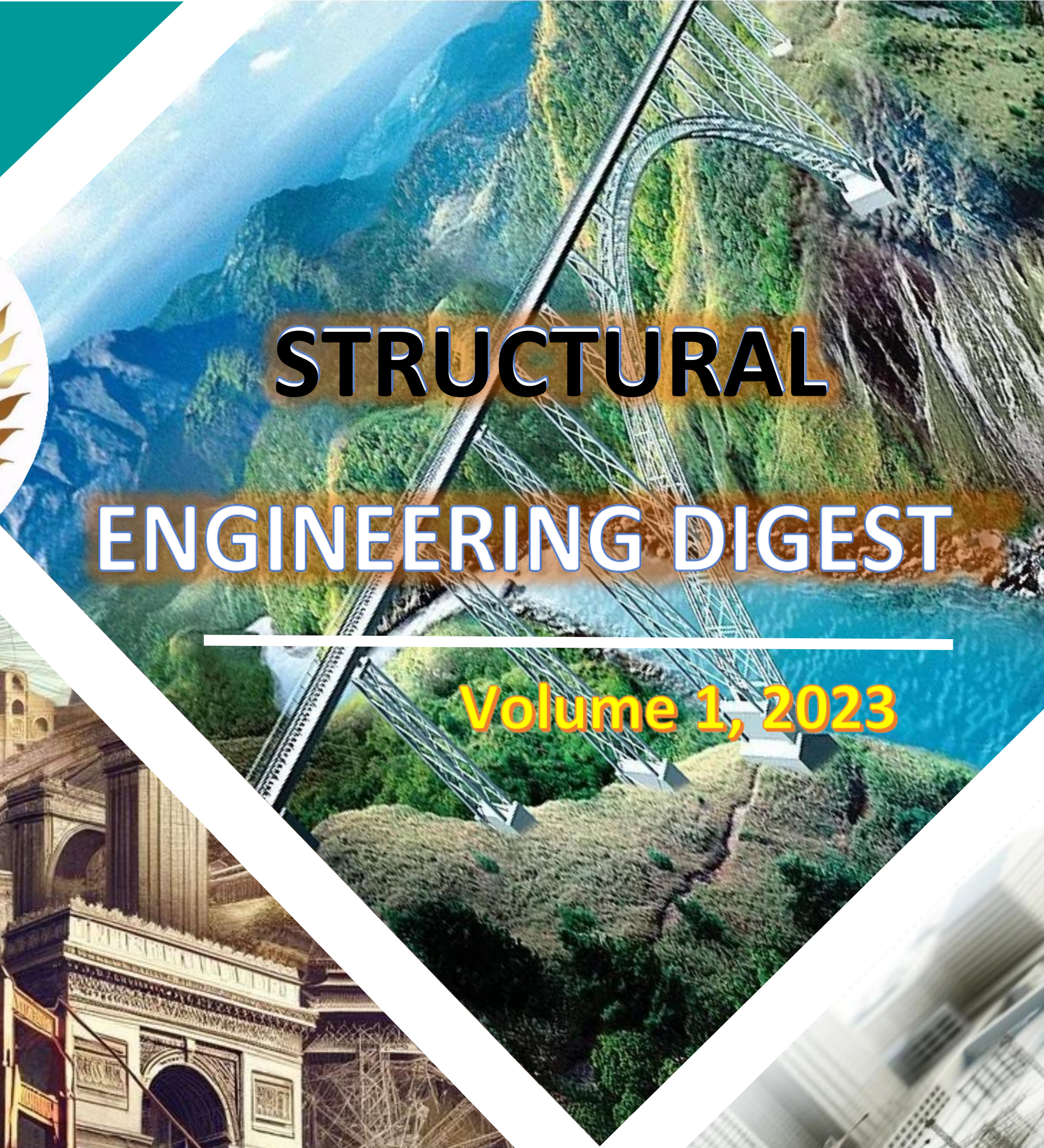
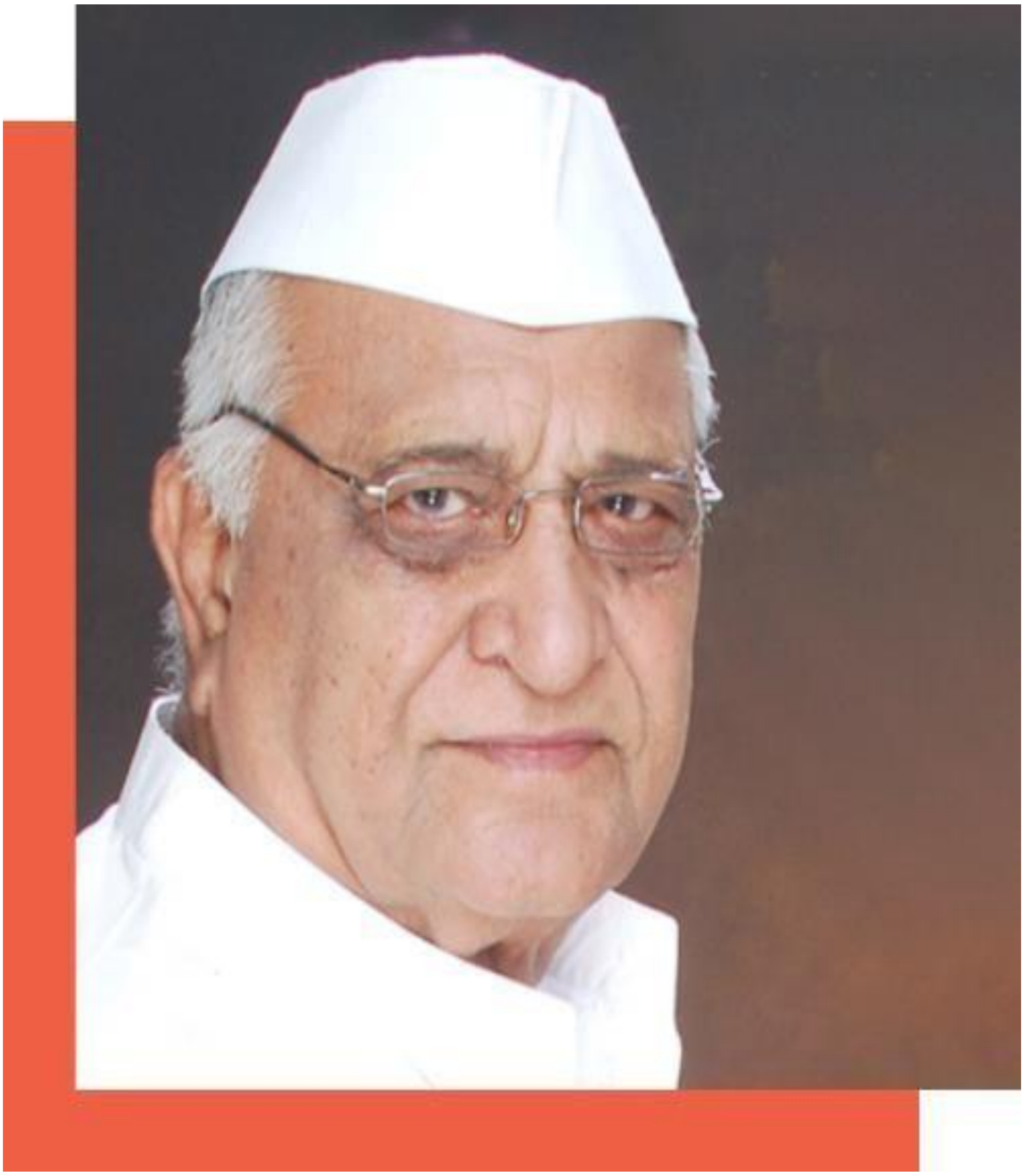


STRUCTURAL ENGINEERING DIGEST

Volume 1, 2023

Department of Structural Engineering,
Sanjivani College of Engineering, Kopargaon, 423603, M.S. India

OUR INSPIRATION



Late Shree Shankarrao G. Kolhe Saheb

Founder, Sanjivani Rural Education Society,

Hon’ble Shri Nitin S. Kolhe
Chairman, Sanjivani Group of Institute Kopargaon

Hon’ble Shri Amit N. Kolhe
Managing Trustee, Sanjivani Group of Institute Kopargaon

Dr. A. G. Thakur
Director

We strive to provide our students with an educational journey that transcends the conventional boundaries of textbooks and classroom learning. Our aim is to foster a well-rounded educational experience that encompasses more than just academic knowledge. Although we face numerous challenges, we are firm believers in the power of dedication and effort to achieve extraordinary results. It's our aspiration to make a meaningful impact in your lives by sharing our insights and knowledge. I'm delighted to engage with you via this Technical Magazine, titled "Structural Engineering Digest.

I am deeply convinced that offering sincere, committed, and systematic services undoubtedly leads to unmatched success. I want to express my sincere congratulations to everyone who has been instrumental in Sanjivani's accomplishments. My appreciation goes to Team Sanjivani for their steadfast dedication and persistent efforts in providing top-notch education to rural communities. Your commitment is invaluable and plays a significant role in enhancing our community's well-being.

Sanjivani is dedicated to creating an encouraging atmosphere that minimizes competition and encourages the pursuit of excellence, while also nurturing close connections among students to foster friendship and enduring relationships. I express my deepest gratitude to the Structural Engineering department for launching the "Structural Engineering Digest" Technical magazine this academic year. I wish them the best in its successful journey ahead. This innovative approach to showcasing the research work of departmental students is set to have a significant impact on society.

Editor-in-Chief

Dr. Atteshamuddin S. Sayyad
Professor and Head

It is with immense pride and a sense of collective achievement that I address you in the inaugural edition of our very own "Structural Engineering Digest." This magazine is a testament to the vibrant academic and research environment fostered at Sanjivani College of Engineering, Kopargaon, under the aegis of the Sanjivani Rural Education Society (SRES).

Since our establishment in 1983, we have been at the forefront of delivering exceptional education in the rural heartlands of Maharashtra. Recognizing the burgeoning demand for skilled professionals in the field of structural engineering both in India and globally, we embarked on an ambitious journey by introducing our B. Tech. and M. Tech. programs in Structural Engineering in the academic year 2020-2021. Our journey over the past three years has been nothing short of remarkable. The department has not only made significant strides in academic excellence but has also marked its presence on the national stage by becoming a lifelong member of the Indian Society of Structural Engineers. This affiliation not only honors our past achievements but also lays a robust foundation for our future endeavors.

At Sanjivani, we believe in a holistic approach to education. Our experienced and highly qualified faculty members have been instrumental in driving this vision, ensuring a blend of rigorous academic curriculum, and engaging extracurricular activities. We are equally committed to contributing to the body of knowledge in structural engineering through fundamental and applied research, alongside offering consulting services that bridge the gap between academia and industry.

As we launch "Structural Engineering Digest," we aim to create a platform for sharing knowledge, discussing innovative ideas, and showcasing the exemplary work of our students and faculty. I encourage each one of you to actively participate in this endeavor, making this magazine a rich repository of knowledge and a beacon for aspiring structural engineers.

I extend my heartfelt congratulations to the editorial team and all contributors for their hard work and dedication in bringing this magazine to life. Let us embark on this exciting journey together, aiming to inspire and be inspired.

Associate Editor

Hrushikesh N. Kedar
Assistant Professor

Welcome to the inaugural edition of "Structural Engineering Digest" by Sanjivani College of Engineering, Kopargaon. As Associate Editor, I'm proud to launch this magazine, which is dedicated to the ever-evolving field of structural engineering and aimed at spreading knowledge and sparking innovation among our students and faculty. This publication, a symbol of our commitment to engineering excellence, coincides with our educational strides, particularly with our B.Tech. and M.Tech. programs in Structural Engineering. The magazine will showcase a range of research works by students, faculty, and experts, serving as a stage for our community's creative efforts. Our heartfelt thanks go to everyone involved in this premiere edition, and we look forward to what lies ahead. This publication is more than just a knowledge repository; it's a source of inspiration for future engineers. We invite you to embark on this journey of exploration and learning with us.

Editorial Board

Vision of Department

To Achieve National and International Recognition in Structural Engineering Education.

Mission of Department

1. To maintain a healthy environment in the department that encourages our graduatesand faculty to achieve their best in academics and research.
2. To nurture graduates as problem solvers who develop innovative solutions for industry-related problems.
3. To create graduates who possess the knowledge and skills for future challenges and lifelong learning as structural engineers.

Program Educational Objectives (PEOs)

PEO 1: To impart basic and advanced knowledge of structural engineering so that graduates are able to analyze and solve industrial problems.

PEO 2: To provide hands-on training to the graduates on the latest equipment and latest software to make them suitable for industries and consultancies.

PEO 3: To equip the graduates with basic professional skills to work as a team member or leader for the socio-economic growth of the nation.

PEO 4: To motivate the graduates to pursue research, higher education, and entrepreneurship in the structural engineering field.

Program Specific Outcomes (PSOs)

PSO 1: Graduates will be able to provide the best possible solutions for the analysis and design problems using conventional and modern engineering tools for sustainable development related to structural engineering.

PSO 2: Graduates will be able to identify societal and industrial needs through allied courses such as planning and drawing, infrastructural engineering, project management, materials, mechanics, etc.

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Utilization of Construction and Demolition Waste Material in Low Volume Road Construction: Experimental Study

Snehal V. Waghchaure, Priyanka A. Rakshe, Rutika S. Jadhav, Rutuja A. Gavhane

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Abstract

Due to urbanization the generation and extraction of materials like soil, aggregate, cement will have an ecological impact. Therefore, to minimize the environmental impact, waste disposal and global warming, concrete made with demolition and construction waste functions well as a solution. Hence, in the present research work the feasibility study of using the construction and demolition wastes in the low volume road construction in rural areas, is presented. The recycled coarse aggregate produced from building and demolition waste is used to replace the coarse aggregates in concrete as (0%, 50%, and 100%) % replacement. The main objective of the present work is to determine the compressive strength of concrete produced using recycled aggregate. The experimental results of 7 days and 28 days compressive strength of concrete using recycled coarse aggregate are presented in the paper. Based on the results the feasibility and suitability study of the concrete with recycled coarse aggregate is discussed.

Keywords: C and D waste, Compressive strength, Recycled coarse aggregate (RCA), concrete,

1. Introduction

Concrete is a composite material made from cement, sand, water, and aggregates. It is strong, durable, and flexible, and can be shaped into various shapes and textures. Steel can be used for added tensile strength and crack resistance. Concrete is usedin construction for various structures, but its strength decreases with age due to factors like temperature changes, chemical attacks, and cracks. To improve the structure's service life, it is altered or demolished, generating a significant amount of solidwaste.

2. Literature Review

Tavaakoli and Soroushin [1] has presented the study on, regular concrete's strength, aggregate content compared to RCA, andthe proportion of fine to coarse particles in regular concrete, to determine the strength characteristics of RCAs. In his study author has used Los Angeles abrasion loss and water absorption test to determine the that the strength characteristics of RCAs. Limbachiya et al. [2] have presented a study on use of C & D waste in concrete. Author have studied the effect of coarse RCAon ceiling strength, bulk engineering and durability properties of concrete.

Mandal et al. [3] has studied that, the RCA concrete strength can be improved by changing the W/C ratio while the concrete is being mixed. Based on the data, the author concluded that, for 28 days of design strength, specimens constructed using RCA concrete nearly equaled those constructed with normal aggregate concrete in terms of durability and technical performance. Zaki et al. [4] have studied that the RCA may replace NA up to 50% and is suitable for non-structural applications such as sidewalks, curbs and concrete driveways. The guidelines and aspirations for the future call for the addition of an admixture to strengthen recycled aggregate concrete used in structural applications.

3. Experimental Study

3.1 Physical Characteristics of NA and RCA (Gravel)

The physical characteristics of NCA and RCA as shown in Table 1.

Table 1. Basics Properties for NCA and RCA

Properties	Natural Coarse Aggregate (NA)	Recycle Coarse Aggregate (RCA)	Standard Specifications
Specific Gravity	2.7	2.5	2.40 to 2.90
Water Absorption (%)	1.8	3.5	0.20% to 4.0% for NA 3.0 % to 12.0% for RCA
Bulk Density(kg/m3)	1600	1423	1200 kg/m^3 to 1750 kg/m^3

according For designing the concrete mix, the Bureau of Indian Standards (IS10262:2019) is employed. Stipulation of proportioning to IS 10262:2009 codification and IS 456:2000 (Grade of concrete =M25, Grade of cement = OPC 53grade, Aggregate Size (Maximum) =20 mm, Water to cement ratio = 0.5)

Step 1: Mean Target Strength

The mean target strength is expressed as,

$f' = f_{ck} + 1.65 \times S$

$\therefore f_{ck}' = 25 + 1.65 \times 4 = 31.6\ N/mm^2$

Compressive strength of concrete at 28 days = 25 N/mm^2

Step2: Selection of water content

Max. water content = 186 *lit* (for 25-50 mm slump)

$\therefore$Corrected water content = $186 + (186 \times 3)/100)$

$\therefore$W =191.5 *liters*

Step 3: Determination of cement content

Cement content per unit volume of concrete for W.C. ratio = $\frac{191.5}{0.5}$

= 383.16 Kg/m^3

Step 4: Determination of Coarse aggregate content

Aggregate Size = 20mm Zone II

W.C ratio = 0.5 Volume of CA = 0.62

Step 5: Determination of Fine aggregate content

Volume of FA $= 1 -$ Volume of CA

$= 1-0.62 = 0.38$

Step 6: Mix Proportion Calculation

Volume of Concrete = 1 m^3

Volume of cement = (mass of cement/specific gravity) $\times 1/1000$

$=(333.16/8.15) \times 1/1000 = 0.121 m^3$

Volume of water $= mass\ of\ water\ /(specific\ gravity \times 1000)$

$=191.5/(1 \times 1000) = 0.191 m^3$

Volume of all in aggregate

$e = [a - (b + c + d)]$

$= 1 - [0.121 + 0.193] = 0.686 m^3$

$Mass\ of\ CA = e \times volume\ of\ CA \times Specific\ gravity\ of\ CA \times 1000$

$= 0.686 \times 0.62 \times 2.89 \times 1000 = 1229.17\ kg$

Mass of FA $= e \times volume\ of\ FA \times Specific\ gravity\ of\ FA \times 1000$

$= 0.686 \times 0.62 \times 2.89 \times 1000 = 669.94$ kg

Therefore, the final Mix Proportion is expressed as Cement: Fine aggregate: Coarse aggregate = 1:1.75:3.22.

4. Results and Discussion

4.1 Properties of the Hardened Concrete

4.1.2 Compression Test

A compression test is a common method for determining the compressive strength of a material such as concrete, masonry, or rock. A compressive load is applied to a sample of the material until it fails, and the load at failure is measured. The results of compressive strength of concrete for various % replacement of RCA for & and 28 days is shown in Table 2. Fig. 1 shows the variation of 7- and 28-days compressive strength of concrete for 0%, 50% and 100% replacement of aggregate. From table 2 and Fig. 1 it is observed that the 7- and 28-days strength of 50% replacement is more than that of 100% replacement. Also, atthe 50% replacement the results obtained are in close agreement with the 0% replacement.

