

Experimental Investigation on Stabilized Block Masonry using Construction Waste as an Ingredient

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Abstract—Using stabilized mud blocks (SMBs) has recently gained popularity as a sustainable and eco-friendly alternative to conventional building materials. SMBs are manufactured by compressing a saturated mixture of soil, sand, and a certain percentage of adhesive in a machine into a block. Such blocks are utilized in the construction of load-bearing and non-load-bearing masonry. The present work involves the investigation of construction waste, specifically wastes from the plastering work, as an ingredient in the production of stabilized mud blocks. Disposal of construction waste has been a significant problem in the construction industry; finding ways to reuse or recycle it can help reduce the impact of construction activities on the environment. The study involves conducting experimental tests on blocks and masonry units made from stabilized C and D blocks containing varying amounts of construction waste. The tests include determining the compressive strength and water absorption property of the masonry unit thus formed. The study results provide valuable insights into the feasibility and effectiveness of using construction waste in the manufacture of stabilized blocks. Thus, the obtained optimum strength mix proportion is selected and the masonry prism is cast by using recycled aggregate mortar. After a curing period, the prisms are subjected to structural frame loading to obtain compressive strength.

Keywords— Recycled Fine Aggregate, Stabilized Recycled Aggregate Blocks, Masonry Construction, Sustainability.

I. INTRODUCTION

Humans must have adequate shelter to survive, yet many developing nations fail to meet this necessity. The growth of a nation's infrastructure depends heavily on the construction sector, yet traditional building materials and methods can present problems in terms of the impact on cost and the environment. Most of the poor population, urbanization, and rising land and building material prices all contribute to insufficient housing. As a result, both urban and rural communities experience a decline in housing quality. The necessity of devising workable methods to enhance shelter conditions is highlighted in this section. The construction industry has produced several building materials and methods to overcome these issues, including concrete blocks, burnt clay bricks, aerated blocks, and stone, among others. Some of these choices, meanwhile, are not economical and produce a lot of carbon emissions, rendering them unsustainable over the long term. A nation's infrastructure development is largely dependent on the expansion of the construction sector.

Over a few decades, the building business has expanded quickly. Due to socioeconomic issues, such as rising land and building material prices, and population growth brought on by rapid urbanization, most of the people are impoverished and unable to afford adequate housing. In the current study, a sustainable approach has been taken by reusing some of the waste products from various sources as a replacement for natural soil in stabilized mud blocks and masonry mortar, which helps in turning the waste products from landfills into useful products.

A. Earth As a Building Material

The initial material used by mankind was Earth. People have created forms for using the earth that range from the incredibly simple to the extraordinarily sophisticated, using their inborn ingenuity. In reply to diverse capitals, societal wants, and place conditions, they have utilized the material.

People had entry to machinery, readily available fuels, and a variety of newly created materials as a result of the individual revolution. Soil construction abilities were missing or restricted to the dialect builder when new technology gained popularity. Worries about the economy and energy conservation gave Earth's architecture a boost in the years after World War II. However, as Western nations moved toward wealth, the need for modernism eclipsed the use of the land. Earth has traditionally been India's most popular building material and is an integral element of the culture. Traditional mud building differs greatly according to geography, climate, and local requirements. Wattle and daub, rammed earth, cob, and adobe are traditional techniques for earthen construction. In India, the walls of about 55% of all dwellings are still made of bare soil. Earth is no longer regarded as a material for the wealthy due to drawbacks like heavy maintenance and short lifespan. The limitations are:

- Absorption of water
- Water splashing from the ground causes walls to erode.
- Termites and vermin attack.
- Requirements of high maintenance

These restrictions are attained through the compressed earth block by increasing block density via compaction with a machine press. In contrast to the puddle clay utilized in mud bricks, the soil contains less moisture for compaction, which provides considerably enhanced dimensional stability.

