic properties, meaning it can react with lime to create cement-like compounds. Due to these properties, it is commonly used as a supplementary cementitious material.

Fly ash can be used in various applications due to its versatility, such as in

- Concrete
- Dams
- Flowable fill
- Mines
- Landfills
- Geopolymer concrete

4.1.3 lime

Lime is primarily composed of oxides and hydroxides, such as calcium oxide and calcium hydroxide, which are inorganic substances containing calcium. The term "lime" also refers to calcium oxide, which is found as a byproduct of coal seam fires and in modified limestone xenoliths in volcanic ejecta. According to the International Mineralogical Association, lime is a mineral with the chemical formula CaO . The word "lime" comes from its early use as a construction mortar, meaning "sticking" or "adhering."

Throughout history, lime and its derived products have been utilized as crucial components in various applications such as chemical feedstocks, building and engineering materials including cement, concrete, and mortar, as well as in sugar refinement. The production of lime and its usage dates back to prehistoric times in both the Old and New Worlds. In addition to these applications, lime is also widely used in the ferrous sulfate-based wastewater treatment process.

Commonly, these materials are derived from rocks and minerals like limestone or chalk that are mostly composed of calcium carbonate. After being chemically transformed, they are typically broken down, crushed, or ground into smaller particles. The process of burning calcium carbonate in a lime kiln at temperatures above $900\text{ }^{\circ}\text{C}$ ($1,650\text{ }^{\circ}\text{F}$) produces burnt lime or quicklime (calcium oxide), which is highly caustic, and slaked lime (calcium hydroxide, $\text{Ca}(\text{OH})_2$), also known as hydrated lime, which is less caustic but still very alkaline. These materials are widely used in various applications, including chemical feedstocks, building and engineering materials (such as limestone products, cement, concrete, and mortar), and refining sugar. Additionally, lime is commonly used in the ferrous sulfate-based wastewater treatment process.

4.1.4 Gypsum

Gypsum, a soft sulphate mineral, has the chemical formula $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ and is composed of calcium sulphate dihydrate. It is commonly extracted and utilized in various ways, such as in the production of fertilizers and plaster products, as well as

being a primary component in sidewalk or blackboard chalk. Throughout history, alabaster, a form of gypsum with a fine-grained and lightly tinted appearance, has been used for sculpture by various cultures, including Ancient Egypt, Mesopotamia, Rome, the Byzantine Empire, and Mediaeval England. Gypsum can also produce transparent selenite crystals and is formed through the process of evaporation or the hydration of anhydrite.

Unlike most other salts, gypsum displays retrograde solubility, meaning that it becomes less soluble at higher temperatures. At a temperature of 25 °C, gypsum has a moderate solubility in water, with a solubility range of 2.0 to 2.5 grams per liter. Gypsum loses water when heated in the presence of air, changing first into bassanite (often referred to as "plaster") and then, if heated further, into anhydrous calcium sulphate (anhydrite). Similar to anhydrite, the concentration of NaCl (common table salt) has a significant impact on how soluble gypsum is in saline solutions and brines.

The structure of gypsum is composed of layers of calcium ions (Ca^{2+}) and sulfate ions (SO_4^{2-}) that are strongly bonded together. The anion water molecule sheets that connect these layers together are held together by weaker hydrogen bonds, giving the crystal flawless cleavage along the sheets (in the 010 plane).

Selenite is a type of gypsum that occurs naturally in translucent, cleavable masses, and flattened crystals that are often twinned. Selenite doesn't actually contain much selenium; instead, the name of the two compounds comes from the Greek term for the Moon.

Selenite can also be found in a silky, fibrous form, in which case the term "satin spar" is frequently used. Finally, it could also be exceedingly compact or granular. It can range in transparency from translucent to opaque in hand-sized samples. Gypsum with a very fine grain that is either white or mildly coloured is appreciated for ornamental work of all kinds. Gypsum can be found in arid regions as desert rose, an opaque, flower-like substance with imbedded sand grains. In the form of selenite, it also produces some of the biggest crystals ever observed in nature, measuring up to 12 m (39 ft) in length.

4.1.5 Recycled aggregate

An appealing strategy in terms of the ecology and economy is recycling construction and demolition debris in the creation of recycled aggregate concrete. However, using recycled aggregates in place of natural aggregates is difficult due to the inferior properties of recycled aggregate concrete.

The structural uses for recycled aggregate concrete are now fairly limited. This chapter covers the causes of recycled aggregate concrete's subpar mechanical and durability performance.

This chapter also includes a thorough examination and analysis of the mechanical and durability behaviour of recycled aggregate concrete. Readers will have enough information from the discussions and suggestions in this chapter to effectively use recycled aggregates in concrete, resulting in environmentally beneficial building practises.

In place of natural aggregate in the creation of fresh concrete, asphalt, or other construction materials, recycled aggregate refers to the recycling of construction and demolition waste. To create recycled aggregate with qualities akin to those of natural aggregates, the waste material must be gathered and crushed.

There are two categories for recycled aggregates: coarse and fine. Large chunks of concrete or masonry are broken down into tiny pieces to create coarse recycled aggregate, which is then utilised as a subbase for roads, parking lots, and building foundations. Fine recycled aggregate can take the place of sand in the creation of fresh concrete or asphalt by crushing smaller fragments of concrete or masonry into smaller particles.

There are numerous financial and environmental advantages to using recycled aggregate. Reusing construction and demolition trash helps to conserve natural resources, cut down on waste transported to landfills, and lessen the carbon footprint of construction projects. Additionally more cost-effective than natural aggregate, recycled aggregate is a desirable alternative for builders and developers.

4.1.6 Fine Aggregate

Good quality easily locally available M sand will be used. Generally fines are classified based on size, that is below 4.75mm is regarded as fine aggregate

4.1.7 Coarse Aggregate

Crushed angular metal of 10mm size from local source will be used as Coarse aggregate. In General Coarse Aggregate used for concrete is blast out of quarries and crushed or broken to a size of less than 20mm. This we make use in Conventional concrete preparation. On the contrary for SCC Coarse Aggregate size is limited to 10 to 12mm size such that it passes through 12.5mm sieve. These aggregates are made use in SCC.

4.1.8 Water

According to the Indian Standard code of practice for plain and reinforced concrete, IS 456-2005, potable water is recommended for mixing and curing of concrete.

4.2 Properties to be tested

4.2.1 Test on cement

4.2.1.1 Fineness test on cement

The fineness of cement governs the rate of hydration, heat evolution, and strength development. Finer particles have a larger surface area, leading to faster strength development and more rapid heat evolution.

Two common methods for determining the fineness of cement are the Sieve Test and the Air Permeability Test.

In the Sieve Test, the cement is passed through a set of sieves with progressively smaller openings, and the amount of cement retained on each sieve is measured. The results are then used to calculate the fineness of the cement.

In the Air Permeability Test, air is passed through a known volume of cement powder, and the rate of flow is measured. Finer powders allow more air to pass

through, resulting in a higher flow rate. This flow rate is then used to calculate the specific surface area of the cement, which is a measure of its fineness.

The Sieve Test is conducted by sieving the cement for 15 minutes in a circular and vertical motion after breaking up any air-set lumps. The residue left on the sieve is then weighed, and it should not be more than 10% for standard cement. However, this test is seldom used to determine the fineness of the cement.

4.2.1.2 Setting Time of cement

Cement's initial setting time and final setting time are determined using Vicat's instrument(Fig 4.1).

Initial Setting Time: A needle measuring 1 mm square is used for this test. According to the consistency test, the paste is a mixture of water and cement, and the needle is authorised to pierce it. The first setup time is defined as the amount of time needed to penetrate 33-35 mm of depth.



Fig 4.1 Vicat Apparatus

Final Setting Time: The needle may only pierce the paste 0.5 mm deep once it has reached the desired hardness. The initial setting time is defined as the time from the addition of water to the cement until the paste starts losing its plasticity and hardening. On the other hand, the final setting time is defined as the time when the cement paste completely loses its plasticity and becomes hard enough to resist any deformation or indentation, and the needle used for the test doesn't pierce the paste more than 0.5 mm.

4.2.1.3 Specific Gravity Test on Cement

The quantity of cement in a given volume divided by the mass of water in the same amount of cement is known as the specific gravity of cement. It can alternatively be described as the ratio of cement density to water density for a given volume(Fig 4.2).