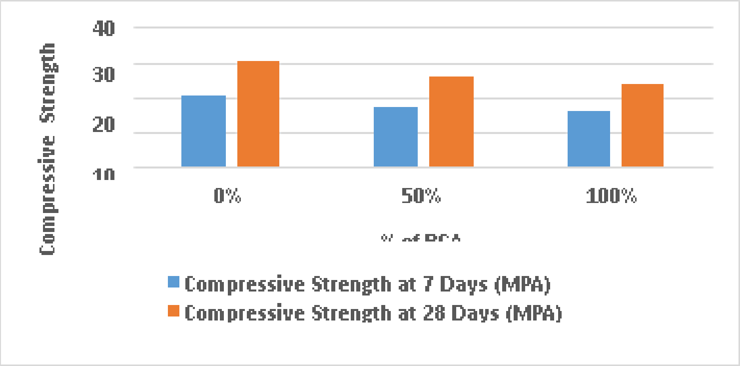

Fig.1 Comparison of Compressive Strength of concrete for various proportions of RCA.

Table 2. Results of Average Compressive strength of the Concrete for RCA %.

RCA Percentage(%)	Average Compression Load (KN)	Compressive Strength at 7 Days (MPa)	Compressive Strengthat 28 Days (MPa)
0.00	695	20.5	30.79
50.00	590	17.38	26.11
100.00	545	16.15	24.26

5. Conclusions

In conclusion, using C&D waste in low volume road building has major positive effects on the environment, the economy, and society. It fosters the circular economy, lowers the use of natural resources, improves road performance, and helps with sustainable waste management. In the present study the compressive strength of concrete is determined where, natural coarse aggregate are replaced by RCA obtained from C & D waste. From the results obtained it is concluded that the 28 days compressive strength of concrete at the 50% replacement of RCA is in close agreement with the 0% replacement.

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Use of Coconut Coir Fibre in Limestone Calcined Clay Cement (LC^3) Concrete

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Abstract

Concrete is increasingly being used in the industrial sector. Carbon dioxide (CO_2) emissions are increasing as a result of the use of concrete. Limestone Calcined Clay Cement (LC^3) is one such alternative discovered by researchers to reduce CO_2 emissions and safeguard the environment from being polluted. LC^3 is ternary blended cement prepared by 50% clinkers, 30% calcined clay, 15% low grade of limestone and 5% gypsum. Agricultural waste disposal, such as coconut coir fibres, also pollutes the environment. So, in this study, M25 grade concrete is made by combining LC^3 with Coconut coir fibre. Coconut fibre percentages such as 0.3, 0.6, 0.9, 1.2, and 1.5 were utilized to estimate compressive strength on both LC^3 and normal concrete. The result shows that using 1.2 % coconut fiber has better strength properties compare to other mixes. The use of coconut fibre decreases the workability of concrete.

Keywords: Coir fibre, Limestone, Calcined clay, Compressive strength.

1. Introduction

Concrete is one of the second largest used material in the world after water. Cement is an essential component of concrete and ordinary Portland cement (OPC) produces high carbon dioxide (CO_2) emission [1]. Rapid production of construction industries and structures using concrete is responsible for 4% - 8% of CO_2 emission in the world [2]. CO_2 emission becomes environmental issues for overcome these issues, researchers found new solution or alternative that is limestone calcined clay cement (LC^3) [3]. Use of LC^3 in construction industries reduces more than 50% CO_2 emission in the environment compare to OPC [4]. LC^3 made up of 50% cement, 30% calcined clay, 15% limestone and 5% gypsum [5]. Agricultural waste are plant residues or parts of crops that are not used for human and animal food. One of the wastes is coconut coir [6]. It is a natural fibre, extracted from outer husk of coconut (Cocos nucifera). It is used in products such as brushes, floor mats, mattresses, doormats and coir ropes etc [7]. The purpose of this work is to use of coconut coir fibre with LC^3.The parameters coconut coir fibres are 0.3%, 0.6%, 0.9%, 1.2% and 1.5% used for prediction its compressive strength (CS) 100mmx 100mm x100mm cubes on both LC^3 and normal cement. Most of researchers investigate on LC^3 so these studies aim to investigate on both limestone calcined clay cement and coconut coir fibre simultaneously.

2. Materials

Ground calcined clay, 53 grades of OPC conforming to IS 12269-2013 [8], ground limestone powder, and gypsum (manufactured by TARA in New Delhi) conforming to Indian Standard (IS) were used in the preparation of LC^3. The fine aggregates used in this proportion are size less than 4.75mm having fineness modulus (FM) 2.45. Crushed stone aggregate of size 20mm and 12.5mm were used in the proportion of 70:30 confirming to IS 383-1970 [9]. As per IS 1727-1967 the pozzolanic reactivity of calcined clay was found to be 8.35 MPa. The specific gravity of calcined clay is reported as 2.65. Coir is available in large quantities and it is renewable resources. Coir fibre is used as a raw material in this study. Each fibres are taken 20 to 25mm long and average diameter is used as 0.230 mm. The fundamental properties of coconut coir fibre is given in below Table 1.

Table 1. Properties of coir fibres

Property	Specification
Length (mm)	20-25
Diameter (mm)	0.230
Density (g/cm^3)	1.4

Table 2. Mix design of M25 grade of concrete used in this study

Sr. No.	Grade	Mix Id	W/C	Cement kg/m^3	Aggregate (Fine)kg/m^3	Aggregate (Coarse)kg/m^3 12.5(mm)	20(mm)	Workability by Slump cone (mm)
1	M25	M25-OPC	0.5	OPC-380	750.00	350.00	760.00	110
		M25-LC^3	0.5	LC^3-380	750.00	350.00	760.00	125

Figure 1. Coir Fibres

2.1 Mix proportion

In this work, M25 grade of concrete was prepared using IS 10262. Table No 2 shows the mix design of M25 grade of concrete used in this study. Total twelve different mixture with different parameters of coir fiber was used. The parameters of coir fiber which were used in this work such as 0.3%, 0.6%, 0.9%, 1.2% & 1.5%. These same parameters were used for both OPC and LC^3. The concrete was tested after 28 days of curing. All the raw materials were weighed carefully before mixing or casting. In amount of making LC^3 concrete 50 percent clinker, 30 percent limestone, 15 percent calcined clay and 5 percent gypsum were used. Mixtures of LC^3 and OPC with coir fibers carefully placed into cube mold of 100mmx100mmx100mm. A mixing process was attentively applied to make mixture homogeneous with coir fiber and to get accurate results.

2.2 Compressive strength test.

The compressive strength (CS) is determined for each cube of normal concrete and LC^3 concrete using coir fiber. The CS was tested under universal testing machine (UTM) having 2000KN capacity. The cured cubes at age of 28 days were removed from the water chamber and then were air dried for 24 hours until testing was not done. For every testing of cubes of normal cement and LC^3 with parameters of coir fibers as 0.3%, 0.6%, 0.9%, 1.2% & 1.5% were tested. Each parameter of coir fibers with normal cement and LC^3 have different compressive strength as given below in figure 2 and Table 3

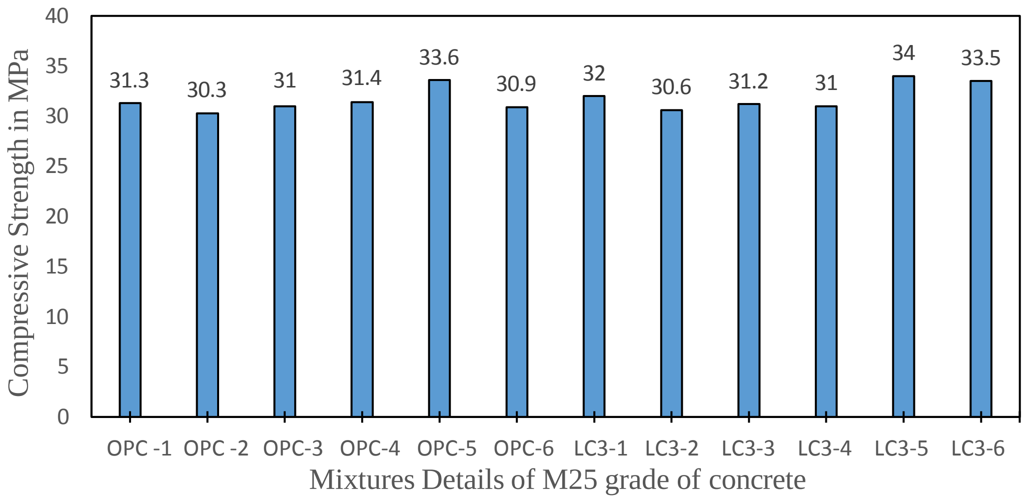

Figure 2. Compressive strength M25 grade of OPC and LC^3 concrete**.**

3. Result & Discussion

3.1 Initial properties of LC^3 cement system

The cement prepared by mix proportion of LC^3 in which initial physical properties such as CS, initial and final setting time, consistency and soundness test were taken. All test were satisfied Indian standard provision. Table 3 indicate the physical properties of materials.

Table 3. M25 grade of OPC and LC^3 concrete compressive strength

Description	LC^3 system	OPC system
Consistency	34.30 %	29.00 %
Setting Time Initial	55.00 Min.	60.00Min.
Setting Time Final	320 Min.	340 Min.
Soundness	2.10 mm	2.00mm
Specific gravity	2.80 g/cc	3.15g/cc
Fineness of cement in percentage using 90μ IS Sieve.	4.20 %	5.20 %

3.2 Compressive Strength result of M25 grade of concrete

The workability of M25 grade of OPC and LC^3concrete was 110 mm and 123mm. But as the fiber doses increases the workablity slightly decreases. The CS of M25 grade of normal concrete was 31.3 MPa as fiber increases the strength was nominally increases. At 0.3%, 0.6%, 0.9% 1.2% and 1.5 % was 30.3MPa, 31.0 MPa, 31.4 MPa, 33.6 MPa and 30.7 MPa respectively. At 1.2% of coir fiber the strength was higher than normal concrete which indicates optimum dose. The M25 grade of LC^3 system CS was 32.0 MPa. At 0.3%, 0.6%, 0.9% 1.2% and 1.5% was 30.6 MPa, 31.2 MPa, 31.0 MPa, 34.0 MPa and 33.5 MPa respectively. At 1.2% of coir fiber the strength was higher than normal concrete which indicates optimum dose. From the above observation it indicates that using coir fiber enhance the strength of normal and LC^3 system [13]. Fig.4 a) and b) shows the normal and LC^3 cubes after CS.

Fig.4 a) and b) Cubes showing after compressive strength test

4. Conclusions

In this work, M25 grade of concrete is made by combining LC^3 with coconut coir fibers. Coconut fibers parameters such as 0.3%, 0.6%, 0.9%, 1.2% & 1.5%. The testing of strength was obtained at 28 days of curing ages. The conclusions gets as follows:

1. The addition of coir fibers in normal cement and LC^3 increases strength of concrete. With an increase an amount of coir fibers in normal cement and LC^3 the CS strength increases up to certain addition after that it decreases.
2. The amount of coir fibers increases the CS in M25 grade of concrete. However, the use of 1.2% of coir fiber in M25 grade of normal concrete LC^3 concrete has highest CS of 33.6 MPa and 34.0 MPa respectively at 28 days curing age than other parameters.
3. This study shows that using coir fibers in LC^3 is very effective solution to increase the strength of concrete. It has less environmental affect and sufficient contribution to the climate caused OPC uses.

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Performance of Sugarcane Baggase ash in Compressed Stabilized earth block.

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Abstract.
Earthen materials have been used in civil engineering construction worldwide with different forms, such as mud, adobe, rammed earth and bricks. Compressed stabilized earth blocks (CSEB) can be considered as a new member of the earthen building material family. Also, it can overcome the problems associated with fired bricks and cement blocks. Cement is the most commonly used as stabilizers to enhance the properties of CSEB. The use of Compressed earth blocks (CSEBs) is a sustainable solution for building affordable and eco-friendly houses. In this study, an experimental investigation was conducted to explore the effect of sugarcane bagasse ash (SBA) as an admixture on the compressive strength and durability of CSEBs made from a blend of earth and cement. A series of CSEBs were produced with varying proportions of SBA and tested for compressive strength and water absorption. The results of the study showed that the addition of SBA significantly improved the compressive strength and durability of the CSEBs. Furthermore, it was found that the optimum replacement level of cement with SBA. The use of SBA not only enhances the strength and durability of CSEBs but also promotes the utilization of a waste product from the sugar industry, thereby reducing environmental pollution. The findings of this study have important implications for the construction industry in terms of providing an eco-friendly and sustainable alternative to conventional building materials.

Keywords: compressed stabilized earth block Mix compressive strength.

1. Introduction

Compressed Stabilized Earth Blocks (CSEBs) have emerged as a sustainable and environmentally friendly alternative for traditional building materials. These blocks are created by compacting a mixture of soil, stabilizers, and water to form a durable and cost-effective construction material. Sugarcane Bagasse Ash (SBA), a by-product of the sugarcane industry, has shown potential as a partial replacement for conventional stabilizers in CSEBs. SBA is obtained from the combustion of sugarcane bagasse, the residual fibrous material left after extracting juice from sugarcane. It contains silica and various mineral components that can enhance the strength and durability of CSEBs. By incorporating SBA into CSEB production, not only can the disposal of agricultural waste be addressed, but also the mechanical properties of the blocks can be improved.

The proportion of SBA in CSEBs plays a crucial role in determining their performance. Different percentages of SBA can influence key properties such as compressive strength, water absorption, shrinkage, and durability. These variations allow for customization and optimization of CSEBs based on specific project requirements and local availability of SBA.Previous studies have demonstrated the positive effects of SBA on CSEBs, including increased strength, reduced water absorption, improved resistance to weathering and cracking, and enhanced thermal insulation. However, the optimal percentage of SBA may vary depending on factors such as soil composition, climate, and intended application of the blocks. On the other hand, the production process of these materials is highly energy-intensive, non-eco-friendly and acts as a source of waste generator. It is reported that the Indian construction industry alone is responsible for 22% of the total green house gases emitted into atmosphere. A brick kiln emits about 70gm - 282gm of carbon dioxide, 0.001gm - 0.29gm of black carbon, 0.29-5.78gm of carbon monoxide per kilogram of brick fired depending on type of kiln and fuel used for firing.The research delves into the characteristics of soil blocks fortified with fibers derived from agricultural waste. In a controlled laboratory setting, an array of experiments was carried out, encompassing assessments of density, water absorption, shrinkage, compressive strength, tensile strength, as well as resistance to wear and erosion. These experiments were conducted on soil blocks crafted from two distinct soil types and enriched with three different fiber types, each at concentrations ranging from 0.25% to 1% by weight [4].The objective is to create a seamless and cohesive synergy between buildings and their natural surroundings by employing locally sourced earth materials in the fabrication of construction blocks [6]. The findings from a preliminary investigation indicate that higher dry density is achieved when the clay and silt content is below 15%. Additionally, the water absorption test revealed that the minimum water absorption occurs when the clay and silt content ranges between 10% to 15%. Furthermore, the compressive strength remains relatively stable within the clay and silt content range of 5% to 20%, showing no significant fluctuations [8,9]. It primarily examines the strength and elastic properties of Compressed Stabilized Rammed Earth (CSRE). The properties of CSRE are subject to variation based on factors such as soil composition, rammed earth density, cement content, and moisture levels. Fired clay bricks have undergone a trans formative evolution, marked by mass production in kilns. This evolution aligns with the increasing awareness of sustainable building materials and environmental concerns . The overview of research studies conducted worldwide on particle packing, with a specific focus on its application in concrete. Notably, it validates the suitability of the model for concrete applications. Soil properties and varying cement content impact the physical properties of compressed earth blocks and soil mortars. To achieve the desirable results, they had fabricated a series of test blocks using a diverse range of composite soils. These blocks are stabilized with both 5% and 10% cement content and compacted using a manual press. To achieve further reductions in cement consumption while maintaining performance, it becomes necessary to decrease the overall content of cementitious materials.

This research aims to investigate the influence of varying percentages of SBA on the properties of CSEBs. Through comprehensive experimental analysis, the compressive strength, water absorption, shrinkage, and durability of CSEBs will be evaluated for different SBA proportions. The findings will contribute to a better understanding of the potential of SBA as a sustainable stabilizer in CSEBs and provide valuable insights for designing optimized mixtures and guidelines for utilizing SBA in practical construction applications.In summary, the addition of Sugarcane Bagasse Ash (SBA) in Compressed Stabilized Earth Blocks (CSEBs) holds promise for improving their performance and sustainability. This research aims to determine the optimal percentages of SBA that result in enhanced strength, reduced water absorption, minimized shrinkage, and improved durability in CSEBs. The findings will contribute to the advancement of eco-friendly construction materials and promote sustainable practices in the building industry.

2.2 Material and Methodology

2.1 Materials

In the current study, soil samples were obtained from a borrow area along the Kokamthan near the bank of the Godavari River. These samples were collected at a depth ranging from 0.50 to 1 meter below the ground surface. The physical properties of the soil used in the production of compressed stabilized earth blocks (CSEBs) indicating key characteristics relevant to the study.The Stabilizing Binding Agent (SBA) was obtained from Sanjivani Sugar Factory, Kopargaon. The physical properties of SBA Table 1. It was observed that SBA contains coarser particles that closely resemble the particle size distribution of soil.

Table 1 Properties of SBA

Sr. No.	Properties	SBA
1	Color	Grey
2	Loose Bulk Density	510kg/m3
3	Compact Bulk Density	677 kg/m3
4	Fineness Modulus	2.16
5	Specific Gravity	0.49

The stabilizing agent used in the study was Ordinary Portland cement of 53 grade. The physical properties of the cement were evaluated in the laboratory, and the results are presented in Table 2.

Table 2 Properties of Cement

Physical Properties of Cement	Result
Standard Consistency	28.50 %
Soundness (Le-Chatelier App.)	2.31 mm
Initial setting time	115 minutes
Final setting time	385 minutes
Compressive strength,	
@ 3 days	30.50 MPa
@ 7 days	43.33 MPa

2.2 Production and Evaluation of Compressed Stabilized Earth Blocks (CSEBs):

In this section, the manufacturing process and testing procedures for compressed stabilized earth blocks (CSEBs) are described. This research focuses on the production and evaluation of compressed stabilized earth blocks (CSEBs) with the incorporation of sugarcane bagasse ash (SBA) as an admixture. The soil used for block manufacturing was carefully sieved to ensure particle sizes below 4.75 mm. The addition of cement at a constant weight percentage of 8% was found to enhance the compressive strength of the blocks.

Fig 1. Dry Mix of Material   Fig 2. Filling and Compaction of Material Mix

3. Result and discussion:

3.1 Density Measurement:

Density Assessment: To precisely gauge the density of the specimens, a meticulous weighing process was employed, with the collected weights serving as the basis for density calculations. The outcomes of the dry density tests, as illustrated in Graph 1 consistently demonstrate an average density spanning from 1500 kg/m3 to 2300 kg/m3 across various specimens. This observation underscores the robust and well-structured nature of the Compressed Stabilized Earth Blocks (CSEBs) manufactured in this study. This favorable density range aligns with the desired parameters for high-quality construction materials, ensuring the reliability and strength of these CSEBs for real-world applications.