B. Masonry unit

Brickwork is a mixture of masonry units and mortar. Brickwork is the oldest building material that has survived since the ancient past which is visible in the most impressive historical structures. Masonry is generally used for the walls of a building. The properties of mortar, masonry units, craftsmanship quality, and the assembly pattern all affect how efficient masonry is. The features and behavior of masonry are controlled by the characteristics of the mortar, the masonry units, and the bonding between them. For the masonry to function as a single unit, the mortar and masonry unit must have a perfect bond to withstand the stresses caused by different loading situations. Numerous factors, including joint thickness, slenderness ratio, moisture transfer, and binding strength between the masonry units and the mortar, affect how masonry behaves. Brick, stone, granite, limestone, stabilized mud block, and concrete block are examples of common masonry units.

C. Masonry mortar

Masonry mortar is a uniform material used to fill and seal the spaces between masonry units and to bind them together. It is made of water, sand, and cement. Masonry is thought to have started when bricks and stones were joined together using mud as mortar. The mechanical and physical properties of mortars are influenced by the water-to-cement ratio and aggregate grading.

A mortar serves as a sealer, a gap-filling glue, and it holds the masonry unit together. The performance and bonding qualities of brickwork are directly influenced by the mortar. Masonry's strength, flexibility to water infiltration, and durability are all influenced by the mortar. In ancient times different materials were combined to make mortar, like naturally occurring bitumen mixed with clay. Also, gypsum was burnt and the resulting material was used to make mortar and plaster. Slaked lime with aggregate was also used to make mortar. Now there are various types of mortars like Portland cement mortar, polymer cement mortar, lime mortar and pozzolanic mortar. Engineers must come up with a replacement for river sand for mortar due to the depletion of resources and taking environmental constraints into account.

Different applications have made use of soil-based mortars. Depending on how they are used, they can also be referred to as mud mortar or earth mortar. As a result, C and D waste are employed as an alternative for fine aggregates in the current study. The objectives of the present investigation are to evaluate the suitability of the alternatives selected as a replacement for Soil and fine aggregates.

- Construction and demolition waste recycling: Finding ways to recycle and reuse construction waste recovered from demolished plastered surfaces, which can help reduce the amount of non-biodegradable waste that ends up in landfills and reduce environmental impact.
- To find the optimum mix proportion of stabilized C and D blocks that produces the required compressive strength (CS) and water absorptions as per the codal provisions.
- Study of structural masonry units made with recycled construction waste: Investigating the strength properties of structural masonry units made with recycled construction waste.

II. LITERATURE REVIEW

Malkanthi S N and colleagues (2020) [26] researched utilizing construction debris to adjust soil grading for creating compressed stabilized earth blocks (CSEB). The research used the particle packing optimization technique to manage the higher particle volume while reducing the amounts of clay and silt. Sand and construction debris were used to reduce the quantity of larger particles. In this research, compressed stabilized earth bricks were made with 12 distinct soil mixtures, utilizing cement ratios of 6%, 8%, and 10%, while the percentages of clay and silt were modified at 5%, 10%, 15%, and 20%. The SLS 1382: Specification for Compressed SEBs was applied to assess the properties of the generated CSEB. The findings from the CS tests show that blocks composed of 10% and 5% clay and silt content, irrespective of the cement percentage applied, are categorized into one of three grades as outlined in SLS 1382: Grade 1, Grade 2, or Grade 3. Only elevated cement percentages meet the minimum strength requirements when using high clay and silt levels. Every compressed stabilized earth block adhered to SLS 1382 standards. Manjunath S, et.al (2020) [27] The article presents the results of various studies conducted on stabilized mud blocks and masonry, including the percentage stabilizer influence on block and masonry strength. The authors cast SMB blocks of sizes $230 \times 190 \times 100$ mm with three percentages of cement stabilizers (7.5%, 10%, and 12%) and studied the influence of stabilizer percentage on block strength. They also cast masonry prisms using these blocks with alternative types of mortars, leading to a prism strength range of 2.78-4.82 MPa. The article concludes that the use of SMBs has significant benefits, including reducing the cost of blocks, reducing the energy consumed in block Manufacturing, and promoting sustainable growth in the construction industry. Overall, this paper provides valuable insights into the use of SMBs in construction and their strength.