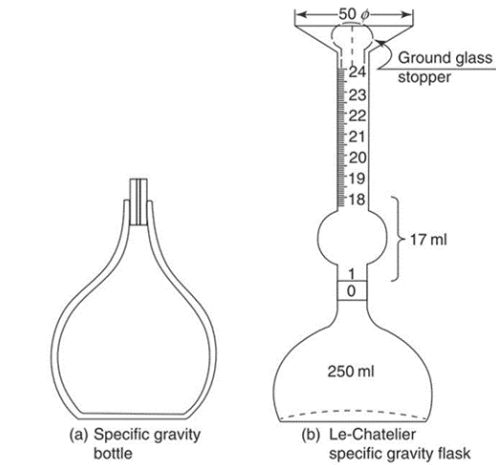


Fig 4.2 Le Chatelier

The Specific Gravity of Cement is 1440 kg/m³. Around this value, the Specific Gravity of Cement is Considered to be standard and suitable for construction. Table 4.1 says the physical properties of the cement.

Table 4.1 Physical properties of cement

S.NO	PHYSICAL PROPERTIES	RESULTS
1.	Normal Consistency Test	32%
2.	Fineness of cement	4.8%
3.	Specific Gravity of cement	3.14
4.	Setting Time (initial)	34 minutes
5.	Setting Time (final)	615 minutes
6.	Soundness of cement	5 mm

4.2.2 Test on coarse aggregate

4.2.2.1 Crushing test

Crushing under compressive stress is one of the models in which pavement material might fail. The crushing strength of aggregates is measured using a test that adheres to the standards set forth in IS:2386 part-IV. The aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied crushing load. The test entails running a compression test with a standard load on an aggregate specimen in a standard mould.

Dry aggregates that have been screened through 12.5 mm sieves and kept through 10 mm sieves are put into a cylindrical shape with an 11.5 mm diameter and three layers of 18 cm height. 25 times are used to tamper each layer using a typical tamping rod. To perform the aggregate crushing value test, a sample of the aggregate is taken and weighed before being placed in a cylindrical mold in three layers. Each layer is then compacted by tamping 25 times using a standard tamping rod. A compressive load of 40 tonnes is then gradually applied to the specimen at a rate of 4 tonnes per minute until the total load is reached. The crushing value is calculated as the ratio of the weight of fines passing the specified sieve to the total weight of the sample, expressed as a percentage.

The aggregate crushing value is then determined by sieving crushed aggregates through a 2.36 mm screen and expressing the weight of the material that passes as a percentage of the weight of the entire sample. A score of less than 10 denotes an unusually strong aggregate, whereas a value of more than 35 would often be considered weak.

4.2.2.2 Abrasion test

The purpose of an abrasion test is to evaluate the hardness of aggregates and determine their suitability for various pavement construction projects. The Los Angeles abrasion test, which has been standardised in India (IS:2386 part-IV), is the primary method for determining the hardness attribute. The Los Angeles abrasion

test aims to determine the percentage of wear caused by the relative rubbing between the aggregate and steel balls used as an abrasive charge.

The Los Angeles machine is made up of a rotating circular drum with an interior diameter of 700 mm and a length of 520 mm that is mounted on a horizontal axis (see Figure 2). Along with the aggregates, an abrasive charge of cast iron spheres measuring 48 mm in diameter and weighing 340–445 g is added to the cylinder. The number of abrasive spheres changes depending on how the sample is graded. The amount of aggregates to be utilised varies depending on the gradation and typically falls between 5 and 10 kg. Depending on the aggregate gradation, the cylinder is then locked and revolved for a total of 500–1000 revolutions at a speed of 30-33 rpm.

After a certain number of revolutions in the Los Angeles abrasion test, the material is sieved through a 1.7 mm sieve, and the percentage of the material that passes through the sieve is calculated as a percentage of the total weight of the sample. Los Angeles abrasion value is the name given to this value.

In Indian conditions, the WBM base course may not exceed a value of 40%. There is a maximum value of 35 for bituminous concrete.

4.2.2.3 sieve analysis

Sieve analysis is a common and widely used technique for determining the particle size distribution of coarse aggregates. The process of determining the particle size distribution of an aggregate involves gradually reducing the size of the sieve openings and passing the aggregate through a series of sieves. The amount of material retained on each sieve is then measured, and the percentage of material that passes through each sieve is calculated. This information is used to create a particle size distribution curve, which can be used to assess the suitability of the aggregate for various applications in construction. The results are typically presented as a percentage of the total mass of the aggregate Table 4.2 shows the results of the sieve analysis of coarse aggregate.

Here are the general steps involved in performing a sieve analysis on coarse aggregate:

- **Select the sieves:** The sieves used for sieve analysis are typically made of woven wire mesh with square openings of varying sizes. The sieves are arranged in a stack with the largest opening at the top and the smallest opening at the bottom. The number of sieves used depends on the size of the aggregate and the desired level of accuracy. The commonly used sieves are 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 600 microns, 300 microns, and 150 microns.
- **Weigh the sample:** A representative sample of the coarse aggregate is collected, typically weighing about 2 kg. The sample is dried in an oven at a temperature of $110\pm 5^{\circ}\text{C}$ to remove any moisture present in the sample. After drying, the sample is weighed and the weight is recorded.
- **Sieve the sample:** The process of sieve analysis involves placing the dried sample on the top sieve of a stack of sieves with progressively smaller openings. The stack is then shaken either manually or with a mechanical shaker for a specified period of time. The shaking time varies depending on the size of the aggregate and the desired level of accuracy. After shaking, the material retained on each sieve is weighed and recorded.
- **Calculate the particle size distribution:** The percentage of material passing through each sieve is then calculated by subtracting the percentage of material retained from 100%. This information is used to create a grading curve, which is a graphical representation of the particle size distribution of the aggregate. A cumulative percentage is then calculated by adding the percentages of material retained on each sieve. The results are typically presented as a graph of particle size distribution, with particle size on the x-axis and cumulative percentage on the y-axis.
- **Sieve analysis on coarse aggregate provides important information on the gradation of the aggregate, which is essential for determining the workability,**

strength, and durability of concrete. The results of sieve analysis can also be used to optimize the proportions of aggregate in concrete mixes and to ensure that the concrete meets the required specifications.

Table 4.2 Table of gradation of coarse aggregate

Sieve size (mm)	Cumulative weight retained (gm)	Percentage retained	Cumulative percentage retained	Percentage passing
80	0	-	-	100
40	0	-	-	100
20	850	85	85	15
10	148	14.8	99.8	0.2
4.75	2	0.2	100	0

4.2.3 Test on fine aggregate

4.2.3.1 sieve analysis

Sieve analysis is a widely used technique to determine the distribution of particle sizes in fine aggregate, which is usually composed of sand. The process involves separating the sand into various particle size fractions by passing it through a series of sieves with different mesh sizes. The results are presented as a percentage of the total weight of the sand retained on each sieve Table 4.3 shows the results of fine aggregate.

Here are the general steps involved in performing a sieve analysis on fine aggregate:

- Obtain the sample: A representative sample of the fine aggregate is obtained by following a standard sampling procedure. The sample is typically obtained from the production site or from the site where the material will be used.
- Dry the sample: The sample is dried in an oven at a temperature of $110 \pm 5^{\circ}\text{C}$ to remove any moisture present in the sample. After drying, the sample is weighed and the weight is recorded.
- Select the sieves: A set of sieves with different mesh sizes is selected, ranging from the largest opening at the top to the smallest at the bottom. The commonly used sieves are 10mm, 4.75mm, 2.36mm, 1.18mm, 600 microns, 300 microns, and 150 microns.
- Weigh the sieves: The sieves are weighed individually to determine their tare weight.
- Sieve the sample: The sample that has been dried is then put on the uppermost sieve, and the series of sieves is subjected to shaking by hand or mechanically for a predetermined amount of time. The shaking time varies depending on the size of the aggregate and the desired level of accuracy. After shaking, the material retained on each sieve is weighed and recorded.
- Calculate the particle size distribution: The percentage of material retained on each sieve is calculated by dividing the weight of material retained by the total weight of the sample. A cumulative percentage is then calculated by adding the percentages of material retained on each sieve. The results are typically presented as a graph of particle size distribution, with particle size on the x-axis and cumulative percentage on the y-axis.