3.2 Dry Compressive Strength Testing of Soil and Waste Mix Specimens: Thoroughly examining the dry compressive strength of soil and waste mix specimens has allowed for a comprehensive assessment of their strength characteristics under dry conditions. These test results yield essential insights into the structural integrity and load-bearing capabilities of these specimens. Furthermore, they furnish vital data for evaluating the applicability of the soil and waste mix in diverse construction scenarios. These tests are pivotal in guaranteeing the long-term durability and performance of Compressed Stabilized Earth Blocks (CSEBs) in practical, real-world applications. The graph 2 explains in detail the compressive strength of CSEB Blocks for given combinations.

3.3 Water Absorbtion Test : Incorporating Sugarcane Bagasse Ash (SBA) into Compressed Stabilized Earth Blocks (CSEBs) significantly lowers water absorption compared to kiln bricks. This enhancement highlights the improved water resistance and overall durability of CSEBs, positioning them as a sustainable and eco-friendly substitute for conventional bricks. Graph 3 explain the water absorption of CSEB blocks.

4. Conclusions:

Incorporating SBA significantly enhances the durability of Compressed Stabilized Earth Blocks (CSEBs), extending their lifespan and reducing maintenance requirements. Using SBA results in reduced water absorption, effectively mitigating moisture-related issues that can compromise structural integrity. SBA also contributes to lower shrinkage, which, in turn, enhances the dimensional stability of CSEBs, ensuring they maintain their shape over time.The mineral components found in SBA further bolster the strength of these blocks, improving their load-bearing capacity. Beyond performance benefits, SBA-based CSEBs provide eco-friendly advantages by utilizing agricultural waste, thereby reducing the overall environmental impact. Opting for SBA-based CSEBs can offer cost-effective solutions for construction projects, making them an economically viable choice. These blocks prove versatile, suitable for various building applications, from residential to commercial projects. Incorporating SBA promotes sustainable practices within the construction sector, aligning with Eco-conscious building trends.

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Use of Agave Fibers in Concrete to Improve Its Engineering Properties

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Abstract

Due to its strength, durability, and affordability, concrete is one of the most often used building materials. Conventional concrete does, however, have significant disadvantages, including brittle behavior, poor tensile strength, and limited ductility. Steel, fibre glass, and synthetic fibers have all been utilized as reinforcing materials to get around these restrictions. However, these materials are challenging to work with, and harmful to the environment. Concrete has been researched as an alternative reinforcement material using natural fibers including hemp and jute. This study examines the viability of employing agave fibers as a low-cost, environmentally friendly way to improve the strength and durability of concrete used in civil construction. Agave fibers were chosen because of their superior strength, low density, and global availability. The report provides a thorough description of the characteristics of agave fibers and analyses earlier studies on the use of natural fibers in concrete. A variety of concrete mixtures including various amounts of agave fibers are tested as part of the experimental programmed to see how they affect the material's compressive strength, workability, and durability. According to the results, fibers can greatly increase the strength and durability of concrete, offering a practical answer for the building sector. The results of this study important light on the potential of agave fibers as a long-lasting and environmentally friendly replacement for conventional reinforcement materials in concrete. In order to maximize the mix design and get the optimum outcomes, additional research is required to examine the long-term durability of concrete made with agave fibers.

Keywords: Agave Fibers; Concrete; Compressive Strength, Natural Fibers.

1. Introduction

The performance and durability of concrete structures have been improved by the addition of fibers, revolutionizing the construction sector. Although commonly used in construction, concrete has inherent shortcomings in terms of tensile strength, flexibility, and crack resistance. Concrete is known for its compressive strength. Different kinds of fibers have been added to concrete mixtures as reinforcements to get around these restrictions. A composite material that combines the advantages of fibers with concrete is referred to as fiber-reinforced concrete (FRC). fibers are a group of materials that resemble hair and come in single elongated segments or continuous threads, much like thread. They could be included into composite materials. In recent years, agave fibers have drawn a lot of attention as a viable and environmentally friendly alternative to conventional cementitious materials for reinforcing concrete. They are the perfect choice for improving the structural performance and sustainability of concrete because of these qualities. Agave fibers can replace or reduce the requirement for traditional reinforcement materials like steel or synthetic fibers, which has a positive impact on the environment and lowers construction costs. An ability to be recycled is one of its main benefits of Agave fibre.

Sonmali and Autade [1] have performed research study on the impact of agave fibers on compressive strength of concrete. The impacts of Agave Vera-Cruz Mill fibre on the mechanical characteristics of concrete matrix in wet and hardened state tests have been discussed by the authors. The M30 grade of concrete was tested for mechanical strengths with fiber-cement ratios of 0.05%, 0.1%, and 0.15%. With the addition of fibre, workability was shown to decrease as measured by the Vee-Bee instrument. The Vee-Bee time was recorded as 7, 10, 13, and 17 seconds, respectively, with various fiber-to-cement ratios of 0%, 0.05%, 0.1%, and 0.15 percent. Prior to compounding, Langhorst et al. [2] studied the impact of heat treatment on the mechanical performance and morphology of blue-agave fibre. The authors observed that when fibers were heated to 180°C, their secondary modulus increased by around 150% while their strain at break decreased by about 80%. Heat-treated fibers failed in a more brittle way than untreated fibers, according to morphological study of fibre fracture surfaces, which is consistent with an increase in fibre crystallinity and stiffness. Tameem et al. [3] studied the mechanical strengths of M25 grade concrete using agave fibers, varying the dosage of the fibers from 1%, 2%, 3%, and 4% by volume of cement with an ideal length of 40mm. The mechanical characteristics of M25 grade conventional concrete, including its compressive strength and split tensile, were compared. Contrary to conventional concrete, it has been found that adding fibre to concrete increases it‘s compressive and split tensile strengths. The fibre extraction, tensile, and flexural characteristics of agave fiber-reinforced epoxy hybrid composites were studied by Sathiamurthi et al. [4]. The relative fibre weight proportion can be 10, 15, 20, or 25%, and the fibre lengths can range from 1 to 4 cm. The hybrid composites with random mixed fibre reinforcement were created using the simple layup technique and compression moulding. The specimen's micro-structure was examined using scanning electron microscopy. According to experimental study, fibers with a length of 3 cm and a weight percentage of 20%

produce the greatest tensile and flexural strength values. A sustainable composite material made of Portland cement and reinforced with "Agave lecheguilla" fibers with a high tensile strength was developed by Juarez et al. [5]. The findings showed that the lechuguilla fibre, also known as "Agave lecheguilla" or simply "lechuguilla," exhibits a high tensile capacity but can suffer significant degradation in the alkaline environment of the composite. The authors draw the conclusion that the composite performs tolerably well when exposed to harsh environments and fluctuations in humidity and temperature if the fibre is protected with paraffin and the composite matrix is amended with a pozzolan admixture, such as fly ash. To achieve the best physicomechanical properties for composite materials.

The main Objective is to study the effect of on sisal fiber reinforced concrete and investigate the optimum percentage of fiber mix. Fibers are mixed in different proportions by cutting it into small pieces of sizes 25mm.To study the mechanical and transport properties of concrete for compressive test on concrete cubes (150×150×150mm).

2. Material and properties

In preparing M20 concrete, 53-grade Portland cement, fine and coarse aggregates, water, and agave fibers are used. Fine aggregates range from 0.075mm to 4.75mm and are sourced from crushed natural sand or gravel. Coarse aggregates, larger than 4.75mm, provide strength and stability. Specific gravity measures aggregate density, crucial for concrete strength. Sample sizes for sieve analysis are 500 grams for fine aggregates and 6000 grams for coarse aggregates, ensuring well-graded particles. Concrete mixing requires pure and safe water within a pH range of 6 to 8 for optimal chemical reactions during hydration in Table 1.

Table 1. Properties of material by various test

Properties of cement		Properties of fine aggregate		Properties of course aggregate	
Grade	OPC 53	Sieve Analysis result	Zone I	Sieve Analysis result	20 mm
Specific Gravity	3.15	Specific Gravity	3.12	Specific Gravity	3.07
Fineness Modulus	95%	Water Absorption	2.06%	Water Absorption	1.53%

3. Experimental methodology

Dried agave fibers used for the preparation of the present M20 concrete are extracted from the plant using the following process.

Step1: At a very initial step we just soak the freshly cut leaves in water with a normal room temperature for 7-8 days.

Step 2: After 7 days we just take out the leaves from water and scratch the leaves with wire brush. Just to remove the green skin over the leaves.

Step3: Cutting the fibers in 25mm length with the help of scissors.

Step 4: After cutting the fibers in the desired length we just dried the fibres form 3 days in shade.

4. Concrete Mix Design

In order to design concrete mixes, I.S. 10262-2009 is used. Following the calculation and mix design process, the mix proportion is found to be 1:2.14:3.17. Three cubes of standard size (150mm x 150mm x 150mm) were made for the testing mix as shown in Fig. 1. Concrete was poured, compacted, and the mould was prepared in line with I.S. 10262-2009. The samples were remolded and allowed to air dry for 24 hours. By completely submerging them for three days in potable water, all the specimens were treated. The specimens were air dried for 24 hours after the curing period was through.

Mixing of Concrete **Mixing of fibers**

Fig. 1 Preparation of concrete cube

To ascertain the compressive strength of concrete, a compression test, commonly referred to as a concrete cube test, is carried out. Concrete's capacity to support loads or endure compression is determined by its compressive strength. In order to evaluate the strength and quality of concrete constructions, this test is crucial. For the compression test on the concrete cube, the steps below must be followed.

1) Usually, these samples are taken from the batch of concrete A cube measuring 150 mm × 150 mm × 150 mm is the most typical sample shape.
2) The samples must be properly cured after being taken. This normally entails keeping the samples in a moist setting for a predetermined amount of time, typically 28 days as depicted in Fig 2a.
3) The samples are evaluated in a compression testing machine after the curing period. A hydraulic piston is used in the device to provide a compressive load to the concrete sample until it breaks. The sample cracks when the load is gradually raised.
4) Align the concrete sample correctly and set it on the compression testing apparatus (Fig. 2b). Apply a compressive load on the sample that increases progressively until it fails. The testing standard normally calls for a consistent rate of load application.
5) As demonstrated in Fig. 2c, the failure of concrete samples is typically signaled by a sharp decrease in load or a characteristic cracking sound. Once the sample fails, note the highest load that was put on it.

The testing of 3 cubes from the calculated proportion, we do not meet required target compressive strength of M20 concrete. Therefore, after some changes in the mix design proportion are done according to the trial-and-error process. The final proportion calculated is 1:1.87:3.56. Using this final mix proportion, 15 cube specimens were casted with varying percentage of Agave fibers. Total quantity of materials required for the preparation of 15 cubes. The specimens were tested after 7 days of curing. In each category there should be three specimens to be tested and average value is reported. All specimens were curved into the potable water for 7 days. After 7 days, the blocks were ready to test.

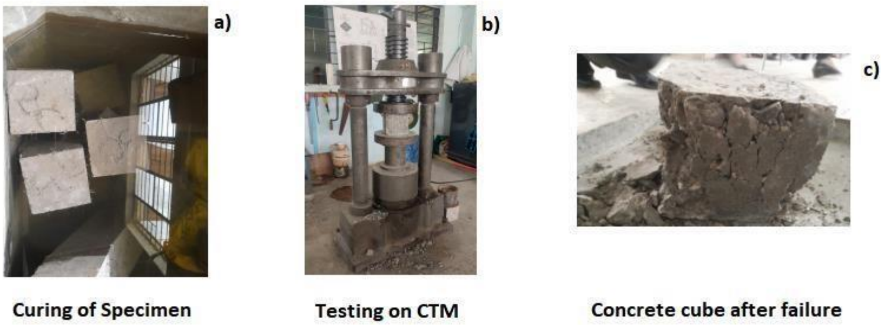

Fig. 2 Curing and testing of concrete cube on CTM

The compression strength test using a Compression Testing Machine (CTM) indicated that the initial M20 concrete mix didn't meet the required strength. A new mix proportion of 1:1.87:3.56 was established, and 15 cubes were cast with varying Agave fiber percentages. Testing was done after 7 days of curing.

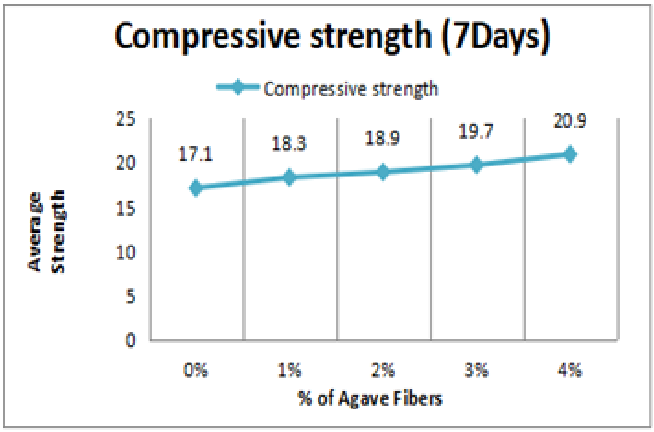

Figure 3. Compressive strength of cubes for different percentage of agave fiber

Table 2. Final Result

Sr.no	% of fibers	Number of block	Wt. of block before curing (kg)	Compressive Strength (MPa)	Average Compressive Strength (MPa)
1	0%	A	8.900	17.8	17.1
2		B	8.730	18.7	
3		C	8.775	14.9	
4	1%	A	8.375	18.9	18.3
5		B	8.605	17.3	
6		C	8.700	19.5	
7	2%	A	8.420	18.2	18.9
8		B	8.505	18.0	
9		C	8.355	20.5	
10	3%	A	8.305	20.6	19.7
11		B	8.350	19.4	
12		C	8.340	19.0	
13	4%	A	8.370	21.8	20.9
14		B	8.485	21.2	
15		C	8.895	19.8	

Table 2 shows the values of average compressive strength of concrete cube prepared with inclusion of different percentage of agave fibers. The effects of inclusion of agave fibers (1%, 2%, 3%, and 4%) in the concrete are examined with normal concrete (0%). Table 2 shows that the compressive strength increases with increase in the percentage of agave fibers. It is observed from the Fig.3 that the addition of 4% of agave fibers gives maximum compressive strength.

5. Conclusions

Increasing Agave fiber content in concrete (1%, 2%, 3%, 4%) enhances compressive strength, promoting eco-friendliness by utilizing a renewable resource. It positively impacts engineering properties, improving ductility, flexibility, and reduci ng overall weight in applications like transportation and precast elements.

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Experimental Study on Hollow Interlocking FaL-G Bricks

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Abstract:
Thermal power industries produce a large amount of fly ash, a waste product. Lime is a material used in many companies in chemical processes and deposited as waste. Phospho-gypsum is a by-product of the fertilizer industry. In our country the proper disposal of industrial waste is a big issue. To find remedial measure for disposal of industrial waste, in this study an attempt is made to check whether it is possible to create hollow interlocking bricks out of all these waste materials. The present study reveals that all these materials can be effectively used to produce an alternative to conventional burnt clay bricks. If such bricks are used in construction activities, it will help to check the land pollution which is there due to use of good agricultural clay for the manufacturing of bricks as well as avoid the air pollution due to burning of bricks. The bricks manufactured using fly ash, gypsum, and lime (Fal-G) require air drying no burning is required hence avoid air pollution as well.
Keywords: Building Material, Eco-friendly, Fly ash, Hollow Interlocking Bricks, Phospho-gypsum

1. Introduction

A practical, eco-friendly, and energy-efficient option is provided by FaL-G bricks. FaL-G bricks and blocks are replacements for the conventional burnt clay bricks used in construction as well as alternative building materials. Sintering is not a part of the FaL-G brick and block manufacturing process. Thus, by replacing the burned clay bricks, FaL-G bricks and blocks totally eliminate the need for burning fossil fuels during the production of clay bricks, which eventually reduces greenhouse gas emissions. On the other hand, interlocking brick masonry has become increasingly popular as a sustainable housing alternative to traditional bricks in many foreign nations. To satisfy this requirement, one sustainable building option would be FaL-G interlocking bricks. Production of clay bricks is responsible for loss of fertile land as well as air pollution because of coal as a fuel in burning process. The ecological balance is being preserved while also growing natural resources sustainably by employing fly ash and phosphor-gypsum in place of soil and reducing the amount of soil used to manufacture conventional bricks. Nature‘s kind heartedness is gifting the humankind with its resources of course, has a threshold limit and the utilization of clay has reached such a point in construction. This is where innovations on alternatives to clay bricks have summoned the research and development work.

Ali and Hussain [2018] carried work on different techniques were used to improve the mechanical properties of cement clay interlocking hollow bricks, sand, cement, and fly ash were used to develop new mix designs. Results showed a marked increase in the compressive strength of the newly manufactured cement clay interlocking hollow bricks as compared with the original bricks. Ambalavanam and Roja [1996] carried out research work regarding utilization of waste lime and gypsum with fly ash for FaL-G bricks, the results of study are discussed in the subsequent topics. In [2004], Shiqun Li and Jishan Hu studied weathering resistance of fly ash-lime compacts. Paper shows that the mix can offer good resistance to freezing, thawing and dry shrinkage. Eco carbon private limited Hyderabad [2006] has studied the environmental aspects and potential impacts, assessment of environmental and social impacts and done the work on identification of environmental and social issues. Analysis done on environmental aspects shows that FaL-G bricks offer a viable, energy efficient and environment friendly alternative that would contribute in reduction of emission of greenhouse gases. As such there are no specific environmental regulations marked for the FaL-G units. Overall adverse impact on environment by FaL-G bricks units has been much less than that of clay bricks kiln technology. Fly ash-lime calcined gypsum and water were the components used for study by Marincovic and kostik-Pulek [2007]. The study demonstrates that a system comprising fly ash, gypsum, and lime can produce a compact product. Bhanumathidas and Kalidas [2007] and Bhanumathidas and Kalidas [2011] studied the developing FaL-G bricks. Suggested the use of FaL-G as an alternative material for manufacturing of bricks, that the FaL-G technology can be used efficiently for manufacturing of bricks and the technology is easily accessible to the entrepreneurs of small-scale industries.

2. Materials

The lack of affordable housing is a major issue nowadays. The standard burnt clay brick is the most fundamental building material for dwellings. These bricks are made with a substantial amount of fuel. Additionally, the continuous removal of top soil during the manufacture of ordinary bricks causes environmental issues. This study‘s goal is to determine whether using FaL-G for hollow interlocking bricks as an alternative to burned clay bricks is practical.

Table 1. Mix proportions of FaL-G

Mix Design	Constituent materials (Percentage)		
	Fly Ash	Cement	Phosphogypsum
M-1	25	50	25
M-2	30	40	30
M-3	35	30	35
M-4	40	20	40
M-5	45	10	45
M-6	50	---	50

3. Result & Discussion

3.1. Normal consistency test

To determine the amount of water needed to create FaL-G cement paste with normal consistency, a normal consistency test was conducted.

Table 2. Standard consistency of mix proportions

Mix Proportion	M-1	M-2	M-3	M-4	M-5	M-6
Normal Consistency (%)	40	37.5	36.25	35	33.75	32.5

3.2. Compression test

To perform compression test, blocks of size 70.7mmx70.7mmx70.7mm was prepared and tested on compression testing machine after 7, 14 and 28 days of water curing. To calculate the compressive strength of the FaL-G cement mortar. To complete this procedure IS 10086:1982 [6] and IS 4031: 1988 [7] was used.

Table 3. Compressive strength, water absorption and dry density of mix proportions

Mix	Compressive Strength MPa			Water Absorption (%)	Dry Density KN/m^3
	7 Days	14 Days	28 Days		
M-1	10.67	16.80	23.33	21.74	17.15
M-2	9.33	15.47	21.60	22.15	17.20
M-3	9.60	14.13	19.73	23.23	16.99
M-4	6.53	12.80	18.27	20.05	17.57
M-5	4.67	10.13	13.20	24.71	16.75
M-6	0	0	0	0	0

3.3 Testing of solid interlocking FaL-G bricks

After carrying above investigation, considering all requirements for good bricks, it was decided to cast bricks using mix proportion M-4. The reasons are as M-4 consist 80% of waste material i.e., fly ash of 40% and phosphogypsum of 40%, by which brick gives strength approximately equal to 20MPa which is sufficient as compared to conventional brick, water absorption equal to 20% of weight which satisfies the criteria required for good brick and dry density equal to 17.57 KN/m^3 which is also satisfies the requirement as compared to conventional bricks.

To check the compressive strength of solid interlocking bricks, compression test was performed on solid interlocking bricks of M-4 mix proportion having a size 200mmx100mmx100mm and 100mmx100mmx100mm shown in Fig. 1. IS 3495 (Parts 1 to 4):1992 [9], IS 4031:1988 (Part-I) [7] and IS 1077:1992 [10] was used for testing.

Figure 1. Solid interlocking FaL-G bricks

Table 4 shows the variation of compressive strength of solid interlocking bricks at 7, 14 and 28 days. Also, the variation of % water absorption. It clearly seen that the compressive strength of solid interlocking bricks has gain sufficient compressive strength after 28 days of water curing is 15.25 MPa and 16.40 MPa of rectangular and square brick respectively and %water absorption equal to 20.44% and 20.02% of its weight of rectangular and square brick respectively. These results from solid interlocking bricks are satisfactory as compared with traditional burnt clay bricks.

Table 4. Compressive strength and water absorption of solid interlocking FaL-G bricks

Size of Brick	Compressive Strength MPa			Water Absorption (%)
	7 Days	14 Days	28 Days	
200x100x100mm	5.47	10.80	15.25	20.44
100x100x100mm	6.13	11.33	16.40	20.02

3.4. Testing of hollow interlocking FaL-G bricks

After carrying above investigation, the results from testing solid FaL-G interlocking brick have gain sufficient compressive strength after 7, 14 and 28 days of testing also experimental study states that the dry density and water absorption of these bricks satisfied the requirements according to Indian standards. After getting satisfactory results from solid interlocking bricks, it was decided to cast hollow interlocking bricks using mix proportion M-4.

Compression test on hollow interlocking FaL-G bricks were taken to check the performance of mix M-4 as it gives good results while tested for solid interlocking bricks. The bricks of size 300mmx150mmx100mm and 150mmx150mmx100mm shown in Fig. 2, were prepared to calculate the compressive strength of hollow interlocking FaL-G bricks. Procedure used for casting and testing of bricks is adopted from reference IS 4031:1988 (Part-I) [7] and IS 3952:1988 [8].

Figure 2. Hollow interlocking FaL-G bricks

Table 5 shows that the compressive strength of hollow interlocking bricks at the age of 7, 14 and 28 days is less than the solid interlocking bricks as well as less than the blocks of same proportions. This is because of the fact that as size of brick increases, due to change in shape of brick, possibility of formation of weak spots in the mass increases. This is true to some extent because smaller specimen can be better compacted. Also, %water absorption of these bricks is satisfactory, which are 21.92% and 19.78% of its weight of rectangular and square brick respectively

Table 5. Compressive strength and water absorption of hollow interlocking bricks

Size of Brick	Compressive Strength MPa			Water Absorption (%)
	7 Days	14 Days	28 Days	
300x150x100mm	3.66	9.14	11.39	21.92
150x150x100mm	5.01	9.75	11.82	19.78

4. Conclusions

Based on the experimental investigation reported in this study, following conclusions are drawn:

1. Unique possibility exists for the bulk utilization or fly ash in producing FaL-G bricks in the proximity of thermal power plants, phosphoric acid and fertilizer industries.
2. The test results of FaL-G cubes are having sufficient strength and have potential as a replacement for conventional burnt clay bricks.
3. From the testing of bricks for compression and water absorption it can be concluded that such bricks are having sufficient compressive strength to be used as a replacement for traditional bricks.
4. Being lighter in weight, FaL-G will reduce the dead weight and material handling cost in multi storied constructions.
5. From results of testing, it is concluded that the FaL-G holds sufficient strength to use it for casting of hollow interlocking bricks by which construction of building get easier as compared to traditional one.
6. For casting of hollow interlocking bricks, any type of material can be used but FaL-G has a plus advantages than others i.e., eco-friendly, utilization of waste and economical, these are the best reasons for adopting FaL-G for casting of hollow interlocking bricks.

The utilization of wastes in making cementitious binder will help in solving the disposal and health hazard problems. It is further needed to develop awareness among users, professionals and financial supporters for using these waste materials for techno-economic reasons in addition to balance economy and achieve energy conservation. The use of these wastes for building industries will definitely reduce the environmental pollution which will be there because of use of burnt clay bricks.

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Nationality of the Applicants	Indian
Name / Title or Description of the article to be protected in less than 15 words	Square Column Plaster Carving Trowel
Description of article, functionality and advantages of the article	**Description:** To get a perfect groove at the exterior of column **Functionality:** It is the equipment used to give design/perfect carving on circular columns. There are four angular grooves made inside the circumference of the sheet to print design easily.Nut-bolts are used to fix the both end which provide smooth operation during working. **Key Features:** 1) It is easy to handle 2) Maintain accuracy efficiently 3) Saves time and money 4) Does not require skilled labour
Perspective view	

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तारीख / Date	:	30/08/2023
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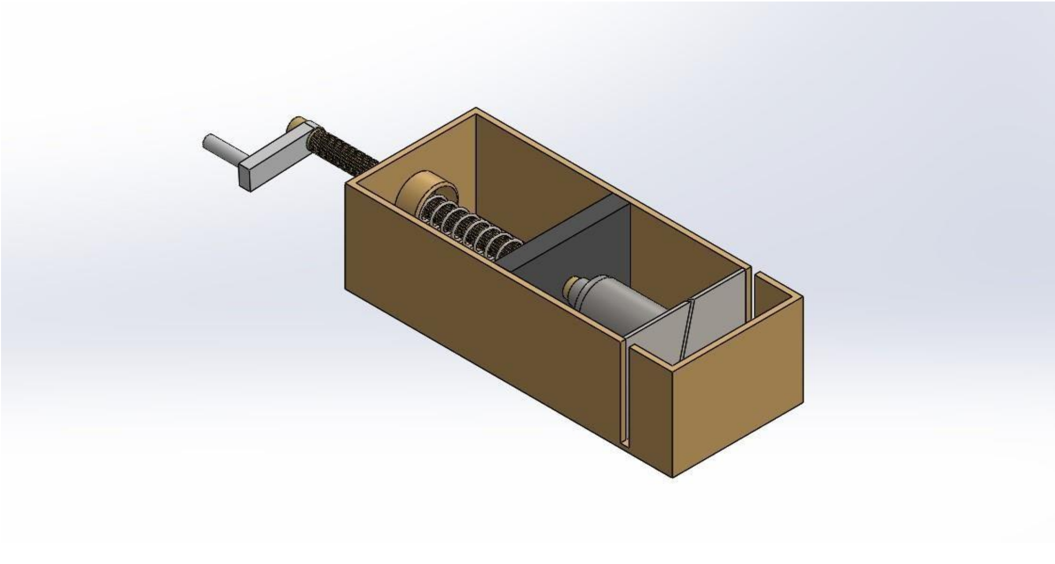
Nationality of the Applicants	Indian
Name / Title or Description of the article to be protected in less than 15 words	**Plastic bottle fiber cutter**
Description of article, functionality and advantages of the article	**1) Description:** A plastic bottle cutting mechanical device, consisting of a handle, has been created to extract fibers from discarded. bottles. Within the metal box (D), there is a rotating spring arm (A) connected. to a sliding plate (C) that facilitates pushing the bottle forward while the fiber is drawn from the bottom of the stationary bottle. Once the bottle is securely placed in the frame, only a slight pulling force is needed to extract a strip of fiber. **2) Functionality:** The bottle fiber cutter operates similarly to a stapler machine, where an empty plastic bottle is fixed, and its fibers are extracted for various purposes. It utilizes a straightforward spring mechanism that involves pulling a thread from the plastic bottle to retrieve the desired fibers. **3) Key Features:** 1. Simple and time saving operation. 2. No special adjustment and per-requirements for operation. 3. No electricity requirement. 4. Mobile and handy so can be transported at requited location,
Perspective view	

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Full name and address of the applicant/s	Sanjivani College of Engineering 1) Dhamane Pratik Pramod 2) Shinde Bharti Machhindra .
Nationality of the Applicant/s	Indian
Name / Title or Description of the article to be protected in less than 15 words	Autoclaved Aerated Concrete Block Cutter
Description of article, functionality and advantages of the article	**Description:** Autoclaved Aerated Concrete (AAC) Block Cutter is designed for application in field of cutting the AAC concrete blocks. It helps us to give smooth finish to block within less time and proper accuracy. It helps to manufacture blocks within stipulated time. It is more efficient to cut the block with proper scale. **Functionality:** Autoclaved Aerated Concrete Block Cutter is combination of metal stand, Cutting blade and horizontal metal stand. The cutter is vertically fitted on the metal stand. AAC block is kept below the height of steel cutter, which allow to cut the AAC block with smooth finish in vertical direction. It is having two folding stands on which scale is marked on one of the top surfaces of stand, which gives the idea of measurement for smooth cut of the AAC block. **Key Features:** 1) Easiest way to cut the AAC Block. 2) Reduced Damages of AAC block. 3) Cutting of AAC block is clean and efficient with proper measurement cuts. 4) Require less workmanship. 5) Reduce wastage. 6) Maintenance cost of Cutting blade is very negligible.
Perspective view	

FACULTY ARTICLES

Discussion on nonlocal continuum theories

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Abstract

Since the classical continuum theories are insufficient to account the small size effects of nanostructures, the nonlocal continuum theories such as Eringen‘s nonlocal elasticity theory, couple stress theory, strain gradient theory and surface elasticity theory have been proposed by researchers to predict the accurate structural response of nanostructures. The present article discusses the development and applications of these nonlocal continuum theories.

Keywords: Nonlocal continuum theories; Eringen‘s nonlocal elasticity theory; Couple stress theory, Strain gradient theory; Surface elasticity theory.

Introduction

Nanostructures are the most widely used nanostructures in small size devices such as micro- and nano-electro-mechanical systems such as atomic force microscopes, micro-resonators, micro-switches, micro-actuators, etc. [1, 2]. Since the classical continuum theories are insufficient to account the small size effect of nanostructures, the nonlocal continuum theories such as strain gradient theory, couple stress theory, modified couple stress theory, surface elasticity theory, and Eringen‘s nonlocal elasticity theory have been proposed by many researchers to predict the accurate response of nanostructures.

Eringen’s nonlocal elasticity theory

One of the most popular size dependent continuum mechanics models used by researchers for the analysis of nanostructures is the nonlocal elasticity theory of Eringen [3-12]. According to the Eringen, the stress at a location depends on both the strain there and the strains at all other points throughout the body. As a result, Eringen's integral constitutive equation-based formulation of nonlocal elasticity theory is as follows:

$$\sigma_{ij}^{NL} = \int_{\bar{x}} \bar{k}(|x-\bar{x}|, \mu_0)\sigma_{ij}^{L}\, dx \tag{1}$$

where σ_{ij}^{NL} and σ_{ij}^{L} represents the nonlocal and local stress tensors respectively; $\bar{k}$ represents the kernel function which is determined using nonlocal parameter ($\mu_0 = e_0{}^2a^2$) and neighborhood distance$|x-\bar{x}|$. e_0 represents the material constant and a is the internal characteristics length. By considering a specific kernel function ($\bar{k}^2 = \mu_0$), and laplace operator (∇), Eringen reformulated the nonlocal constitutive equation in a differential form as,

$$(1-\mu_0\nabla^2)\sigma_{ij}^{NL} = \sigma_{ij}^{L} \tag{2}$$

For the isotropic nanobeams, the explicit form of Eq. (7) is expressed as

$$\sigma_x - \mu_0\frac{d^2\sigma_x}{dx^2} = E\varepsilon_x \quad \text{and} \quad \tau_{xz} - \mu_0\frac{d^2\tau_{xz}}{dx^2} = G\gamma_{xz} \tag{3}$$

where E and G are the Young‘s modulus and shear modulus of the nanobeams, respectively. For the functionally graded nanobeams, the explicit form of Eq. (7) is expressed as

$$\sigma_x - \mu_0\frac{d^2\sigma_x}{dx^2} = E(z)\varepsilon_x \quad \text{and} \quad \tau_{xz} - \mu_0\frac{d^2\tau_{xz}}{dx^2} = G(z)\gamma_{xz} \tag{4}$$

where $E(z)$ and $G(z)$ are the Young‘s modulus and shear modulus of the functionally graded nanobeams, respectively. In the case of functionally graded nanobeams, material properties can be graded through the thickness of the beam. The local constitutive relations for the isotropic and functionally graded beams are recovered by setting nonlocal parameter (μ_0) equal to zero in Eqs. (2)-(4). The nonlocal parameter is problem dependent.

Couple stress theory

Many researchers have used couple stress theories for the modeling and analysis of homogenous and non-homogenous nanobeams. The couple stress theory was introduced in 1960s [13-21]. One of the higher order continuum theories, the couple stress theory, contains two additional material length scale parameters in addition to the conventional constants for an isot ropic elastic material. Second-order displacement gradients are a component of couple stress theories. A generalized formula for calculating the bending inertia of a circular cross-section has been developed by the author. The strain energy (U) expression resulting from strains and stresses can be stated as follows, according to the modified couple stress theory.

$$U = \int_V \left(\sigma_{ij}\varepsilon_{ij} + m_{ij}\chi_{ij}\right)\, dV \tag{5}$$

where

$$\begin{gathered}
\sigma_{ij} = \lambda\, tr(\varepsilon)\delta_{ij} + 2\mu\varepsilon_{ij} \\
\varepsilon_{ij} = \frac{1}{2}\left[(\nabla u)_{ij} + (\nabla u)_{ij}^T\right] \\
m_{ij} = 2l_0^2\mu\chi_{ij} \\
\chi_{ij} = \frac{1}{2}\left[(\nabla\theta)_{ij} + (\nabla\theta)_{ij}^T\right] \\
\theta = \frac{1}{2} curl(u)
\end{gathered} \tag{6}$$

where V is the volume, σ_{ij} is the Cauchy stress tensor, ε_{ij} is the classical strain, m is the deviatoric part of the couple stress tensor, χ is the symmetric part of the curvature tensor, u is the displacement vector, θ is the rotation vector, ∇ is the gradient operator, l_0 is the material length scale parameter which shows the couple stress influences and δ_{ij} is the Kronecker delta. λ and μ are the Lame's constants that can be defined as a function of Young's modulus and Poisson's ratio for homogenous and functionally graded nanobeams

Strain gradient theory

Numerous researchers that are interested in the bending, buckling, and free vibration analysis of homogeneous and non-homogeneous nanobeams have also become interested in the nonlocal strain gradient theory. The total deformation energy in the strain gradient theory depends not only on the first-order deformation gradient but also on the second-order deformation gradients, which are broken down into the symmetric rotation gradient tensor, deviatoric stretch, and dilatation gradient vector [22-30]. The dilatation gradient vector (l_0), deviatoric stretch (l_1), and symmetric rotation gradient (l_2) tensors are three additional material length scale parameters included in this theory. The strain energy (U) expression can be expressed using the strain gradient theory as follows.

$$U = \frac{1}{2}\int_V \left(\sigma_{ij}\varepsilon_{ij} + p_i\gamma_i + \tau_{ijk}^{(1)}\eta_{ijk}^{(1)} + m_{ij}^{(s)}\chi_{ij}^{(s)}\right)\, dV \tag{7}$$

where

$$\begin{gathered}
\varepsilon_{ij} = \frac{1}{2}\left(u_{i,j} + u_{j,i}\right) \\
\gamma_i = \varepsilon_{mm,i} \\
\eta_{ijk}^{(1)} = \eta_{ijk}^{s} - \frac{1}{5}\left(\delta_{ij}\eta_{mmk}^{s} + \delta_{jk}\eta_{mmi}^{s} + \delta_{jk}\eta_{mmj}^{s}\right) \\
\eta_{ijk}^{s} = \frac{1}{3}\left(u_{i,jk} + u_{j,ki} + u_{k,ij}\right) \\
\chi_{ij}^{(s)} = \frac{1}{4}\left(e_{ipq}\varepsilon_{qj,p} + e_{jpq}\varepsilon_{qi,p}\right)
\end{gathered} \tag{8}$$

Here V is the occupied region (volume), ε_{ij} is the classical strain, γ_i is the dilatation gradient tensor, $\eta_{ijk}^{(1)}$ is the deviatoric stretch gradient tensor, and $\chi_{ij}^{(s)}$ is the symmetric rotation gradient tensor, ui and uj are the displacement vector, ε_{mm} is the dilatation strain, and η_{ijk}^{s} is the symmetric part of the second order displacement gradient tensor, δ_{ij} and e_{ijk} are the Knocker symbol and the alternate symbol respectively; a comma followed by a subscript denotes differentiation with respect to the subscript. The constitutive relation is as follows

$$\begin{gathered}
\sigma_{ij} = \lambda\, \varepsilon_{mm}\delta_{ij} + 2\mu\varepsilon_{ij} \\
\tau_{ij}^{(1)} = 2\mu l_1^2\eta_{ijk}^{(1)} \\
m_{ij}^{s} = 2\mu l_2^2\chi_{ij}^{s} \\
\chi_{ij}^{s} = \frac{1}{2}\left[\theta_{i,j} + \theta_{j,i}\right] \\
\theta_i = \frac{1}{2}\left(curl(u)\right)_i \\
p_i = 2\mu l_0^2\gamma_i
\end{gathered} \tag{9}$$

where l_0, l_1 and l_2 are the material length scale parameters corresponding to dilatation gradients, deviatoric stretch gradients, and symmetry rotation gradients respectively; θ_i is the infinitesimal rotation vector.

Surface Elasticity Theory

In the modeling and analysis of nanostructures, surface effects and small-scale parameter effects both play significant roles. The surface elasticity theory was created to explain how surfaces affect nanostructures. Models of the surface [31–39] depict it as a two-dimensional membrane that adheres to the underlying bulk substance.