The results of the sieve analysis on fine aggregate provide important information on the particle size distribution, which can be used to determine the workability, strength, and durability of the concrete. The information can also be used to optimize the proportions of the aggregate in concrete mixes and to ensure that the concrete meets the required specifications

Table 4.3 Table of gradation of fine aggregate

Sieve size	Cumulative weight retained (gm)	Percentage retained	Cumulative percentage retained	Percentage passing
4.75	0	0	0	100
2.30	24	2.4	2.4	97.6
1.18	344	34.4	36.8	63.2
600 microns	150	15.0	51.8	48.2
300 microns	180	18.0	69.8	30.1
150 microns	230	23.0	92.8	7.2
75 microns	50	5.0	97.8	2.2
Pan	22	2.2	100	-

4.2.3.2 Specific gravity test

The specific gravity and moisture content of fine aggregate are assessed using this technique. Dry cleaning is used to clean the pycnometer and determine its mass and brass cap. Put between 200 and 400 grammes of oven-dried soil in the Pycnometer to determine the combined mass of the two.

Distilled water should be poured into the Pycnometer to a height of half and thoroughly mixed with a glass rod. Shake it after adding extra water. Replace the

conical cap's hole with the screw top and Pycnometer. Dry the pyrometer outside and determine the mass. Unfilled Pycnometer Thoroughly clean it, then locate the mass by filling it with distilled water until it reaches the opening in the conical cap.

4.2.3.3 Water Absorption test

The water absorption test is a method used to measure the amount of water absorbed by fine aggregate and determine its percentage of water absorption capacity. In this test take a weight of 200 gm of fine aggregate. The Sample was tested for 24 hrs in full of water. After 24hrs the sample was taken from water and weighs it. Now find out the percentage of water content of Fine aggregate.

4.3 SAMPLES AND SPECIMEN DETAILS

The No. of Cubes, Cylinder, Prisms and RCC Beams to be casted are listed below for each combinations

Conventional concrete M40

- Cubes-9
- Cylinder-9
- Beams-1

25% recycled aggregate replaced with aggregate

- Cubes-9
- Cylinder-9
- Beams-1

30% FAL-G binder replaced with cement

- Cubes-9
- Cylinder-9
- Beams-1

25% recycled aggregate & 30% FAL-G binder both replaced

- Cubes-9
- Cylinder-9
- Beams-1

4.4. EXPERIMENTAL INVESTIGATION

4.4.1. Mix design

To design a concrete mix for M40 grade, we need to determine the proportions of cement, aggregates, and water that will result in the desired strength and workability. Here's an example mix design for M40 concrete with a water-cement ratio of 0.43:

Target strength: 40 MPa (mega Pascals) at 28 days

Maximum size of aggregate: 20mm

Based on these factors, we can calculate the following proportions for the mix:

- Cement: 433 kg/m³
- Water: 198 kg/m³
- Fine aggregate (sand): 638 kg/m³
- Coarse aggregate (20 mm): 1155 kg/m³

To verify that the mix meets the target strength, we can perform compressive strength tests on concrete cubes made from the mix at different curing ages (e.g. 7, 14, and 28 days). If the results of these tests fall within the desired range, the mix can be considered suitable for use in construction.

It's important to note that the mix design may need to be adjusted based on factors such as the specific properties of the materials used, environmental conditions, and the intended application of the concrete. A qualified engineer or

concrete technologist should be consulted to ensure that the mix is appropriate for the specific project requirements.

4.4.2. Mix proposition

The mix proposition for M40 concrete replaced with 25% recycled aggregate and 30% FAL-G binder for the total amount of aggregate and cement for the mix

There are four mix proposition they are

- Conventional M40
- 25% Recycled concrete with aggregate
- 30% FAL-G binder with cement
- 25% recycled aggregate & 30% FAL-G binder both are replaced

4.4.3. Experimental setup

After 28 days of curing, the RCC beam is tested by selecting two sections at a distance of $L/3$ and $2L/3$ from one side of the beam, where L is the unsupported length. The beams are tested under simply supported end conditions, with a two-point loading system. The purpose of using a two-point loading system is to test the beams in flexure. Three dial gauges are placed, with one at the center of the beam span and the other two at midpoints of support load. The deflection value is obtained from these dial gauges.

4.4.4. Test Procedure

4.4.4.1 Test on fresh concrete

4.4.4.1.1 Slump cone test

The slump cone test is a simple and commonly used test for measuring the workability of fresh concrete. It is also known as the slump test or the Abrams cone test. The test involves measuring the "slump" or deformation of a cone-shaped sample of fresh concrete when it is subjected to a specific amount of force(Fig4.3).

Here are the general steps involved in performing a slump cone test on fresh concrete:

- Prepare the slump cone: The slump cone is a metal mold in the shape of a truncated cone with a base diameter of 200 mm, a top diameter of 100 mm, and a height of 300 mm. The cone is cleaned and lubricated with a thin layer of oil before the test.
- Prepare the concrete: A mixture of concrete is prepared according to a specific design mix. The concrete is mixed thoroughly to ensure that it is homogeneous and free of lumps.
- Fill the slump cone: The slump cone is placed on a flat, level surface, and it is filled with the freshly mixed concrete in three equal layers. Each layer is compacted 25 times with a standard tamping rod, which is a steel rod of 16 mm diameter and 600 mm length.
- Remove the slump cone: After the third layer of concrete is added and tamped, the cone is carefully lifted vertically and removed from the concrete.
- Measure the slump: The deformation or "slump" of the concrete is measured by measuring the difference between the height of the cone before and after the concrete is placed in it. The difference between these two measurements is reported as the slump value in millimeters.

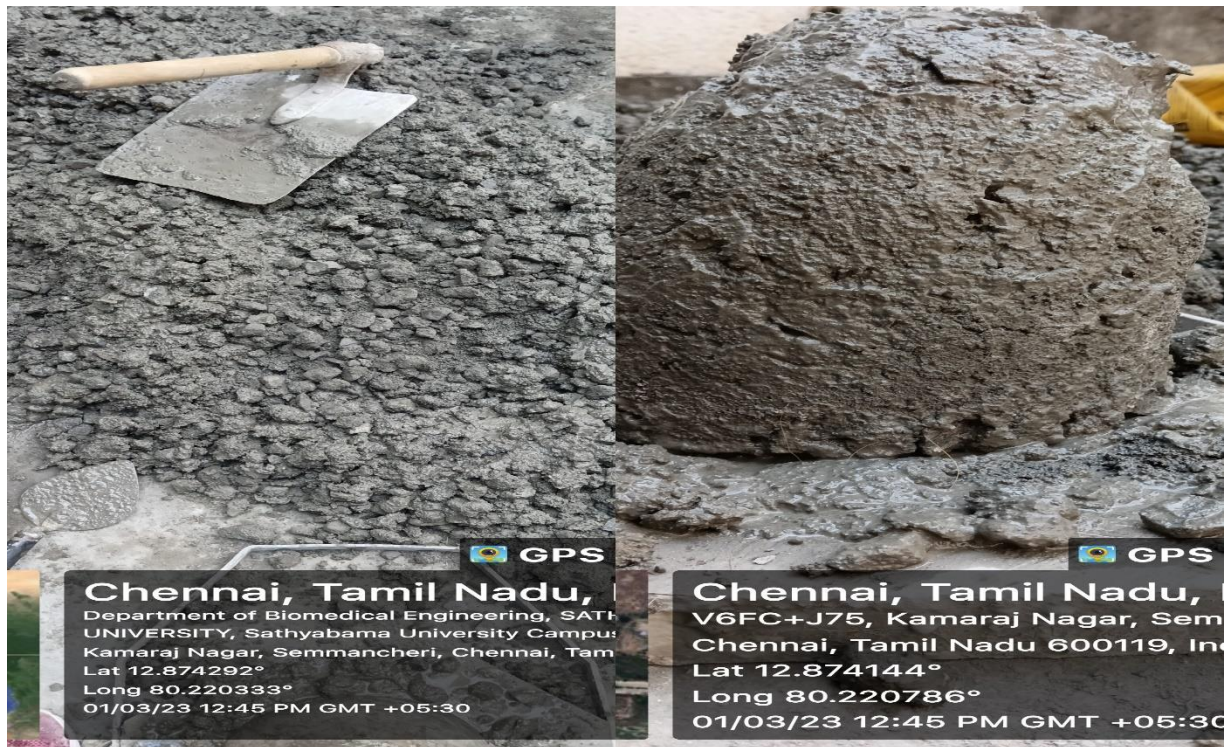


Fig 4.3 Slump cone test

The workability of concrete can be evaluated by measuring the slump value, which refers to the degree of deformation or settling of the concrete after it has been placed in a cone-shaped metal mold and the mold has been removed. The slump value indicates how easily the concrete can be placed, compacted, and finished. If the slump value is too low, it may indicate that the concrete is too stiff and difficult to work with. On the other hand, if the slump value is too high, it may indicate that the concrete is too fluid and may not have enough strength. Therefore, it is important to adjust the mix design and water-cement ratio to achieve the desired slump value for the intended application. The optimal slump value depends on the specific application of the concrete, and it is usually specified in the design mix.