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Experimental Study on Behavior of Steel Fibers and Welding Steel slag waste in Bituminous Mixes (Bitumen Concrete) using Microwave Heating and Self-Healing mechanism

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Abstract

India is country with its large area connected with various National highways, Expressways, State highways major district roads, other district roads and village roads 5,603,293 km which is second largest road network of which almost 90% of the metaled roads as bitumen or asphalt roads which has high maintenance cost and less durability. Heavy traffic and congested road network create traffic jams areas of road maintenance and also now a days potholes are increasing which is more troublesome for users so there is need to find different materials and methods that can increase durability and reduce maintenance cost of roads. Steel fabrication industry releases hundreds of tons of welding steel slag each year in accordance with the World Steel Association report. Due to the landfill disposal solution, this by-product causes many environmental problems, especially concerns on the leaching issues. Road construction has consumed a significant number of nonrenewable resources from our planet. Hence, the utilization of welding steel slag as a replacement for conventional aggregate in HMA is a promising key to release environmental pressure and reserve the natural resources. Extending the service life of an asphalt surface layer is always a continuing desire. This can be done by improving the quality of the product when lying. Another possibility is to upgrade the quality throughout the service's life. This is the method to Self-Healing Asphalt.

Keywords: Asphalt, Self-healing, Microwave heating, Induction heating

1. Introduction

The social preference for wider use of noise reducing road surfaces is growing and growing. On the other hand there are also many negative experiences with this type of road surfaces, especially at locations with high traffic loads. This causes an inhibitory effect on the application of silent roads. For example, durability problems occur on roads with large amounts of motorized vehicles, at intersections, in road bends or alongside parking lots. If some of these critical locations are present in a road, the entire stretch of road can then not be provided with a noise reducing asphalt surface layer. The new availability of the Self-Healing technique changes that. By adding fine steel fibers to the asphalt mix at the critical locations, the road surface will be able to "be healed" locally at those critical locations during its life span. This healing action takes place by a mobile induction apparatus along the road surface. By using the steel fibers as a heat transport medium, a short "heat-shot" is brought into the surface asphalt layer. This will cause the binder inside the asphalt to partially melt, closing the possible fine cracks within the asphalt mixture. The asphalt mixture will thus be "reset" and a new life span can begin.

Objective of Investigation

The main objective of this study was to test the hypothesis that a new generation of asphaltic materials could be artificially healed by embedding metallic fibers and welding steel slag waste in the mix and by applying a magnetic field at the surface.

1. Use of waste products of the steel fabrication industry that is welding slag replacing aggregates in asphalt roads and use steel fibres.
2. To study and analyse self-healing capability of asphalt using steel fibers.
3. Selection of proportion materials that we use to reduce the maintenance cost of asphaltic road pavement at same time increase self-healing capacity of asphalt mix.

To evaluate the efficiency steel slag and steel fibers of road, increase the life span by increasing self-healing capacity

2. Material and Methodology

Materials

1. Bitumen used in project

Bitumen is binding material that holds aggregates together and also keeps pavement layers intact. Penetration grade of the bitumen used for mixture preparation was 60/70 mm at 25 C. The bitumen content for all mixtures was 6% by volume, which considered the fresh bitumen and the optimum bitumen contain is found by marshall stability test.

2. Aggregates

Aggregate can be rounded like gravel or angular like crushed stone and still make for a good mixture. The decision about the best aggregate for any project is usually a joint decision between the producer and the contractor. Part of that decision-making process has to do with the availability of materials, the production capabilities and economic concerns. Aggregate used in project Angular, artificially crushed stone aggregates of Size: 150um, 300um, 600um 4.75mm 6.3mm, 10mm, 12.5mm, 20mm, 25mm.

3. Steel fibres

Steel fibres waste produced during threading, cutting and edging in steel fabrication industry were collected. Size of steel fibres is 10mm to 16 mm with average thickness 0.5mm and width 0.5 to 2mm. Steel fibres are formed of ferrite steel with a density of 7.40 g/cm3-7.9 g/cm3. Both short and long shavings with different types of geometries were added to the asphalt matrix. Some shavings had heical/spiral shape while others were curled long metal fibres.

4. Welding steel slag waste

Welding slag waste produced during welding and cutting of metal plates bars etc. in fabrication industry were collected.

Methodology

Marshall Mix design

For preparation of sample of asphalt mixture following aggregate weights were used

Table 1: Aggregate size and weight for sample preparation

Sr.no.	Passing- Retained	For Course graded (gm)
1	25mm-20mm	420
2	20mm-10mm	96
3	10mm-4.75mm	204
4	4.75mm-600 microns	324
5	600microns-300microns	60
6	300microns -200microns	36
7	200microns-75microns	36
8	Passing 75 microns-Pan	24
	TOTAL	1200

Preparation of asphalt mixture specimens

The sequence for the preparation of asphalt mixtures was the following: 1) heat the aggregates, bitumen, and bowl at 150 C before mixing; 2) place the hot bitumen in the hot metallic bowl; 3) gradually add metal fibres or welding steel slag to the bitumen, constantly stirring the bitumen to avoid clusters of fibres; 4) add four small batches of aggregate blend, starting with the batch with the largest particles. Once each batch of particles was completely coated with fresh bitumen, the next batch with smaller particles was added to the mixture. Once all batches of aggregate had been added, and the mixture was homogenous, a sample of approximately 1200 g was placed in a pre-heated Marshall mold. Then the mixture was compacted using a Marshall hammer, giving 50 blows to each face of the specimen. The cylindrical Marshall specimens, 100mm in diameter and approximately 60mm in height, were left at room temperature in the laboratory for at least one day. The next step was to produce four semi-circular samples by cutting one Marshall specimen, first through its diameter, and secondly through a plane parallel to the original specimen face using a saw for asphalt. Thus, the dimensions of the semi-circular asphalt samples were 100mm in diameter and approximately 63mm thick.

Proportioning aggregates | Heating and mixing of materials | Sample preparation in marshall mould | Final sample

Figure 3: Processes in sample preparation

3.Results and Discussion

Test Results

Tests on Aggregates

The following tests are carried out on aggregates:

1. Specific Gravity of Aggregate- The specific gravity of aggregate is considered to be a measure of strength or quality of aggregate. Low specific gravity may indicate high porosity and therefore poor durability and low strength Density basket method was used to measure the specific gravity of aggregates Specific gravity of aggregate is 2.78, so aggregates have high strength.
2. Aggregate crushing strength- The principle mechanical properties required in road stones are:
   a. Satisfactory resistance to crushing under the roller during construction
   b. Adequate resistance to surface abrasion under traffic Compression Testing Machine (CTM) was used for test. The average crushing value of aggregate is 21.34% <30%, So aggregate can be used for any type of pavement.
3. Los -Angeles Abrasion test- The principle of loss–Angeles‘s abrasion test is to find the percentage wear due to the relative rubbing action between the aggregate and steel balls used as abrasion charge. Los Angeles abrasion machine was used for test. Los Angeles abrasion value is 16.8% < 30% so aggregate can be used in bituminous pavement.
4. Impact value test-Toughness is the property of material to resist impact. Due to traffic loads, the stones are subjected to pounding action or impact and there is breaking of stones into smaller pieces. The road stones should therefore, be tough enough to resist fracture under impact. Average aggregate impact value is 12.33 % is between 10-20 % So aggregate are strong and can be used in bituminous carpet road.

Tests on Bitumen

1. Ductility test- Bitumen serves as satisfactory binder in physical interlocking of aggregate the binder material which does not possess sufficient ductility would crack and thus provide pervious pavement surface. Briquette mould and ductility machine was used for test.
1. Average ductility value is 79.33 cm .so bitumen is ductile
2. Penetration test- Consistency of bitumen property required to know whether bitumen is too hard or soft so to measure it we use penetration test. Penetrometer was used to measure penetration value at 25 C. Average penetration value of bitumen used is 68.33 mm, so bitumen penetration grade is 60/70, So bitumen sufficiently ductile.
3. Softening point test- Softening point is the temperature at which substance attains particular degree of softening under specified condition of test. Ring and ball apparatus was used to test softening point, Softening point of bitumen used was 47 ^{0}C
4. Viscosity test- The degree of fluidity at the application temperature greatly influences the ability of the bituminous material to spread, penetrate into the voids and also coat the aggregates and hence affects the strength characteristics of resulting paving mixes. Apparatus used for test is viscometer with 10 mm orifice. Viscosity value from test was 54 seconds.
5. Specific gravity of Bitumen- The density of bitumen binder is a fundamental property frequently used as and aid in classifying the binders for use in paving jobs. Specific gravity of bitumen used is 1.12

Stability Test Results

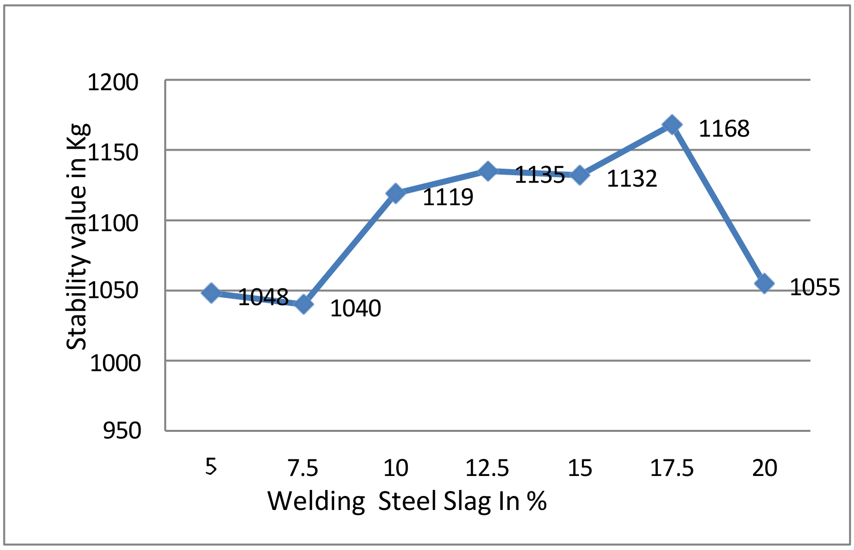

Fig 8: Stability curve for bitumen and Stability curve for Welding steel slag

From above graphs optimum content of bitumen is 6%, welding steel slag is 17.5% and that of steel fibres is 5% by weight of mix.

4. Conclusions

After analyzing result in this project following conclusions are drawn

a. Steel fibres and welding steel slag can be successfully used in asphalt road
b. Optimum bitumen content for tests is 6% by weight of aggregate.
c. Optimum content of welding steel slag and steel fibres are 17.5 and 5% respectively by weight of mix.
d. Both welding steel slag and steel fibres showed the healing capabilities using microwave heating.
e. Steel fibres showed higher efficiency of healing in first healing cycle i.e. 83.67%.

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Seismic Analysis of Vertically Irregular RC Building Frames

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Abstract. This Project is concerned with the effects of various vertical irregularities on the seismic response of a structure. The objective of the project is to carry out Time history Analysis (THA) of vertically irregular RC building frames. Comparison of the results of analysis of irregular structures with regular structure was done. Two types of irregularities, namely mass irregularity, stiffness irregularity were considered. According to our observation, the mass irregular structures were experiencing larger base shear than similar regular structures. The stiffness irregular structure experienced lesser base shear. The absolute displacements obtained from time history analysis of Mass irregular structure at respective nodes were found more displacement for all stories than that in regular structures. When time history analysis was done for regular as well as stiffness irregular structure, it was found that displacements of upper stories did not vary much from each other but as we moved down to lower stories the absolute displacement in case of soft storey were higher compared to respective stories in regular structure. Tall structures were found to have low natural frequency hence their response was found to be maximum in a low frequency earthquake. It is because low natural frequency of tall structures subjected to low frequency earthquake leads to resonance resulting in larger displacements. If a high rise structure (low natural frequency) is subjected to high frequency ground motion then it results in small displacements. Similarly, if a low rise structure (high natural frequency) is subjected to high frequency ground motion it results in larger displacements whereas small displacements occur when the high rise structure is subjected to low frequency ground motion.

Keywords: Time history Analysis, mass irregularity, stiffness irregularity, base shear, displacement

1.Introduction

During an earthquake, failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. For example structures with soft storey were the most notable structures which collapsed. So, the effect of vertically irregularities in the seismic performance of structures becomes really important. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the ‗regular' building.

The irregularity in the building structures may be due to irregular distributions in their mass, strength and stiffness along the height of building. When such buildings are constructed in high seismic zones, the analysis and design becomes more complicated. There are two types of irregularities.

1.1 Structural irregularity

A. Plan Irregularities

B. Vertical Irregularities

a) Stiffness Irregularity- Soft Storey-A soft storey is one in which the lateral stiffness is less than 70% of the storey above or less than 80% of the average lateral stiffness of the three storeys above.

b) Mass Irregularity- Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storey. In case of roofs irregularity need not be considered.

c) Vertical Geometric Irregularity- A structure is considered to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey.

d) In-Plane Discontinuity in Vertical Elements Resisting Lateral Force- An in-plane offset of the lateral force resisting elements greater than the length of those elements.

e) Discontinuity in Capacity- Weak Storey-A weak storey is one in which the storey lateral strength is less than 80% of that in the storey above.

1.2 Objective of study

- To study two irregularities in structures namely mass, stiffness and vertical geometry irregularities.
- To calculate the design lateral forces and displacement on regular and irregular buildings using time history analysis and to compare the results of different structures.

2.Literature Review

Valmundsson and Nau [1] studied the ―Seismic response of building frames with vertical structural irregularities‖ In this study, the earthquake response of 5, 10, and 20story framed structures with non-uniform mass, stiffness, and strengthdistributions has been evaluated. The structures were modelled as two-dimensional shear buildings. The response calculated from TH analysis was compared with that predicted by the Equivalent lateral force procedure embodied in UBC. Based on this comparison, the aim was to evaluate the current requirements under which a structure can be considered regular and the ELF provisions applicable.

Han-Seon Lee and Dong-Woo KO [2] studied the ―Seismic response of high-rise rc bearing-wall structures with irregularities at bottom stories‖ In this paper three 1:12 scale 17-story RC wall building models having different types of irregularity at the bottom two stories to the same series of simulated earthquake excitations to observe their seismic response characteristics. The study investigate through shaking table test. The first model had a symmetrical moment-resisting frame (Model 1), the second had an infilled shear wall in the central frame (Model 2), and the third had an infilled shear wall in only one of the exterior frames (Model 3) at the bottom two stories. The total amounts of energy absorption by damage are similar regardless of the existence and location of the infilled shear wall. The largest energy absorption was due to overturning, followed by the shear deformation.

C.J. Athanassiadou [3] studied the ―Seismic performance of R/C plane frames irregular in elevation‖ This paper addresses multi storey reinforced concrete (R/C) frame buildings with setbacks, i.e. a reduction of the length of the building along its height (irregularity in elevation).In this ten storey frame was designed in that 2 frames have two & four large setbacks in the upper floors respectively, as well as a third one, regular in elevation for the high (DCH) and medium (DCM) ductility classes, and the same peak ground acceleration (PGA) and material characteristics. All frames have been subjected to both inelastic static pushover analysis and inelastic dynamic time-history analysis. DCM frames were found to be stronger and less ductile than the corresponding DCH ones. The over strength of the irregular frames was found to be similar to that of the regular ones, while DCH frames were found to dispose higher over strength than DCM ones. Pushover analysis seemed to underestimate the response quantities in the upper floors of the irregular frames.

Poonam et al. [4] studied the ―Study of Response of Structurally Irregular Building Frames to Seismic Excitations‖ in this present study 10-storey building frame is considered with 5 different irregularities as taken from IS 1893-part-1: 2002. This frame have been analyzed using equivalent static method. The analysis has been carried out on CSI-ETABS program. Results of the numerical analysis showed that any storey, especially the first storey, must not be softer/weaker than the storeys above or below. Irregularity in mass distribution also contributes to the increased response of the buildings. The irregularities, if required to be provided, need to be provided by appropriate and extensive analysis and design processes.

M. Pavan Kumar and Singuri Sirisha [5] studied the ―Effect of vertical discontinuity of columns in R.C. frames subjected to different wind speeds in india‖ In the present study, effects of the structural irregularity which is produced by the discontinuity of a columns in RC space frames subjected to different wind loads was investigated. Investigation was carried out for R.C space frames, with and without vertical discontinuity of columns for G+5, G+10 & G+15 storeys, assumed to be located in different wind zones in India. Both regular and irregular structures were analysed using STAADPro. From the study, it was concluded that frames without vertical discontinuity of the columns having more stiffness when compared to frames with vertical discontinuity of columns.

3.Modeling of Structure

1.2 Identification of problem and statement:

To study behaviour of structure under Seismic performance I have consider 10 storey structure. In that one Regular structure and two Irregular structures will consider- Mass irregular structure, structure with ground storey as the soft storey. Time History Analysis will perform on regular and various irregular buildings using Staad-Pro. The Base shear and Displacement will calculate for each floor and graph will plot for each structure.

1.3 Modelling Parameters:

DESCRIPTION	SIZE
Dimensions	15m X 24m
No. of lines in X-direction	3
No. of lines in Y-direction	6
Spacing in X-direction	5
Spacing in Y-direction	4
Height of storey	3.5 m
Beam	0.400 m X 0.350 m
Column	0.400 m X 0.400 m
Concrete	M25
Steel	Fe415
Thickness of slab	0.150 m
Thickness of wall	0.230 m

Live Load	3kN/m2
Density of RCC considered:	25kN/m3
Density of infill	20kN/m3
Earthquake Zone	IV
Damping Ratio	5%
Response reduction Factor	5
Type of structure	Special Moment Resisting Frame
Type of Soil	Rocky
Importance factor	1

1.4 Modelling:

I. Regular structure (10 storeys):

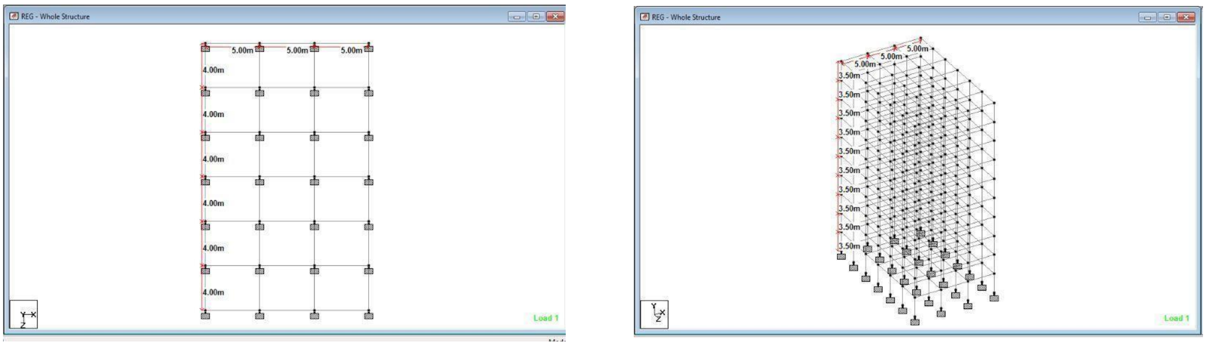


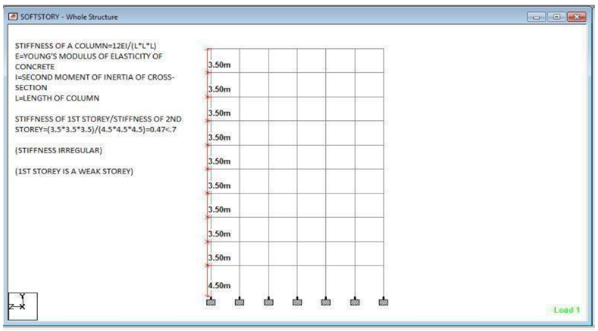
Fig 3.1: plan & 3D view of regular structure (10 storeys)

II. Stiffness Irregular Structure (10 storeys) (Fig 3.3):

The structure is same as that of regular structure but the ground storey has a height of 4.5 m and doesnt have brick infill.

III. Mass Irregular Structure (10 storeys) (Fig 3.4):

The structure is modelled as same as that of regular structure except the loading due to Library heavy equipment etc. are provide in the first and eighth floor



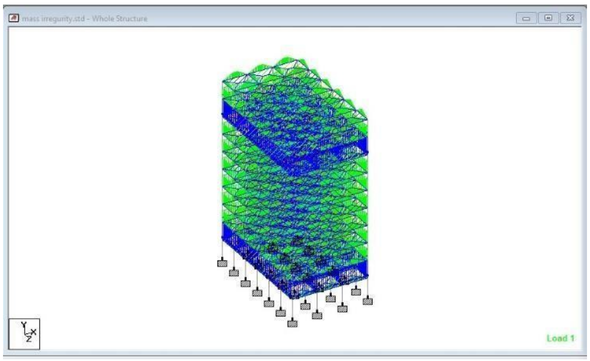


Fig 3.3: stiffness irregular structure (10 storeys)

Fig 3.4: Mass irregular structure (10 storeys)

2. Results and Discussion-

2.1 Results for Regular Structure:

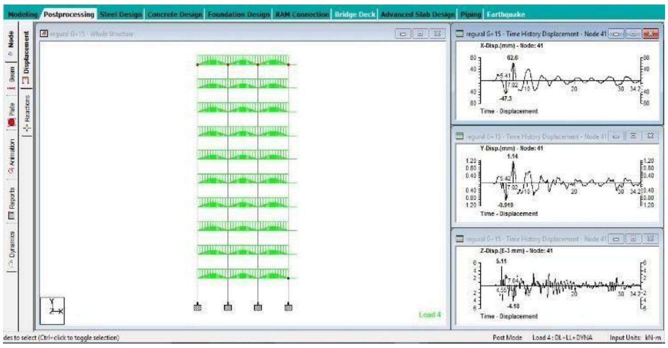


Fig. 4.1: Time history displacement of the highlighted node of stiffness irregular structure

4.2 Results for Stiffness Irregular Structure:

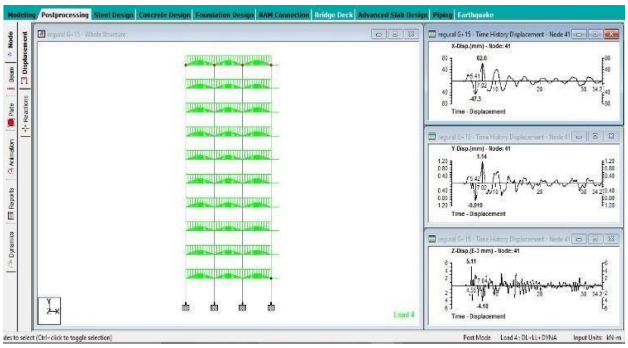


Fig. 4.1: Time history displacement of the highlighted node of stiffness regular structure

4.3 Results for Mass Irregular Structure:

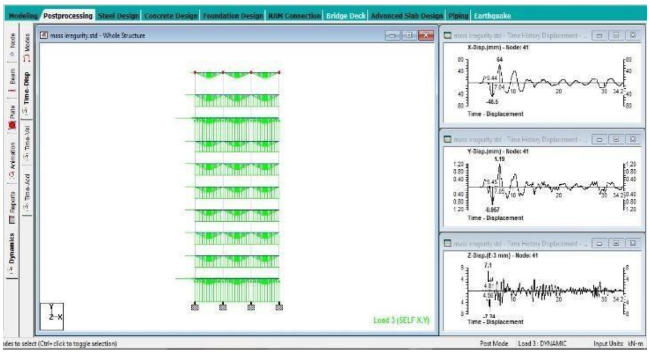


Fig. 4.3: Time history displacement of the highlighted node of Mass irregular structure.

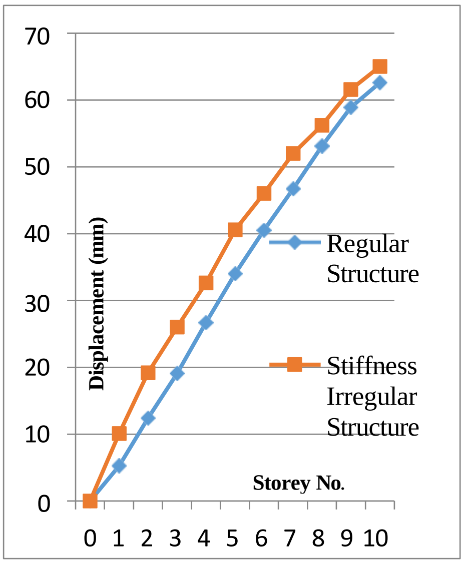
Results for Displacement -

Storey no.	Displacement (mm) For regular structure	Displacement (mm) For Stiffness Irregular structure	Displacement (mm) for Mass Irregular Structure
1	05.23	10.10	4.93
2	12.40	19.20	12.70
3	19.10	26.00	20.40
4	26.70	32.60	26.50
5	34.00	40.58	34.50
6	40.50	46.01	41.30
7	46.70	52.00	48.10
8	53.10	56.23	55.10
9	58.9	61.59	60.70
10	62.60	65.02	64.00

4.4 Base Shear for different Cases

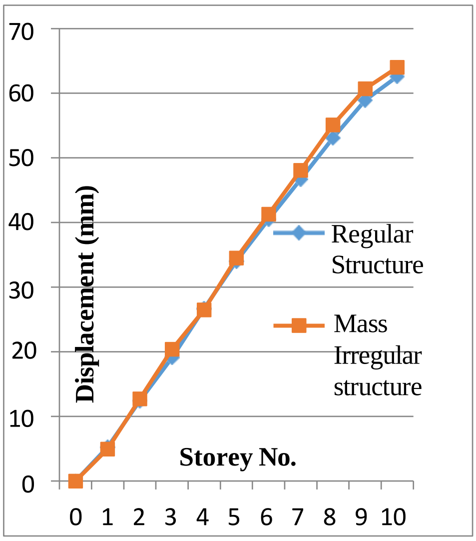
Structure	Regular	Stiffness Irregular	Mass Irregular
Base Shear (KN)	980	877	1190

4.5 Comparison of Time history displacements of different floors of Regular structure and Stiffness Irregular structure



Graph 4.1: Combined Displacement Graph

4.6 Comparison of Time history displacements of different floors of Regular structure and Mass Irregular structure



Graph 4.2: Combined Displacement Graph

Graph 4.1 shows that Displacement of Regular structure is comparatively less than Stiffness Irregular Structure. Displacement of Irregular structure is 4% more than Displacement of Regular structure. Having the Low Displacement is good for Structure. So regular structure is beneficial from displacement point of view.

Graph 4.2 that Displacement of Regular structure is comparatively less than Mass Irregular Structure. Displacement of Irregular structure is 3% more than Displacement of Regular structure. Having the Low Displacement is good for Structure So Regular structure is beneficial from displacement point of view.

4. Conclusions

1. The Mass Irregular Structure shows 3% more Displacement and 22% More Base shear than Regular structure.
2. The Stiffness Irregular Structure shows 4% more Displacement and 11% less Base shear than Regular structure.
3. The Irregular structures are more vulnerable to earthquake than the Regular structure.

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Study on fresh and harden properties of calcined clay-Limestone cement concrete production by marble stone powder

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Abstract
In this paper utilization of waste marble powder for the production of limestone calcined clay cement is investigated. It is advanced ternary blended cement made by using the combination of low-grade calcined clay, limestone and gypsum. It can be replaced by 50% of clinker which is beneficial for the reduction of carbon dioxide (CO_2) emission at the time of production of cement. In the existing paper the physical and chemical characteristics, mineralogical composition carried out by X-ray fluorescence, lime reactivity test for pozzolanic behaviors, mechanical properties of LC^3 using marble powder i.e., compressive strength is checked and compared to the Portland pozzolana cement (PPC) and ordinary Portland cement (OPC).
Keywords – Marble powder, calcined clays; limestone; blended cement; compressive strength.

1. Introduction

Day by day demand of concrete is increasing due to industrialization, globalization and infrastructure development. Developing countries require a large quantity of concrete. Concrete is the heterogeneous mixture of cement, coarse aggregate, fine aggregate, and water. For the production of 1 ton of cement, it emits nearly 1 ton of carbon dioxide (CO_2) into the atmosphere [1]. As compared to the world, India is the second highest cement producer, in which near about 280 million tons of cement is produced in India [2]. Annually from cement production nearly about 1.35 billion tons of greenhouse gas releases, which is represented in the 2013 World Business Council for Sustainable Development Energy Agency (WBCSDEA) [3]. So, for minimizing the demand of ordinary portland cement, a new ternary blended cement is produced [4] called limestone calcined clay cement (LC^3). It contains 50% ordinary portland cement (OPC), 30% calcined clay, 15% limestone powder and 5% gypsum. Similarly, marble stone calcined clay cement (MC^3) is produced and checked the physical and chemical properties of these cement. Cement substitution by a combination of metakaolin and limestone [5] in this research is 30% of metakaolin and 15% of limestone in portland cement give better result as compare to other mixture. Higher kaolin clay content gives good strength than ordinary portland cement (OPC) in concrete mortars. Similarly compressive strength of higher kaolin clay nearly equal to ordinary portland cement and lower kaolin content nearly equal to portland pozzolana cement (PPC) [6].

2. Materials

Ground calcined clay, 53 grades of OPC conforming to IS 12269-2013 [7], ground limestone powder, and gypsum (manufactured by TARA in New Delhi) conforming to Indian Standard (IS) were used in the preparation of LC^3.

The fine aggregates used in this proportion are size less than 4.75mm having fineness modulus (FM) 2.45. Crushed stone aggregate of size 20mm and 12.5mm were used in the proportion of 70:30 confirming to IS 383-1970. As per IS 1727-1967 the pozzolanic reactivity of calcined clay was found to be 8.35 MPa. The specific gravity of calcined clay is reported as 2.65. The details of blends used such as limestone calcined clay cement (LC^3) in that OPC-50%, Calcined clay-30%, Lime powder-15%, Gypsum-5% for marble stone calcined clay cement (MC^3) in that OPC-50%, Calcined clay-30%, Marble powder-15%, Gypsum-5% is used for preparation of cement shown in table 1

Table 1. Details of blends used in this study

Blend Name	OPC	PPC	Calcined Clay	Limestone powder	Marble waste powder	Gypsum
LC^3	50%	-	30%	15%	-	5%
MC^3	50%	-	30%	-	15%	5%
OPC	100%	-	-	-	-	-
PPC	-	100%	-	-	-	

Fig. 1. Mortar Cube of OPC, LC^3 and MC^3

Fig. 2. Concrete cube and Cylinder of OPC, LC^3 and MC^3

2.1 Test on Cements

Laboratory prepared cements such as limestone calcined clay, marble stone calcined clay cement and Ordinary portland cement over that standard consistency in percentage, Initial setting time (Min), Final setting time (Min) and Soundness (mm) test is carried out as per IS 4031-1988 [8] shown in table 2.Similarly compressive strength of cement for 3 days, 7 days, 28 days and 56 days carried out on compressive testing machine shown in table 3. Figure 1 shows the mortar cube of OPC, LC^3 and MC^3.

Table 2. Physical properties of Limestone calcined clay cement; Marble stone calcined clay, Ordinary portland cement.

Description	LC^3	MC^3	OPC
Standard Consistency (%)	33	33.67	29.5
Initial setting time (Min)	90	96	50
Final setting time (Min)	410	430	540
Soundness(mm)	2	2.1	2
Specific gravity (g/cc)	2.85	2.95	3.15

Table 3. Mortar compressive strength of OPC, PPC, LC^3 and MC^3 blends

Sr. No.	Mix	Compressive strength N/mm2			
		3days	**7days**	**28days**	**56days**
1	OPC	15	34	49	50.5
2	PPC	10	25	35.5	38
3	LC^3	12	28	36	40
4	MC^3	13	29.6	39	42

2.2 Test on Concrete

M25 Grade of concrete is prepared using IS 10262-2009 [9] such that water to cement ratio is taken as 0.5, Cement content 380 kg/m3, the fine aggregate confirming zone-I which has fineness modulus 3.11 and ratio of coarse aggregate such as 12.5mm:20 mm taken as 0.3:0.7 respectively. The mix proportion and workability by slump shown in table 4. Compressive strength of different mix at 3 days, 7 days, 28 days and 56 days shown in table 5. Figure 2 shows the concrete cube and cylinder of OPC, LC^3 and MC^3

Table 4. Mix design of M25 grade of concrete

Sr No	Concrete Grade	W/C	Cement Kg/m^3	Fine aggregate Kg/m^3	Coarse Aggregate Kg/m^3 12.5mm	Coarse Aggregate Kg/m^3 20mm	Slump mm
1	M25	0.5	380	738.72	334.85	781.36	90

Table 5. Compressive strength of different mix of concrete

Sr. No.	Mix	W/C	Compressive Strength N/mm2			
			3days	7days	28days	56days
1	OPC-M25	0.5	11	24	35	38
2	PPC-M25	0.5	8.6	18.5	28.3	31
3	LC^3-M25	0.5	10	20.5	30.2	33
4	MC^3-M25	0.5	10.2	21.3	30.6	34

3. Result and Discussions

The physical characteristics such as standard consistency of limestone calcined clay cement and marble stone calcined clay cement are more than ordinary portland cement because of calcined clay is present in this cement [10] similarly initial setting time, final setting time and soundness satisfies the requirements given by Indian standard. The compressive strength of limestone calcined clay cement and marble stone calcined clay cement satisfies the Indian standard for portland pozzolana cement. The compressive strength of ordinary portland cement is more than LC^3 and MC^3 because of the amount of clinker in OPC (100%) greater than LC^3 and MC^3. The reactivity of the calcined clay is dependent on the kaolinite content present in the clay. Clays containing about 40% kaolin or above give strengths comparable to plain Portland cement when used in LC^3-50 (50% clinker, 30% calcined clay, 15% limestone and 5% gypsum) [11]. With more substitution, it is possible to obtain good mechanical performance, at early ages, at higher levels of substitution than other pozzolans. Because the clay is finely divided, it can react faster and to a higher degree than fly ash. Similar, levels of substitution are possible with slag, which is a hydraulic material rather than a pozzolan.

When calcined clay $AS_2 + 3CH + 6H = C\text{-}A\text{-}S\text{-}H + C_2ASH_8$ is added in clinker calcium aluminium silicate hydrate, (C-A-S-H) are formed and further addition of limestone formation of carboaluminates which is an enhancement of carboaluminate A (from calcined clay) + Cc + 3CH + H = $C_3ACc_0,5H_{11}$ formation and contribute to the strength. Similarly, the combination of calcined clay and marble stone which content carbonate source form carboaluminates enhanced ettringite contribute towards the strength.

The M25 concrete prepared by limestone calcined clay cement and marble stone calcined clay cement compressive and spilt tensile strength is less than ordinary portland cement but more than portland pozzolana cement satisfies by the Indian standard for portland pozzolana cement.

4. Conclusion

Based on experimental studies conducted on physical and mechanical properties study on limestone calcined clay cement and marble stone calcined clay cement following conclusion can be drawn

1. Cement prepared by limestone calcined clay cement and marble stone calcined clay cement has comparable physical properties of the ordinary portland cement.
2. The presence of carbonate stone dust studied leads to the stabilization of ettringite and the formation of carboaluminates.
3. Mortar compressive strength prepared by LC^3 and MC^3 is more than portland pozzolana cement at all curing ages investigated in this study.
4. Compressive strength of M25 grade prepared by OPC is more than limestone calcined clay cement; marble stone calcined clay cement and portland pozzolana cement. The similar mixture prepared by LC^3 and MC^3 has more compressive strength than portland pozzolana cement at all days.

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Structural Engineering Digest, Vol. 1, 2023

Enhanced Foundation Solutions for Offshore Structures: Insights into Helical Pile Group Response in Soft Clay under Uplift and Lateral Load

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Abstract

The utilization of helical piles has witnessed remarkable growth, particularly in the realm of offshore foundation systems, owing to their distinct advantages over alternative solutions. Helical piles are frequently deployed in groups to support substantial loads. This research endeavors to comprehensively investigate the behavior of group piles in soft clay soil subjected to both uplift and lateral forces through the development of a finite element model. The study employs three distinct configurations arranged in rectangular, triangular, and square patterns. Variations in the pile spacing ratio (Sg/D) are considered, encompassing values of 2, 3, 4, and 5. Plaxis 3D software is employed to simulate the problem, with validation against laboratory-scale model test data. Subsequently, the validated model is utilized to explore the group effect for the three configurations, while varying the center-to-center spacing of helical piles. The findings underscore the significant influence of the number of piles, center-to-center pile spacing, and the selected failure criteria used for interpreting the test data on group efficiency. Notably, the results reveal that helical pile spacing ratios equal to or greater than 4 exhibit minimal group effects. In light of the assumed failure criteria, the research proposes optimal spacing ratios for both vertically and laterally loaded group helical piles.

Keywords: Helical piles, offshore foundations, soft clay, pile spacing ratio, group efficiency.

1. Introduction

Helical piles, also known as screw anchors, screw piles, helical piers, torque piles, and helical soil nails, are a type of foundation anchor that can withstand uplift forces. They are made of steel and have a helical plate welded to the circular or square shaft in a consecutive and ordered pattern. The employment of helical piles has gained momentum as a favorable offshore foundation approach. The helical plate's anchoring effect provides enhanced resistance against tensile loads and overturning moments, rendering these piles a viable and effective alternative to driven piles, as highlighted in research by Al-Baghdadi et al. [1]. There is a noticeable scarcity of studies that investigate the tensile performance of group helical piles in soft clay, as well as their response under lateral loads [2,3]. This research aims to fill this knowledge gap by conducting numerical simulations using the Plaxis 3D program to study the behavior of helical pile groups in soft clay under axial uplift and lateral loading effects. The numerical model will be verified using data from small-scale experimental tests, and further analysis will be performed to understand the behavior of helical pile groups with varying configurations. The interaction effect of group helical piles will be analyzed through a parameter known as group efficiency. The obtained numerical results will be compared for different configurations, and the findings will contribute to a better understanding of group helical pile (GHP) behavior in cohesive soils. By evaluating the response of helical pile groups in cohesive soil under axial uplift and lateral loading, this study aims to advance the knowledge in the field of geotechnical engineering and offer valuable insights for the design and implementation of helical pile foundations in offshore renewable energy projects.

Numerical Investigation

In this study, the finite element analysis (FEA) software Plaxis 3D was utilized to carry out the numerical simulation. The material behavior, purpose and properties of the elements used in the model that is soil volume, pile shaft, helical plat pile cap are listed in Table 1 in detail. The helical plates are modeled as planar to avoid the complexity of the model, however the difference in capacity is proven to be negligible when the helical shape is considered. To ensure accurate results in the numerical analysis, a mesh sensitivity analysis was conducted to investigate the influence of the soil block size on the outcomes. Finally, a model with at least 58,089 elements was utilized, with dimensions of 25D in the X and Y directions and 2L in the Z direction was chosen. The bottom of the soil model is confined in all directions, whereas the surface is free to move. Lateral movement is restricted at the side boundaries in the X and Y directions. To perform finite element analysis, the model geometry was divided into finite elements. The optimum number of elements is determined through a mesh independence study (MIS). After conducting the MIS, it was decided to use the fine element distribution option since the predicted capacity values remained unchanged in both cases. Due to the expected large stress concentration and deformation near the helical pile, that region was locally refined compared to other parts of the model. Figure 1 shows the developed model.