Overall, the slump cone test is a quick and easy way to assess the workability of fresh concrete. It is widely used in the construction industry to

ensure that the concrete is of the required quality and meets the design specifications.

4.4.4.2 Tests on the Hardened Concrete

4.4.4.2.1 Compression Strength for cubes

The compressive strength of concrete is determined by testing cubes after seven and twenty-eight days of curing. This test provides a comprehensive understanding of the concrete's properties, including the water-cement ratio, cement quality, material quality, and quality control procedures. The size of the aggregate determines whether 15 cm x 15 cm x 15 cm or 10 cm x 10 cm cubes are used as specimens for the test. The cube test is crucial in evaluating the compressive strength of concrete(Fig 4.5).

Cubical moulds having dimensions of 15 cm x 15 cm x 15 cm are commonly used for most construction works. To avoid any voids, the concrete is properly compacted after pouring it into the moulds. After 24 hours, the moulds are removed, and the test specimens are cured by submerging them in water. The top surface of the specimens should be smooth and level, which can be achieved by evenly applying a layer of cement paste over the entire surface of the specimen.

After the 7 or 28 days of curing, the concrete specimens are placed in a compression testing machine. The specimens are gradually loaded at a rate of 140 kg/cm² per minute until they fail. The compressive strength of the concrete is then calculated by dividing the load at failure by the specimen's cross-sectional area. The compressive strength is reported in units of pressure, such as pounds per square inch (psi) or megapascals (MPa). This test is considered the most common method for assessing the concrete's quality and strength.

$$\text{Compressive Strength} = \text{Load} / \text{Cross-sectional Area}$$

The compressive strength of concrete is commonly evaluated using a 7-day compression test on a cube-shaped sample. The test involves casting a cube of concrete and applying a compressive force to it after 7 days of curing.

In the 7-day compression test on a concrete cube, the cube is typically subjected to a compressive load that is 70% of the expected 28-day compressive strength. This is because concrete gains strength over time, and the 28-day strength is typically used as a reference point for design purposes.



Fig 4.4 Concrete cubes and cylinders

Overall, the 7-day compression test on a concrete cube is an important test used to determine the compressive strength of concrete. The results of this test can be used to evaluate the quality of the concrete, to ensure that it meets the required design specifications, and to predict the long-term performance of the concrete in real-world applications.

Table 4.4 Compression test on cube 7 days

	Mix 1	Mix 2	Mix 3	Mix 4
Cube 1	26.22	16.67	25.56	18.89
Cube 2	27.11	22.67	16.89	18.67
Cube 3	28.89	18.22	18.22	20.89

A 14-day compression test on a cube is a similar test to the 7-day compression test on a cube, but it is performed on a concrete sample after 14 days of curing

instead of 7 days. The 14-day test is another way to measure the compressive strength of concrete at an earlier age than the standard 28-day test.

The 14-day test provides an indication of the strength of the concrete at an earlier age than the standard 28-day test. It is useful in situations where early strength is important, such as in precast concrete production or in construction projects where formwork needs to be removed early. However, it is important to note that the 28-day compressive strength is still the most common and widely used measure of concrete strength.

Overall, the 14-day compression test on a concrete cube is another method used to determine the compressive strength of concrete at an earlier age than the standard 28-day test. The results of this test can be used to evaluate the quality of the concrete and to ensure that it meets the required design specifications

Table 4.5 Compression test on cube 14 days

	Mix 1	Mix 2	Mix 3	Mix 4
Cube 1	31.11	24.44	27.11	18.67
Cube 2	30	26.67	27.55	19.78
Cube 3	24.44	25.56	28.89	23.33



Fig 4.5 cube testing

A widely used method to determine the compressive strength of concrete is the 28-day compression test on a concrete cube. This test involves casting a cube-shaped sample of concrete, which is then cured for 28 days before subjecting it to a compressive force.

The 28-day compressive strength of concrete is considered the standard measure of concrete strength. This is because concrete gains strength over time, and 28 days is the time at which the strength of most concrete reaches its maximum. The compressive strength of the concrete is used to evaluate its quality, to ensure that it meets the required design specifications, and to predict its long-term performance in real-world applications.

Overall, the 28-day compression test on a concrete cube is an important test used to determine the compressive strength of concrete. The 28-day compression test on a concrete cube is widely adopted in the construction industry as a standard

test to assess the quality of the concrete and ensure that it meets the desired design specifications(Fig 4.6).

Table 4.6 Compression test on cube 28 days

	Mix 1	Mix 2	Mix 3	Mix 4
Cube 1	40.12	35.66	37.41	36.55
Cube 2	41.55	37.11	38.81	36.89
Cube 3	41.95	38.22	38.54	37.25



Fig 4.6 Cube testing

4.4.4.2.2 Split Tensile strength for Cylinder

The tensile strength of concrete is a critical characteristic that significantly impacts the size and extent of cracking in structures. Concrete is brittle and weak in tension, making it unable to withstand direct stress, leading to the formation of cracks in concrete when tensile forces exceed its tensile strength. Therefore, it is essential to determine the tensile strength of concrete to determine the load at which the concrete members may crack. One approach to determine concrete's tensile

strength is by splitting a concrete cylinder, which is based on ASTM C496, a code similar to IS 5816 1999, and other codes(Fig 4.7).

To determine the tensile strength of concrete using the splitting method, there are a few steps that need to be followed. Firstly, the wet specimen is removed from the water after the desired age, typically 7 or 28 days. The surface of the specimen is then wiped clean of any remaining water. Next, diametrical lines are marked on both ends of the specimen to ensure that they are in the same axial location. The weight and dimensions of the specimen are then recorded.

The compression testing device is set to the required range, and a plywood strip is placed on the lower plate. The specimen is placed on top of the plywood strip and aligned such that the diametrical lines are perpendicular to the loading axis. A compressive load is applied at a constant rate until the specimen fractures. The load at failure is recorded, and the tensile strength is calculated using the formula specified in the testing code.

To estimate the tensile strength of concrete, the wet specimen is removed from the water after 7, 28, or any other desired age, and the surface is wiped dry. Then, diametrical lines are marked on the specimen's two ends to ensure that they are in the same axial position, and the weight and dimensions are recorded. The compression testing device's range is set, and a plywood strip is placed on the lower plate before the specimen is placed on it with the vertical, centred lines on the ends over the bottom plate. The second piece of plywood is then placed over the specimen, and the top plate is lowered until it barely touches the plywood strip. The load is applied continuously at a rate of 0.7 to 1.4 MPa/min (according to IS 5816 1999, 1.2 to 2.4 MPa/min) without any shock. Finally, the breaking load (P) is recorded.

Table 4.7 Tensile test on cylinder 7 days

	Mix 1	Mix 2	Mix 3	Mix 4
Cylinder 1	3.18	1.41	2.9	2.75
Cylinder 2	3.25	2.29	2.97	2.82

Cylinder 3	2.48	3.18	3.11	2.26
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Fig 4.7 test on cylinder

Tensile strength testing of concrete cylinders is less common than compression testing, but it can still provide valuable information about the material properties of concrete. Tensile strength testing involves subjecting a cylindrical sample of concrete to a tensile force until it fails. The testing is typically performed at different ages, such as 7, 14, and 28 days after the concrete has been cast.

Table 4.8 Tensile test on cylinder 14 days

	Mix 1	Mix 2	Mix 3	Mix 4
Cylinder 1	2.97	2.68	3.18	2.26

Cylinder 2	3.39	2.97	3.11	2.68
Cylinder 3	3.25	2.83	3.25	2.47

Tensile strength testing of concrete cylinders can provide valuable information about the material properties of concrete, including its ductility and toughness. The results of these tests can be used to evaluate the quality of the concrete and to ensure that it meets the required design specifications. However, it is important to note that tensile strength testing is less common than compression testing, and the results of these tests should be interpreted with caution.

Table 4.9 Tensile test on cylinder 28 days

	Mix 1	Mix 2	Mix 3	Mix 4
Cylinder 1	4.1	3.5	3.2	3.45
Cylinder 2	3.9	3.81	3.24	3.51
Cylinder 3	4.2	3.9	3.3	3.61



Fig 4.8 Testing on cylinder

4.4.4.2.3 Loading frame test

A loading frame flexural behavior test is a type of mechanical test used to determine the bending or flexural strength of a material. This test is typically performed on materials that are used in construction, such as concrete or steel beams, to determine their ability to withstand bending forces(Fig 4.9).

The test involves applying a load to a sample of the material that has been prepared in a specific size and shape. The sample is placed on two supports, and a load is applied at the center of the sample using a loading frame. As the load is increased, the sample will begin to bend or deflect, and the amount of deflection will be measured.

The flexural strength of the material is determined by calculating the maximum load that the sample can withstand before it breaks or fails, and by measuring the deflection of the sample at that point. This information is important for engineers and designers who need to ensure that their materials can withstand the stresses and forces that they will encounter in real-world applications.

Overall, a loading frame flexural behavior test provides valuable information about the mechanical properties of a material, and helps to ensure that it will be able to perform as expected in its intended application.

The test involves preparing a sample of the material to be tested in a specific size and shape, typically a rectangular or cylindrical shape. The dimensions of the sample will depend on the specific standards or requirements of the test being performed. The sample is usually cast or molded to ensure consistency and accuracy of the test results.



Fig 4.9 beam testing

The sample is then placed on two supports, which are typically located at a specific distance apart, also based on the requirements of the test. A loading frame is used to apply a load to the center of the sample, typically in the form of a vertical force applied to the top surface of the sample.

As the load is applied, the sample will begin to bend or deflect, and the amount of deflection will be measured using a device called a dial gauge or displacement transducer. The load is typically applied gradually, at a constant rate, until the sample reaches its maximum deflection or until it fails completely.

The flexural strength of the material is then calculated based on the maximum load that the sample can withstand before it fails, and by measuring the deflection of the sample at that point. The unit of measurement for flexural strength is typically reported as force per unit area, such as pounds per square inch (psi) or megapascals (MPa).

The test can also provide additional information, such as the modulus of elasticity, which is a measure of how much the material will deflect under a given load. This information can be useful in designing structures and determining the appropriate materials to use for specific applications.

Overall, the loading frame flexural behavior test is an important tool for engineers and designers, as it provides valuable information on the strength and behavior of materials under bending or flexural loads. This information can be used to ensure that structures and materials are designed to withstand the stresses and forces they will encounter in real-world applications (Fig 4.10).

Table 4.10 shows the result of the beam





Fig 4.10 beam testing

Table 4.10 Experimental deflection results for four beam specimen

Si.no	Load (KN)	Displacement in 'mm'			
		Mix 1 Con- M40	Mix 2 Rec agg- rep	Mix 3 FAL- G rep	Mix 4 Both rep
1.	10	0.25	0.24	0.19	0.2
2.	20	0.33	0.39	0.3	0.35
3.	30	0.48	0.55	0.45	0.47
4.	40	0.70	0.72	0.73	0.75
5.	50	0.95	0.99	0.91	0.93
6.	60	1.02	1.11	1.05	1.09
7.	70	1.29	1.32	1.28	1.3
8.	80	1.81	1.9	1.75	1.81
9.	90	2.15	2.21	2.1	2.18
10.	100	2.43	2.51	2.39	2.49

CHAPTER 5

ANALYTICAL MODEL

5.1 FINITE ELEMENT ANALYSIS

Finite element analysis (FEA) is a computational method used to determine the behavior of a complex system or structure under various conditions. It is widely used in engineering and science to simulate the physical behavior of materials and structures in response to external forces, such as stress, vibration, heat, and fluid flow.

The FEA process involves dividing the structure or system into smaller, more manageable parts, known as finite elements. Each finite element is modeled using mathematical equations that describe the behavior of the material under various conditions. The equations are solved using numerical techniques, such as the finite element method, to simulate the response of the structure or system to external forces.

Here are the general steps involved in performing a finite element analysis:

- Define the problem: The first step is to define the problem and the goals of the analysis. This includes specifying the geometry, materials, and boundary conditions of the structure or system.
- Create a mesh: The structure or system is divided into smaller elements, and a mesh is created to connect the elements. The size and shape of the elements are chosen based on the complexity of the problem and the desired level of accuracy.
- Define the material properties: The material properties, such as stiffness and density, are defined for each element.
- Apply loads and boundary conditions: The loads and boundary conditions, such as external forces and constraints, are applied to the structure or system.

- Solve the equations: The mathematical equations for each element are solved numerically using the finite element method. The equations are combined to simulate the behavior of the entire structure or system.
- Analyze the results: The results of the analysis are analyzed to determine the behavior of the structure or system under various conditions. This includes analyzing the stresses, strains, and deformations in the structure or system.
- Refine the model: The model is refined based on the results of the analysis. This includes adjusting the mesh size, material properties, and boundary conditions to improve the accuracy of the analysis.

FEA has many practical applications, including the design and optimization of structures and systems, such as bridges, aircraft, and automobiles. It can also be used to simulate the behavior of materials under extreme conditions, such as high temperatures and pressures, and to optimize manufacturing processes.

5.2 ABAQUS

Abaqus is a powerful and widely used software for performing Finite Element Analysis (FEA) simulations. It is developed and marketed by Dassault Systèmes, a leading software company in the engineering and scientific domains. Abaqus is used in a wide range of industries, including aerospace, automotive, biomedical, civil engineering, and defense, among others.

Here are some of the key features and capabilities of Abaqus:

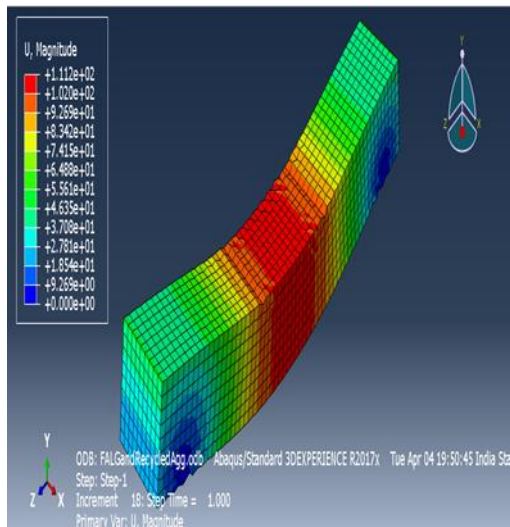
- Finite element modeling: Abaqus provides a robust set of tools for creating and analyzing complex finite element models. Users can create geometric models, define materials and boundary conditions, and generate meshes for various types of analyses.
- Material modeling: Abaqus includes a comprehensive range of material models, including elastic, plastic, hyperelastic, viscoelastic, and

damage models. These models enable accurate representation of material behavior under different loading conditions.