Table 1. The purpose and properties of various elements created in the FE model.

Element	Soil	volume pile	Shaft plate	Helical plates	Interfaces	Pile cap
The purpose is to Simulate	The soil behavior	As helical pile shaft	As shaft and to connect helical plates	Helical plates as a planar element	Allow separation	Connect helical piles group
Material model	Hardening soil model	Linear elastic	Linear elastic	Linear elastic	Mohr-Coulomb	Linear elastic
Drainage type	Undrained B	Non-porous	-	-	Drained	Non-porous
Unit weight, γ (kN/m^3)	γunsat = 16 γsat = 18	78.5	0.0785	78.5	16 18	78.5
Young's modulus, (kN/m^2)	E_{50}^{ref}= 5730 E_{oed}^{ref} = 4590 E_{ur}^{ref}= 17190	200 x 10^6	200	200 x 10^6	5730	200 x 10^6
Poisson's ratio, μ	0.49	0.3	0.3	0.3	0.49	0.3
Soil strength, su (kN/m^2)	7.5	-	-	-	7.5	-
Undrained friction angle, ϕu	0	-	-	-	0	-

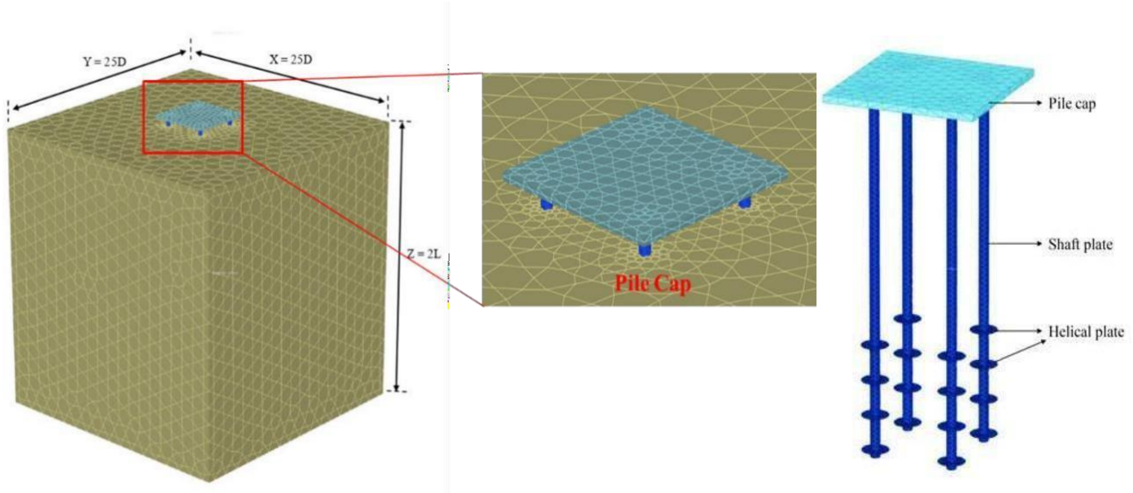
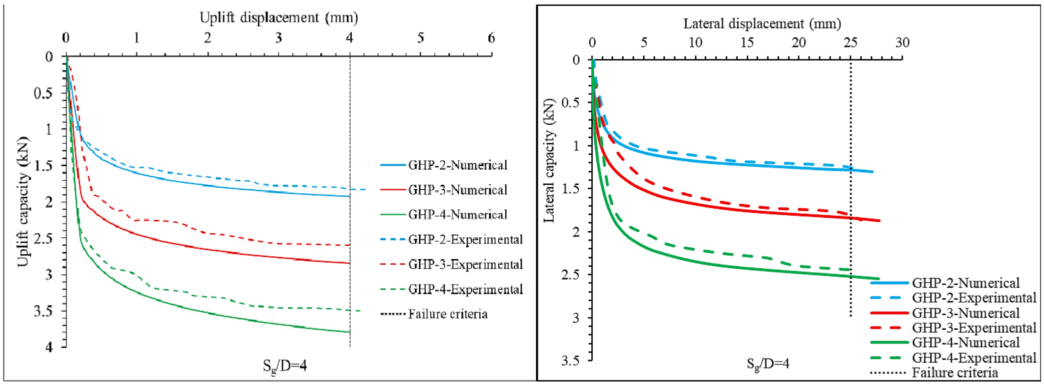


Figure 1. Soil Model mesh discretization and modelled group helical pile

2. Results and Discussions

Validation of the developed model

A total of six load tests were undertaken, comprising three tests to assess the behavior of the GHP under uplift loading and another three tests to analyze their response to lateral loading. To compare the performance of the GHPs under uplift and lateral loading, the experimentally measured results were compared against the numerically predicted responses. Upon analyzing the results, it is evident that the 3D finite element (FE) model effectively anticipates the load-displacement behavior, showcasing an over-prediction of less than 8% for uplift capacity and merely 3% for lateral capacity scenarios.

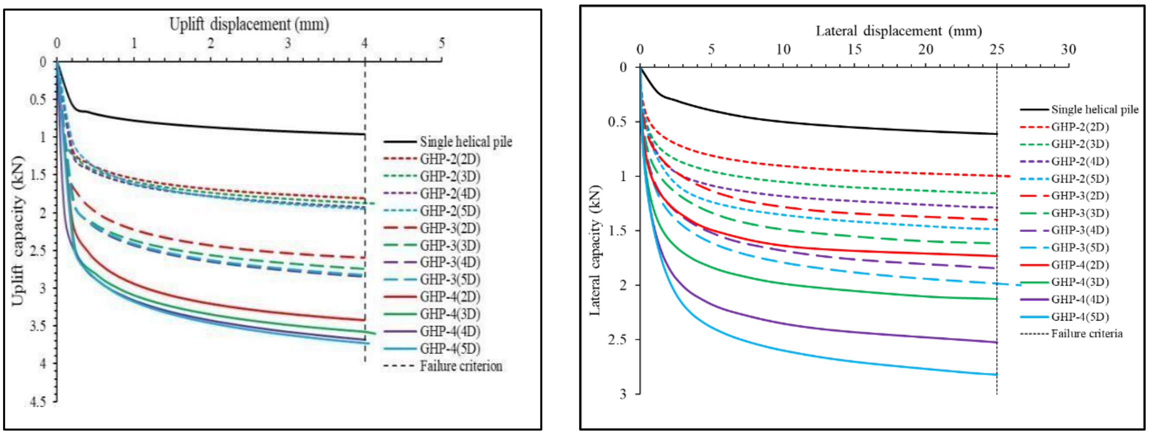


(a) (b)

Figure 1 Comparison of experimentally and numerically obtained GHP response under **(a)** uplift loading and **(b)** lateral loading

Response of GHP to uplift and lateral loads

Figure 2 (a) and (b) visually portrays the load-displacement curves corresponding to GHPs with varying pile spacing for different group configurations under uplift and lateral loading, respectively. A discernible trend is observed: the uplift and lateral capacity of the GHP escalates proportionally with the augmentation in the number of helical piles. This curve typically exhibits three distinct zones: an initial elastic phase characterized by high stiffness, succeeded by a nonlinear segment, and finally a swift failure phase marked by a near-zero linear slope. It becomes evident that the group capacity experiences a diminishing trend as the pile spacing surpasses *4D* under uplift load conditions. But different trend was observed in lateral loading conditions where the increment is consistent regardless of the pile spacing and the specific configuration type.



(b) Uplift loading **(b)** Lateral loading

Figure 2. Total uplift displacement vs Uplift capacity among SHP and GHP with various configurations at different pile spacings (Sg)

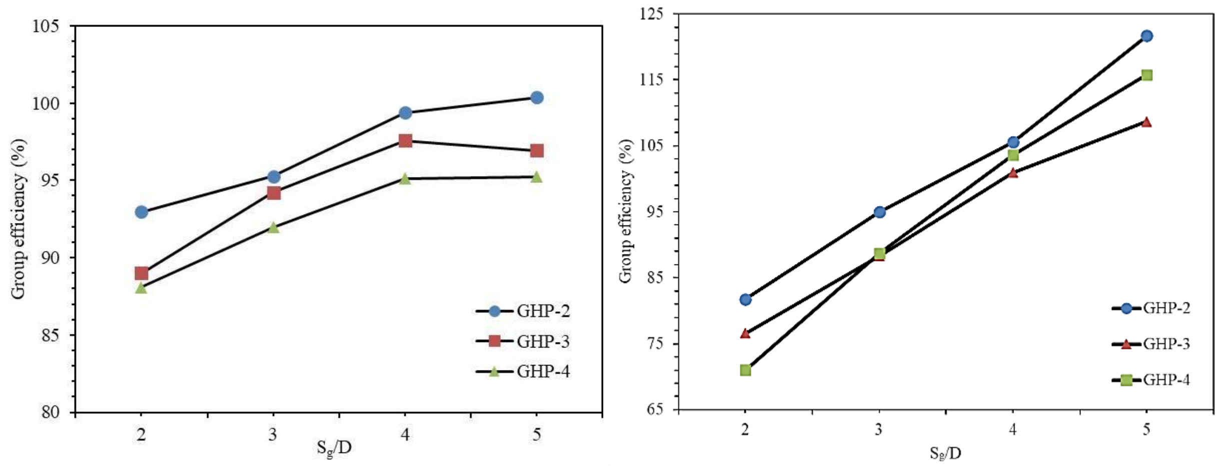
Group Efficiency Factor (ηg)

To conveniently express the influence of a group interaction effect on the ultimate load-bearing capacity, regardless of whether individual piles failure or the block failure, engineers employ a factor known as the pile group efficiency factor (*ηg*). This factor is commonly used to signify the impact of the group configuration on the ultimate load capacity. It can be calculated using the following formula:

η = Ultimate capacity of GHP __________________(1)

g N x Ultimate capacity of SHP

The observations revealed that the least group efficiency values (*ηg*) were achieved at an *Sg/D* ratio of 2. As the pile spacing ratio increased, the group efficiency exhibited an upward trend for all the configurations examined here. This suggests that the influence of the group effect diminishes with larger pile spacing, resulting in higher *ηg* values. The significance of the group effect appears to lessen when *ηg* surpasses 95% [3]. Based on the outcomes, it is evident that for groups with pile spacing of $Sg \geq 4D$, the impact of the group effect starts to diminish in both loading cases. Figure 3 (a) and
(b) shows Group Efficiency vs pile spacing ratio under uplift and lateral loading condition, respectively.



(a) Uplift loading **(b)** Lateral loading

Figure 3. Group Efficiency vs pile spacing rat

3. Conclusions

The conclusions drawn from the findings are as follows: (1) The numerically predicted ultimate uplift and lateral capacities of the typical GHP demonstrated a strong alignment with experimentally determined ultimate capacities derived from laboratory-scale model testing. (2) The uplift and lateral capacity of GHPs exhibited an increase with the expansion of the group size. Additionally, Finite Element Method (FEM) results for both uplift and lateral responses indicated that an increase in the pile spacing ratio (*Sg/D*) led to an enhancement of the group efficiency, ηg value, subsequently resulting in a diminished group effect. (3) The uplift capacity increase for GHPs was constrained beyond $Sg > 4D$, and this enhancement became minimal after the pile spacing reached 4D, regardless of the specific group configuration. The insignificance of the group effect was evident as *ηg* surpassed the threshold of 95%. However, concerning lateral loading, the *ηg* value consistently increased irrespective of the *Sg/D* values. (4) The lowest *ηg* values were reached with a pile spacing ratio, *Sg/D* of 2, and it rises as the pile spacing ratio increased in both uplift and lateral loading cases. The findings suggest that for the group with pile spacing of $Sg \geq 4D$, the group effect appears to be insignificant in both loading conditions.

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Non-Linear FEM Analysis of SFRSCC and SFRNCC one-way Restrained Slabs Using ANSYS

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Abstract

This study utilizes the ANSYS finite element software to emulate the behavior of concrete slabs reinforced with steel fibers when exposed to a four-point load. We examined ten slabs under bending stress and compared the results with actual experimental data. Half of these slabs were made with Steel Fibre Reinforced Normal Compacted Concrete (1.0%Vf), and the other half with Steel Fibre Reinforced Self Compacting Concrete (1.0%Vf). All slabs used M40 grade concrete, and there were five distinct tensile steel ratios (1.2%, 0.89%, 0.69%, 0.6%, 0.57%) for both SFRNCC and SFRSCC. However, the fiber content remained consistent across all slabs at 1.0%Vf. Each slab had the same dimensions: 1300x500x65 mm. When tested, they faced a four-point bending load and were fully secured on two short sides. We assessed the ultimate load and load-deflection for every scenario and juxtaposed these with existing experimental data. This research conducted a detailed finite element assessment, considering both geometric and material non-linearities, through ANSYS. The concrete's representation was achieved using the 'SOLID65' element, an eight-node brick element adept at representing the brittle material's potential cracking and crushing. The tension reinforcement was distinctly represented using the 'LINK180' – a 3D spar element.

Keywords: SFRSCC, SFRNCC, FEM, ANSYS etc…

1. Introduction

In RCC structures, slabs play a pivotal role. They are among the primary elements that utilize a significant amount of concrete (1). Traditionally, slabs were designed to bear only vertical loads. However, with the growing focus on improving living environments, there's an increasing concern about noise and vibrations from slabs (2). Moreover, as building spans enlarge, attention to slab deflection becomes paramount. As a result, there's a trend towards thicker slabs. This added thickness results in heavier slabs, necessitating larger columns and bases. Consequently, this elevates the consumption of materials like concrete and steel in buildings (3). This study introduces a theoretical exploration, aiming to forecast flexural attributes such as ultimate load, deflection, concrete compressive strain, and crack patterns, using the nonlinear finite element tool, ANSYS 14.5.

1.1 Details of Experimental Test

Ten slabs underwent testing, with comprehensive specifics of their measurements, reinforcement steel configurations, and loading arrangements depicted in Figure (1). The examined variables can be found in Table (1).

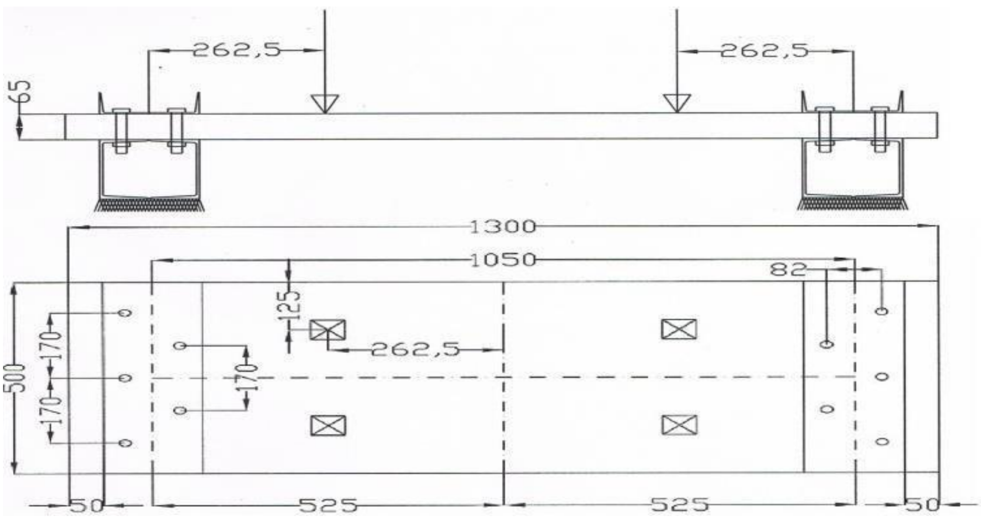

Fig -1: Cross Section and Plan of the Location of Loading Points

Table -1: Details of the slab dimension and spacing of steel.

Slab No	L (mm)	B (mm)	D (mm)	f_{ck} (N/mm^2)	% of Main Steel
M70-NCC-75	1300	500	65	78.48	1.202
M70-NCC-100	1300	500	65	83.71	0.859
M70-NCC-150	1300	500	65	72.34	0.687
M70-NCC-175	1300	500	65	74.34	0.612
M70-NCC-200	1300	500	65	69.33	0.57
M70-SCC-75	1300	500	65	78.05	1.202
M70-SCC-100	1300	500	65	75.77	0.859
M70-SCC-150	1300	500	65	71.39	0.687
M70-SCC-175	1300	500	65	77.23	0.612
M70-SCC-200	1300	500	65	70.47	0.57

2. Tested Method and Measurement

Samples were evaluated using a four-point bending system, employing a hydraulic jack and a quartet of loading plates to replicate real-life loading scenarios. For every slab sample, we recorded the initial crack load, mid-span deflection, peak concrete compressive strain, and the highest load endured.

FINITE ELEMENT MODELLING, MATERIAL PROPERTIES AND CONSTITUTIVE MODELS

Element Type

The concrete was represented using an eight-node solid element named Solid65. This element consists of eight nodes, each possessing three degrees of freedom, allowing movements in the x, y, and z directions at every node. It can undergo plastic changes, experience cracks in three perpendicular directions, and withstand crushing. For the steel reinforcement, the Link 180 element was employed. It needs two nodes, each having three movement degrees in the x, y, and z directions. This element too, can endure plastic transformations.

3. Analytical Methodology

Finite Element Analysis Procedure

Pre-Processor Stage

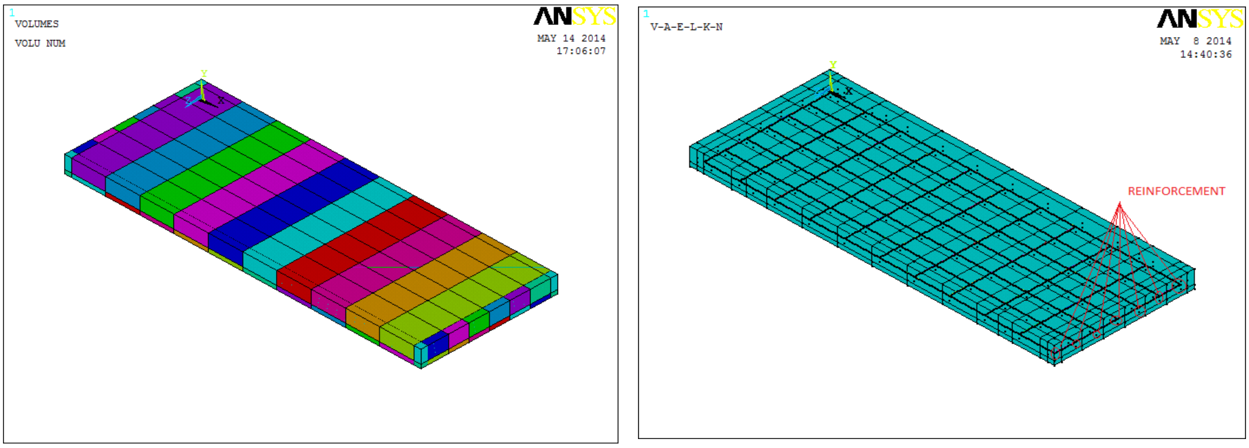

Fig -2: Generation of volume.