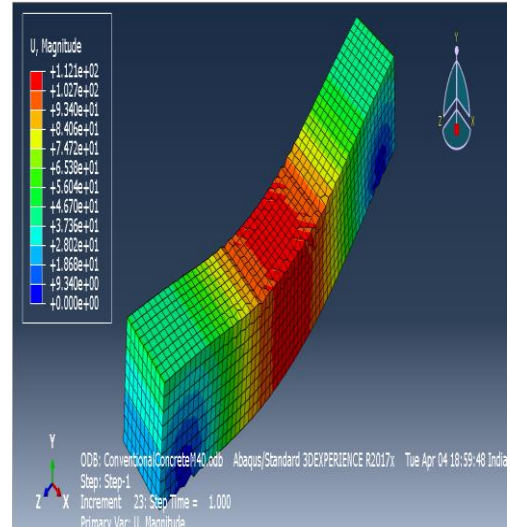
- Multiphysics simulations: Abaqus can perform multiphysics simulations, including structural, thermal, acoustic, and fluid analyses. It allows the coupling of different physics models to simulate complex real-world problems.
- User-defined elements and subroutines: Abaqus provides the capability to create user-defined elements and subroutines, which can be used to implement custom material models, boundary conditions, and other specialized features.
- Parallel processing: Abaqus can take advantage of parallel processing capabilities to accelerate the solution of large and complex problems. It can run on both shared and distributed memory architectures.
- Post-processing: Abaqus includes a suite of post-processing tools for visualizing and analyzing simulation results. It allows users to create plots, animations, and other visualizations to better understand the behavior of the system or structure under study.
- Customization and automation: Abaqus provides a scripting interface that allows users to customize and automate simulation workflows. This feature can significantly improve productivity and efficiency in modeling and analysis.

In summary, Abaqus is a versatile and powerful software package for performing FEA simulations. It offers a range of features and capabilities for creating and analyzing complex models, and provides tools for post-processing and visualization of simulation results.

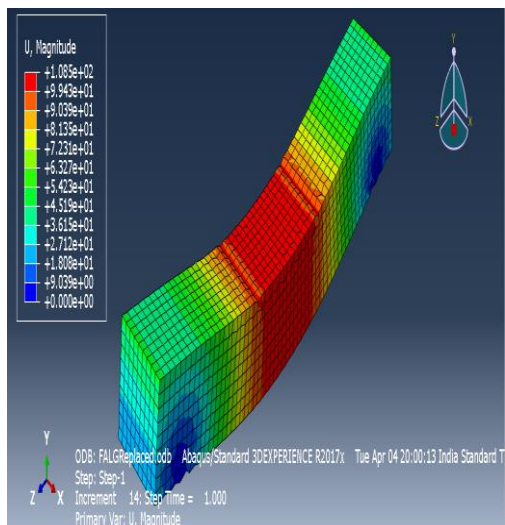
5.3 Analytical model



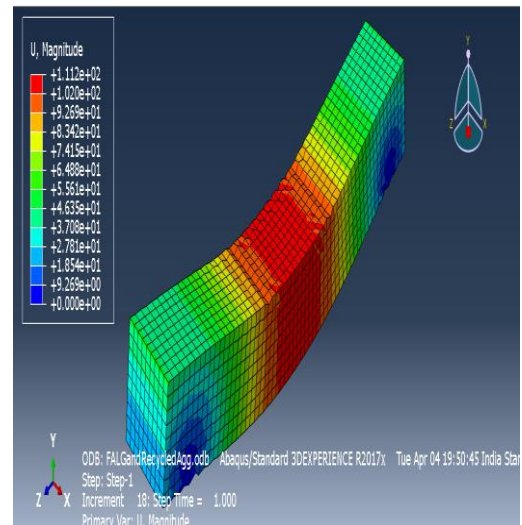
(a)



(b)



(c)



(d)

Fig 5.1 Deflection results from ABAQUS analysis

5.3.1 Analytical results

Table 5.1 Analytical test results for the 4 beams

S.no	Load (KN)	Displacement in 'mm'			
		Mix 1- con	Mix 2- rec agg	Mix 3- FAL- G	Mix 4- both rep
1.	10	0.214	0.249	0.219	0.229
2.	20	0.527	0.501	0.438	0.459
3.	30	0.792	0.755	0.659	0.688
4.	40	1.049	1.010	0.885	0.918
5.	50	1.322	1.260	1.109	1.151
6.	60	1.585	1.511	1.325	1.381
7.	70	1.859	1.762	1.549	1.618
8.	80	2.118	2.015	1.769	1.849
9.	90	2.381	2.259	1.991	2.083
10.	100	2.645	2.518	2.219	2.311

CHAPTER 6

6.1 RESULT AND DISCUSSION

Based on the compression strength values provided, we can see that mix 1 has the highest compression strength of 27.41 MPa, while mix 2 has the lowest compression strength of 19.18 MPa. Mix 3 and mix 4 have similar compression strength values of 20.22 MPa and 19.48 MPa, respectively.

It's important to note that these are 7-day compression strength values, and concrete typically gains strength over time with proper curing. In general, concrete strength can increase by up to 50% or more between 7 days and 28 days of curing, depending on various factors such as the type of cement used, the water-cement ratio, and the curing conditions.

Therefore, it's possible that the compression strength values of the cubes could increase significantly if tested after 28 days of curing. However, based on the 7-day compression strength values, it appears that mix 1 still has the highest strength, while the other cubes have lower strength values. This suggests that the replaced materials used in the other mix may not be as effective in producing high-strength concrete as the conventional materials used in mix 1.

At 7 days of curing, the compression strength results are:

- Mix 1: 27.41 MPa
- Mix 2: 19.18 MPa
- Mix 3: 20.22 MPa
- Mix 4: 19.48 MPa

At 14 days of curing, the compression strength results are:

- Mix 1: 28.51 MPa
- Mix 2: 25.56 MPa
- Mix 3: 27.85 MPa
- Mix 4: 20.59 MPa

At 28 days of curing, the compression strength results are:

- Mix 1: 44.26 MPa
- Mix 2: 41.21 MPa
- Mix 3: 38.25 MPa
- Mix 4: 36.90 MPa

From these results, we can see that Mix 1 has the highest compression strength values at all three curing periods, followed by Mix 2, Mix 3 and Mix 4.

It's important to note that these results are specific to the testing conditions and materials used in this particular experiment, and may not be representative of all possible variations of these mixes. Other factors such as workability, durability, and cost would also need to be considered when evaluating the effectiveness of each mix for a particular application. Fig 6.1 shows the compression strength of concrete.



Fig 6.1 Graph of compression test results on cube

At 7 days of curing:

Mix 1 (represented by Cylinder 1): 2.97 MPa

Mix 2 (represented by Cylinder 2): 2.29 MPa

Mix 3 (represented by Cylinder 3): 2.99 MPa

Mix 4 (represented by Cylinder 4): 2.61 MPa

At 14 days of curing:

Mix 1: 3.20 MPa

Mix 2: 2.82 MPa

Mix 3: 3.18 MPa

Mix 4: 2.47 MPa

At 28 days of curing:

Mix 1: 4.06 MPa

Mix 2: 3.74 MPa

Mix 3: 3.25 MPa

Mix 4: 3.52 MPa

Based on these results, we can see that Mix 1 has the highest tensile strength values at all three curing periods, followed by Mix 2, Mix 4, and Mix 3.

It's important to note that the tensile strength values are significantly lower than the corresponding compressive strength values, and that concrete is typically stronger in compression than in tension. Therefore, it's important to carefully evaluate the tensile strength values in the context of the specific application and conditions in which the concrete will be used. Fig 6.2 represent the tensile strength of concrete

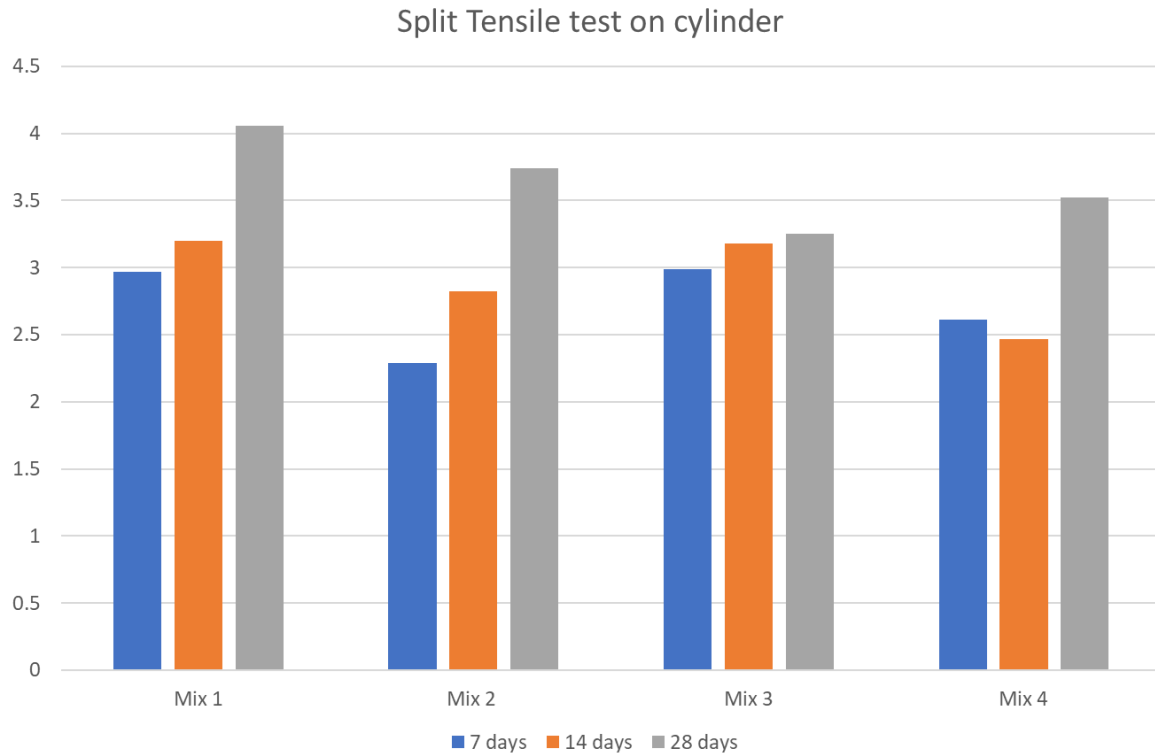


Fig 6.2 Graph of split tensile test results on cylinder

Four concrete beams were casted using Mix 1, Mix 2, Mix 3, and Mix 4, respectively. Each beam had a size of 1.5m x 0.23m x 0.23m.

After casting, the beams were cured for 28 days to ensure that the concrete reached its maximum strength potential. Proper curing involves keeping the concrete moist and at a stable temperature to allow for optimal chemical reactions and hydration.

Following the curing period, the beams were subjected to a loading frame test to measure their deflection. During the test, a load was applied to the center of the beam using a loading frame, causing it to bend or deflect. The deflection of the beam was measured at different load levels, and this data was used to calculate the flexural strength and stiffness of the beam.

It's important to note that the results of the loading frame test can provide valuable information about the performance of the concrete beams under different loading conditions, and can be used to assess their suitability for

various structural applications. However, it's also important to consider other factors, such as the type and quality of materials used, the dimensions and shape of the beam, and the curing conditions, when evaluating the strength and durability of a concrete structure.

In summary, the concrete beams were casted using different mixes and cured for 28 days before being tested in a loading frame to measure their deflection. The results of the test can provide valuable information about the flexural strength and stiffness of the beams, which can be used to evaluate their suitability for various structural applications.

The experimental vs analytical results are shown in Fig 6.3, 6.4, 6.5, 6.6 represented below