NUMERICAL ANALYSIS AND COMPARISION OF RESULTS

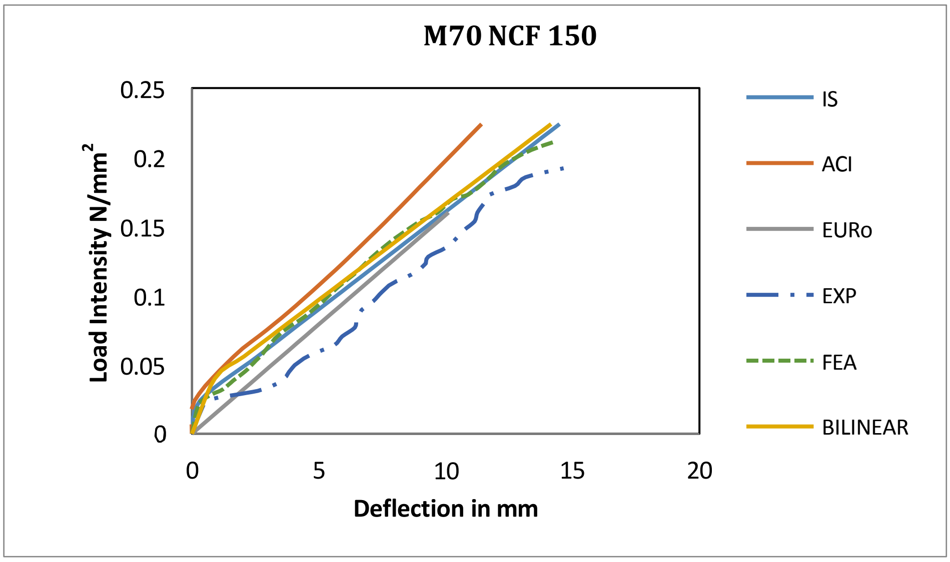

Fig- 3: Load intensity-Deflection curves by Various codes of M70 NCF 150

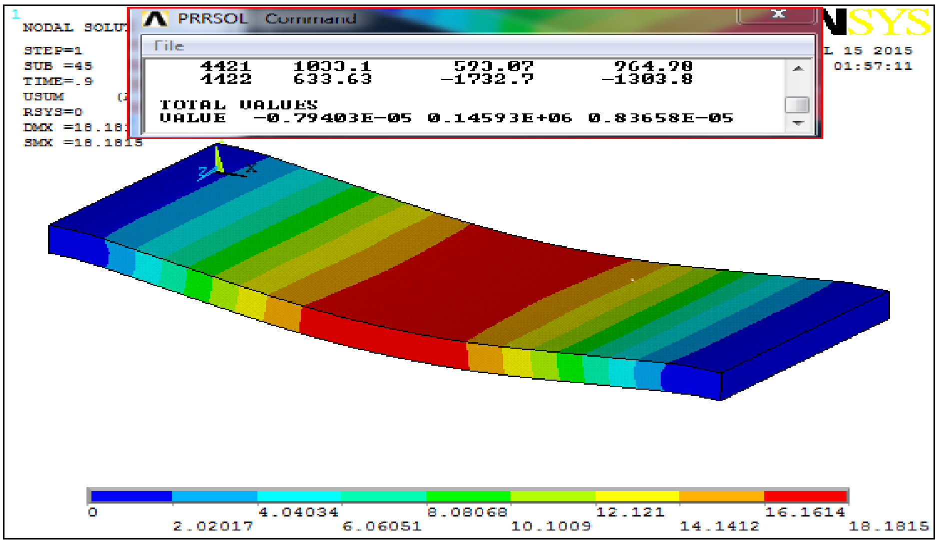

Fig-4: ultimate Deflection of the slab for M70 NCF 150

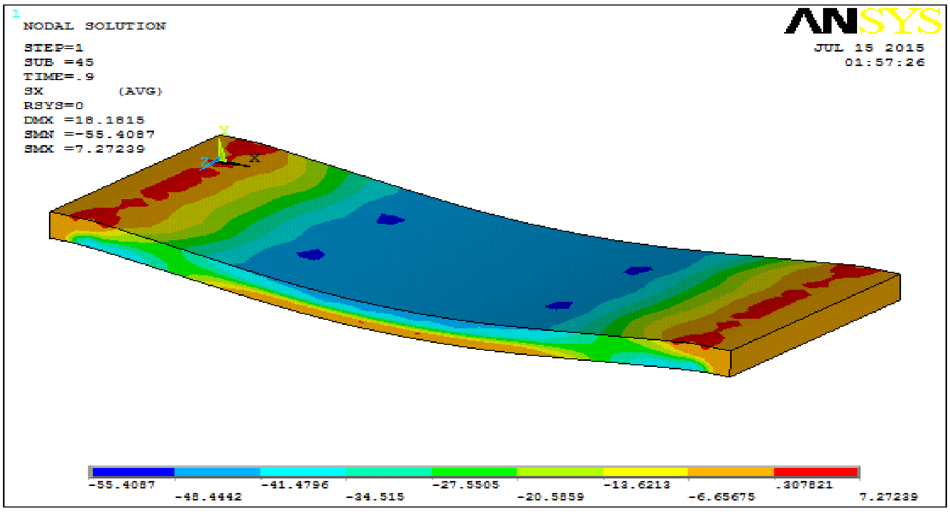

Fig-5: ultimate stress of the slab for M70 NCF 150

Loads at Failure

The ultimate load from the test slabs with the concluding load of the finite element model. This final load from the finite element model is recognized at the last load step prior to the solution deviating because of extensive cracking and significant deflections. As expected, the ANSYS models seem to provide a conservative estimate of the slabs' strength.

Crack pattern

The ANSYS program records a crack pattern at each applied load step.

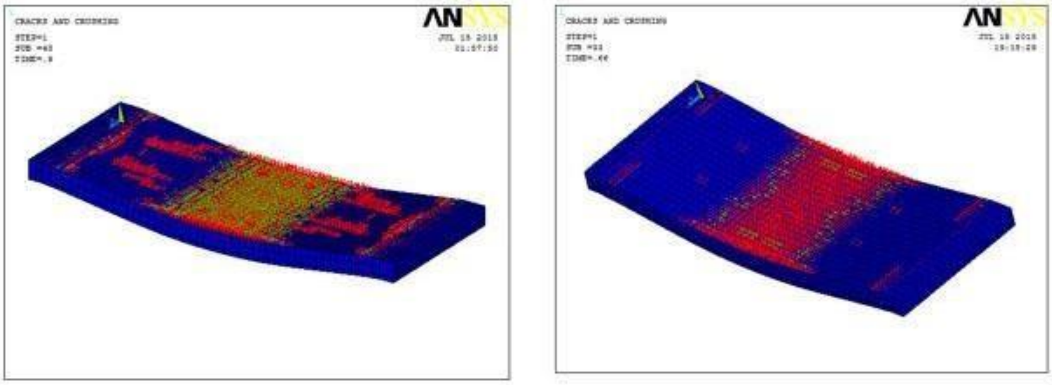

Fig-6: Crack Pattern at Ultimate Load FOR M70 NCF 150

4. Conclusion

This study employs ANSYS to conduct nonlinear finite element evaluations of SFRNCC and SFRSCC one-way restrained slabs. The insights derived from the numerical findings include:

1. The overall performance of the finite element models, as illustrated by the load-deflection graphs at the midpoint, aligns closely with the experimental slab test data. However, these models exhibit a marginally increased stiffness compared to the experimental results in both linear and nonlinear phases. This discrepancy can be attributed to the omission of bond-slip (between concrete and reinforcing steel) and microcracks in the real slabs, resulting in the enhanced rigidity observed in the finite element models.
2. The load-deflection diagrams from specified points in the finite element evaluation reasonably match the experimental data.
3. The peak loads derived from the finite element assessments fall short of the experimental slab's ultimate loads. This discrepancy is likely a result of overlooking concrete's inherent toughening processes.
4. The cracking patterns upon reaching peak loads in the finite element models closely mirror the failure patterns witnessed in the test slabs.

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INVITED ARTICLE

ANGULAR SHAPED FLY ASH AGGREGATE - AN INNOVATIVE MATERIAL FOR USE IN ROAD PAVEMEN

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Abstract

The paper discusses a quick and cost-effective four-step process (mixing, compaction, curing, and crushing) for producing angular shaped fly ash aggregate and compares its engineering properties with that of conventional stone aggregates. After various trials, 96-98% Class C fly ash with 2-4% binder mix is found suitable to produce lightweight fly ash aggregate that is having dense structures, angular shapes for better interlocking, excellent mechanical properties such as toughness and hardness, and high durability. The developed fly ash aggregate satisfactorily fulfils the specifications of MoRTH (2013) and IS 383 (2016) for road aggregate and structural concrete aggregate, respectively. It is found that results of compressive strength test, split tensile strength test, flexural strength test and pull-out test on M25 grade of cement concrete prepared with fly ash aggregate and natural sand are quite comparable with that of conventional concrete for the same cement content, which confirms the suitability of fly ash aggregate for concrete work. The financial analysis for setting up of a pilot plant for production of angular shaped fly ash aggregate with capacity of 2 tons per hour is also presented in this paper. The production cost of fly ash aggregate is found to be Rs. 454 per m^3 which is about 33% of the cost of natural stone aggregate as per the rate of DSR, CPWD, 2021.

Introduction

With the rising need for coal as an energy source, there is a growing requirement for fly ash disposal. Annual fly ash production in India has reached to 232 MT in the year 2020-21. Fly ash aggregates can successfully replace natural stone aggregates, the primary material for all civil engineering infrastructures. Lightweight aggregates have lot of potential for use as a construction material in concrete and highway construction for specific purposes (Baykal et al. 2000). A 2-lane road requires around 8500 tonnes of stone aggregates per km in the base and sub-base layers. India's aggregate demand is anticipated to be between 4,500 and 5,000 million tonnes. The Government of India's main highway projects, the Bharatmala, Sagarmala, and Samrudhi Yojna, are expanding the market for fly ash-based aggregates. The technology for making fly ash-based aggregate is still in its early stages of development, with limited manufacturing capacity. Several researchers have reported manufacturing method for artificial aggregate in the past based on the pelletization and sintering process. This method has the disadvantages of consuming higher energy and complicated process to make the aggregates from the mixture of fly ash and various additives. This method is also expensive and time-consuming resulting in non-use of these aggregates on a large scale in civil engineering applications. It is also found that the pelletization process manufactures round shaped aggregates that have negligible interlocking properties leading to lower load bearing capacity. Therefore, a cost effective angular shaped fly ash aggregate has been developed and presented in this paper.

Recent Development

The author has developed a technology (Indian Patent No. 362571 granted on 23 March, 2021) for producing angular-shaped high-strength fly ash aggregate from Class C fly ash using an accelerated curing process to overcome the drawbacks of sintered fly ash aggregates. A detailed stepwise process for the production of angular shaped fly ash aggregate from Class C fly ash is explained below and the process flow is shown in Figure 1. Typical physical properties of the developed aggregate are presented in Table 1.

1. **Raw material collections and mixing –** Homogeneous mixture of fly ash (96-98%) and hydraulic binder (2-4%) with water equal to optimum moisture content (IS: 2720-VIII) was prepared using a pan mixer.
2. **Compaction using high pressure hydraulic press** – After mixing, the material was being compacted using a high pressure hydraulic press machine to achieve dry density equal to maximum dry density of the mix (IS: 2720 -VIII) and blocks of size 23cm×11cm×6cm were prepared.
3. **Hot Water Bath Curing** – Then green blocks were placed in hot air at a temperature of 50^0C for 6±1 hours for initial setting followed by hot water bath curing for 24 hours at a temperature of 65^0C.
4. **Crushing** – After curing the blocks were placed for minimum 12 hours at room temperature to cool down. Then blocks were crushed in the crusher to produce various required sizes of angular shaped coarse aggregates.

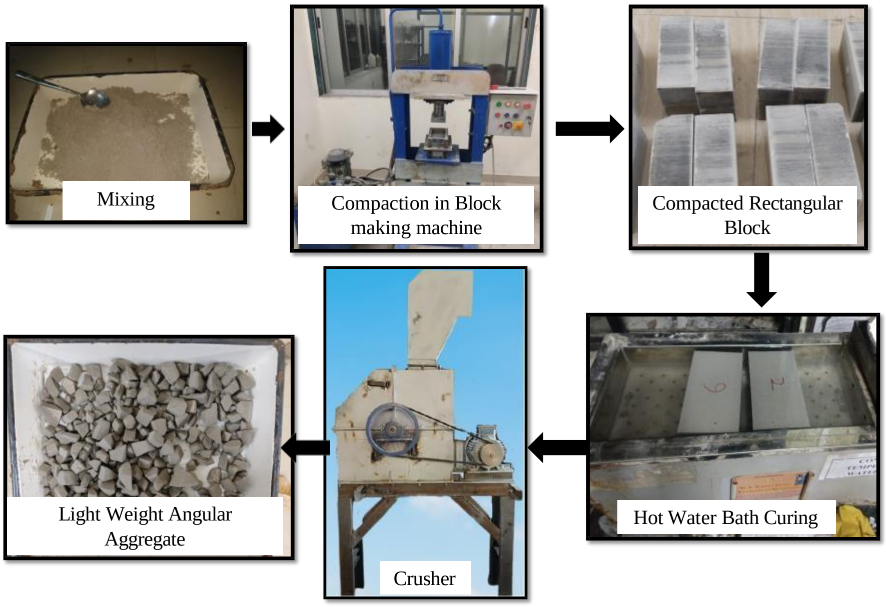

Figure 1: Pictorial process-flow for production of fly ash aggregate.

Table 1: Comparison of typical physical properties of fly ash aggregate

Parameters	**Authors' Fly Ash Aggregates**	**Sintered Fly Ash Aggregates** (From literature)	**Natural Aggregates** (From literature)	**IS:383 (2016) requirements for concrete aggregate**		**MoRTH-2013 Requirements**	**IS 9142 (Part 2) 2018 Requirements**
				Wearing surfaces	**Non - wearing surfaces**		
Specific Gravity	1.48	--	2.9	-	-	--	--
Bulk Density Loose (kg/m^3)	890	650-1050	1350	-	-	--	≤ 950
Water absorption (%)	19	15-30	0.5-2	≤ 2	≤ 2	--	≤ 18
Impact value (%)	21	15-55	12-20	≤ 30	≤ 45	≤ 30	≤ 40
Abrasion Value (%)	36	29	10-18	≤ 30	≤50	≤ 40	≤ 40
Crushing Value (%)	23	-		≤ 30	-		≤ 45
Soundness (%) in Na_2SO_4	9%	--	1-5	<12	<12	≤ 12	≤ 12
Shape of Aggregates	Cubical	Rounded	Cubical			--	--
Production Cost (Rs. Per m^3) (Approx.)	454	1900	1400			--	--

Application of Developed Lightweight Fly Ash Aggregate In Concrete

M25 grade cement concrete was prepared with fly ash aggregate and natural sand with w/c ratio of 0.41 and cement content of 330 kg/m^3. The results of compressive strength tests, split tensile strength tests, flexural strength tests, and pull-out tests were compared with that of conventional M25 grade concrete for the same cement content in Table 2.

Financial Analysis

This section discusses the financial analysis for installation and operation of a pilot plant for manufacturing angular-shaped coarse aggregates from Class C fly ash. This calculation is based on standard parameters and may change according to site location.

Table 2: Comparison of properties for proposed M25 grade of fly ash aggregate concrete with conventional concrete

Parameters	Concrete with fly ash aggregate and natural sand	Concrete with natural aggregate and natural sand	28-day target values for M25 as per IS:456-2000
Density of concrete (kg/m^3)	2015	2370	-
7- Day Compressive strength (MPa)	28.4	25.2	--
28-Day Compressive strength (MPa)	33.8	35.7	31.6
Split Tensile Strength (MPa)	1.7	1.9	-
Flexural Strength (MPa)	8.2	8.3	3.5
Bond Strength (MPa)	4.7	5.3	2.2

A. Capital Investment: Total 220 Lakhs

- Production shed : 50 Lakhs
- Plant and machineries: 140 Lakhs
  1. Press machine & batching plant: 40 Lakhs;
  2. Pellets & Curing Racks: 40 Lakhs;
  3. Hot Water bath: 8 Lakhs;
  4. Crusher: 25 Lakhs
  5. Fork Lift & Loader: 27 Lakhs
- Electrical installation: 30 Lakhs

B. Manufacturing Cost of Aggregate

1. Plant Capacity:

Rated plant output = 43.9 tons/day (2 tons/hour),
Actual Plant Output at 95% PLF = 41.7 tons/day;
Number of working days per year = 300;
Aggregate quantity = 45.1 m^3 / Day = 13,524 m^3/Year

2. Manufacturing cost of aggregate:

Raw material (24% of total cost)	Rs 14,99,140 /year	Rs 110.85/m^3
Electricity expenses (13% of total cost)	Rs 7,93,688 /year	Rs 58.69/m^3
Man Power (37% of total cost)	Rs 22,44,750 /year	Rs 165.99/m^3
Depreciation (15% of total cost)	Rs 9,00,000 /year	Rs 66.55/m^3
Total Maintenance cost (11% of total cost)	Rs 7,00,000 /year	Rs 51.76/m^3
Total	Rs 61,37,578 /year	**Rs 453.84/m^3**

3. Profitability: Schedule rate of coarse aggregate as per DSR, CPWD, 2021 is Rs 1400/ m^3

1) Total Production Cost per year = 13,524 m^3/year @ 453.84 Rs/ m^3 = Rs. 61,37,578
2) Sales Realization per year = 13,524 m^3/year @ 1,400.00 Rs/ m^3 = Rs. 1,89,33,600
3) Profit Before Tax (PBT) = Sales Realization – Total Production Cost = Rs. 1,27,96,022
4) Profit Before Depreciation and Tax (PBDT) = PBT + Total Depreciation = Rs. 1,36,96,022

Conclusions

[1] The present study recommends a simple and cost-effective four-step process for the production of eco-friendly angular-shaped fly ash aggregates. The proposed fly ash aggregates are sufficiently tough, strong, hard, and durable and provide effective interlocking, which also fulfils the specifications of MoRTH (2013) for road aggregate and the requirements of IS 383 (2016) for structural concrete aggregate.

[2] For the same cement content and w/c ratio, the compressive strength of fly ash aggregate concrete is fo und to be similar to that of normal concrete. M25 grade concrete can be successfully prepared from the proposed angular shaped fly ash aggregate with cement content of 330 kg/m^3 and w/c ratio of 0.41.

[3] The various engineering properties of concrete prepared from fly ash aggregates such as compressive strength, split tensile strength, flexural strength and bond strength were found to be comparable with that of normal concrete.

[4] The density of the developed fly ash aggregate cement concrete is 15% lower than that of the natural aggregate cement concrete.

[5] The production cost of aggregate from Class C fly ash was found to be Rs. 454 per m^3, which is about 33% of the cost of natural stone aggregate as per the rate of DSR, CPWD, 2021.

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