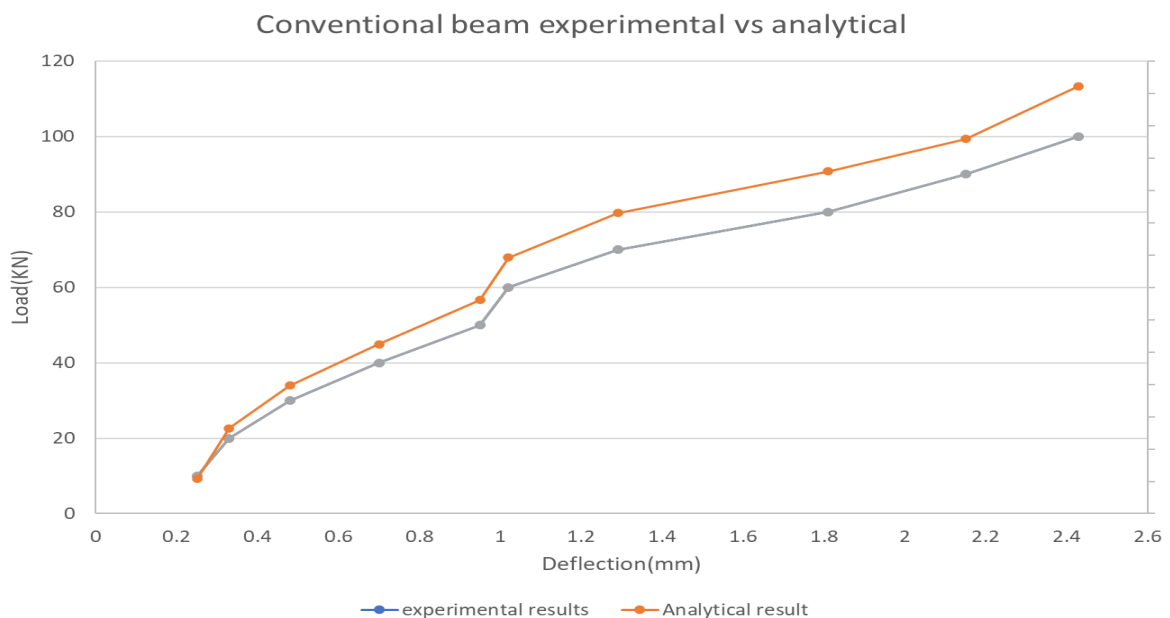


Fig 6.3 Conventional M40 Beam experimental vs analytical results

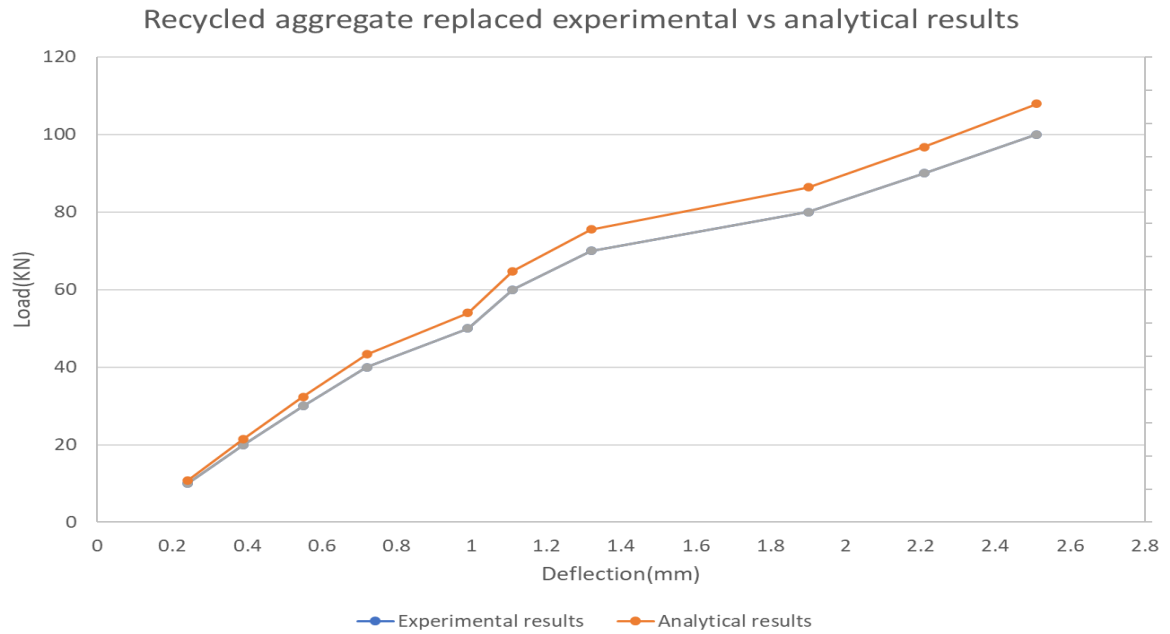


Fig 6.4 Recycled aggregate replaced experimental vs analytical results

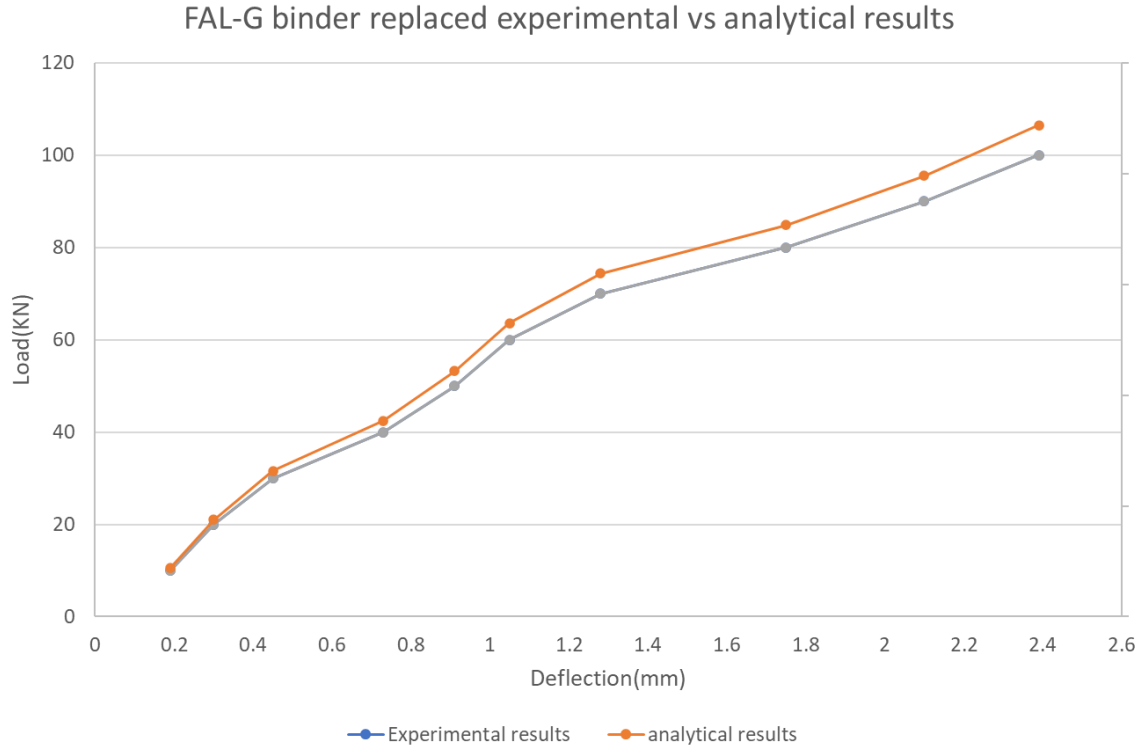


Fig 6.5 FAL-G binder replaced experimental vs analytical results

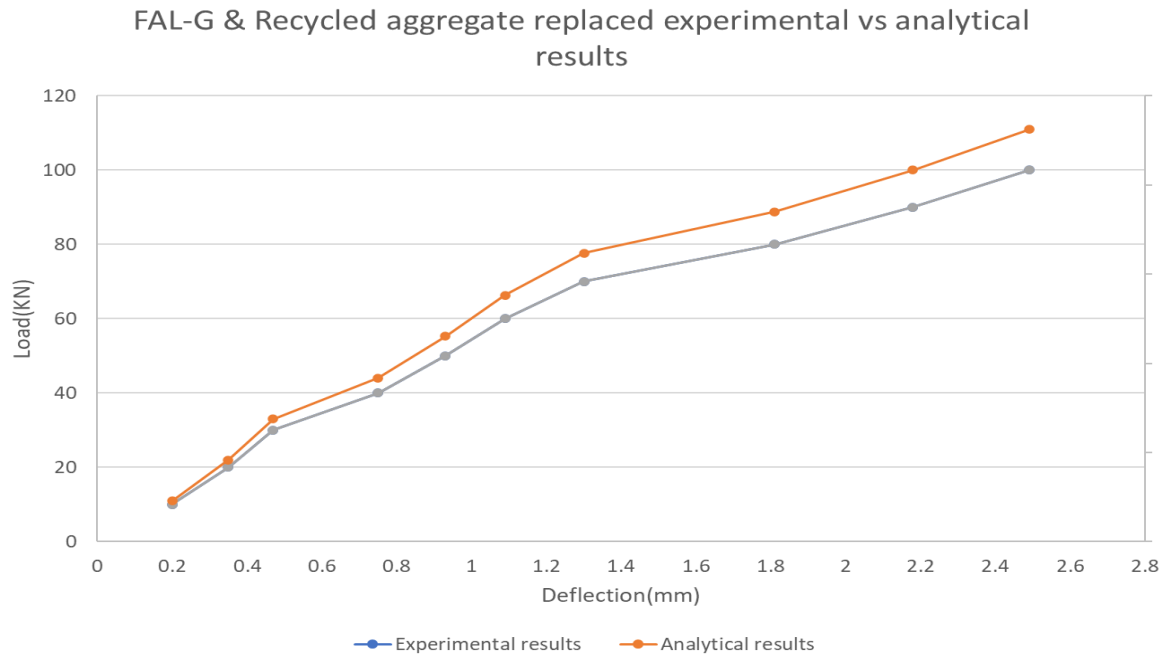


Fig 6.6 FAL-G & recycled aggregate replaced experimental vs analytical results

CHAPTER 7

7.0 SUMMARY

Fly ash lime gypsum binder is a type of construction material that is partially made from fly ash, which is a byproduct of coal combustion. The material is often used as a replacement for cement in concrete mixes, as it can provide a number of benefits including improved workability, durability, and reduced carbon emissions.

When fly ash is used in place of cement, it can help to reduce the amount of CO₂ emissions associated with the production of concrete, as well as reduce the amount of waste material sent to landfills. Additionally, fly ash can improve the overall strength and durability of the concrete, making it more resistant to cracking and shrinkage.

To create a fly ash lime gypsum binder, fly ash is typically mixed with lime, gypsum, and water to form a paste that can be used as a binder for construction materials. The exact proportions of the different materials can vary depending on the specific application and desired properties of the final product.

Overall, the use of fly ash lime gypsum binder in construction can provide a number of benefits in terms of environmental sustainability and performance. However, it's important to carefully consider the specific properties and requirements of each project before deciding to use this type of material. Proper testing and analysis should be performed to ensure that the material will meet the necessary standards and specifications for the intended application.

When recycled concrete is used as an aggregate replacement, it can provide a number of benefits. For example, it can help to reduce the need for virgin aggregates, which can conserve natural resources and reduce carbon emissions associated with transportation and processing. Additionally, recycled concrete can

improve the overall strength and durability of the new concrete mix, as it may contain materials that are already well-suited for construction use.

To create recycled concrete, existing concrete structures are crushed and screened to remove any impurities or debris. The resulting material can then be used as an aggregate replacement in new concrete mixes, either partially or fully. The exact proportions of the different materials can vary depending on the specific application and desired properties of the final product.

Overall, the use of recycled concrete as an aggregate replacement can provide a number of benefits in terms of environmental sustainability and performance. However, it's important to carefully consider the specific properties and requirements of each project before deciding to use this type of material. Proper testing and analysis should be performed to ensure that the material will meet the necessary standards and specifications for the intended application.

7.1 Conclusion

- Fly ash lime-gypsum (FAL-G) binder is a type of cementitious material that is made by combining fly ash, lime, and gypsum. It is considered an eco-friendly alternative to Portland cement due to its lower carbon footprint and the use of waste materials. However, the presence of fly ash in the FAL-G binder can lead to slower strength gain in concrete.
- The strength of conventional concrete is 44.26 N/mm². When 25% of the conventional aggregate is replaced with recycled aggregate, the strength drops slightly to 41.21 N/mm², which is still comparable to the strength of conventional concrete.
- However, when you combine 30% FAL-G binder and 25% recycled aggregate, the strength of the resulting concrete drops significantly to 36.90 N/mm². This is because both the FAL-G binder and recycled aggregate contribute to slower strength gain in concrete.

- The lower strength of the FAL-G and recycled aggregate concrete can be attributed to several factors. Firstly, the fly ash in the FAL-G binder is a pozzolanic material that reacts slowly with the lime to form cementitious compounds. This slow reaction leads to slower strength gain in concrete. Secondly, the recycled aggregate may contain weaker particles or contaminants that can affect the overall strength of the concrete.
- To improve the strength of the FAL-G and recycled aggregate concrete, you may need to adjust the mix proportions or use additives to accelerate the strength gain. Alternatively, you may need to consider using a different type of cementitious material or aggregate that can provide better strength performance.

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