Sajina C (2015) [39]: The investigation into the block's performance was done as part of the study, which was based on IS 1725-1982. It has been noted that the CS at 7 days is between 1.30 and 2.50 N/mm² and at 28 days, it is between 1.90 and 2.90 N/mm². The findings of the water absorption range from 1% to 8% and are within the permitted range according to the IS regulation. The block density ranges from 1.75 to 1.96 gm/cc for each category, with category 1 having the highest block density at 100% soil. According to the earlier research, gypsum increased the CS of the crushed earth block. Any cementitious material that can increase the strength of crushed stabilized earth blocks, such as a cement and jute fibre mixture with a 5%–10% content that has CSs between 1.2 and 6.5 N/mm², is a cementitious material. In the present investigation, it ranges from 1.30 to 3.0 N/mm². According to the previous studies wet CS of compressed block, ranging from 1 to 4 N/mm², and the dry CS, ranging from 5 to 7 N/mm² in the case of water absorption, satisfied the IS recommendation. In the present investigation also satisfying the IS recommendation in the case of water absorption. This investigation recommends that the use of compressed stabilized mud block should be a suitable alternative building material.

Paulo Roberto (2012) [31] explored the mechanical properties, physical traits, and drying shrinkage of mortar, employing recycled fine aggregates sourced from construction and demolition waste (CDW) that included mortar, ceramics, and concrete. Two mortar mixtures using natural sand were produced with cement/sand ratios of 1:4 and 1:8 (by weight), maintaining a uniform consistency index of 260 ± 10 mm. Recycled mortar was produced with a 50% substitution rate, in volume, of natural aggregate using recycled aggregates. Results show that adding 50% recycled aggregate greatly enhances the porosity and absorption compared to the control mortar. For a more substantial mixture (1:4), a decrease in CS of about 8% was observed for the mortar containing 50% recycled aggregate.

B V Venkatarama Reddy, et. al [8] carried out several experiments on mortar using M-sand along with river sand. Two mortar mixtures with volume proportions of 1:6 and 1:4 were prepared and analyzed for grain size distribution, pH, and chemical composition, compressive strength of mortar, flow/workability, water retention, adhesion strength between brick and mortar, along with compressive strength and stress-strain relationships for masonry. The CS of mortar made with M Sand surpassed that of the mortar made with river sand. The tests for CS, modulus of elasticity, and flexural bond strength of masonry using M Sand mortar were significantly higher than those using river sand.

A. Literature Summary

From the above literature, it is observed that C and D wastes can be recycled by using it as alternatives to conventional building materials in the construction of various components of a building. The number of natural resources that are being used can be limited, thus contributing to the sustainable construction of buildings.

From the literature review carried out, the applications of alternative materials to sandy soil in the manufacturing of SMBs have been dealt with in detail. Although the options for various alternatives for fine aggregates in mortar are discussed, very few have attempted their usage in masonry. Hence, the present study aims to determine the alternative materials like C and D waste for sandy soil and clay soil in the block. Further, the behavior of block masonry units under compression, using mortar mix made of C and D waste, is attempted in the present investigation.

III. MATERIALS AND METHODOLOGY

A. Materials used

When natural soil is replaced with alternative materials or recycled aggregates, it helps preserve natural resources and encourages the best possible use of the exhausted resource. Three substitutes for soil from distinct sources have been identified in the current investigation. They are quarry dust, C and D waste, and brunt clay brick powder.

Construction and demolition waste (C and D waste)

C and D waste is recovered from the landfill. The demolition waste consists of composite materials like plastering waste. Plastering surface as a substitute for soil was compressed under the road roller and subsequently sifted to achieve the necessary grain size of fine aggregates. C and D waste was collected from a landfill in Vijayanagar, Mysuru. The series of obtaining the C and D waste is shown below

Construction and demolition waste (C and D waste)

C and D waste is recovered from the landfill. The demolition waste, consisting of composite materials like Brunt clay brick and clayey soil, was crushed under the road roller and then sieved to obtain the desired grain size of fine aggregates. C and D waste was collected from a landfill in Vijayanagar, Mysuru. The process of obtaining the C and D waste is shown below.



Figure 1. Collection of materials from the nearby landfill and Processing of materials

Quarry dust

A by-product of the crushing procedure, quarry dust is a dense material that can be utilized as aggregates for concrete, especially as fine aggregates. The stone has been broken down into several sizes during the quarrying process; the dust generated is known as quarry dust, and it is produced as waste.

Cement

A substance used in building known as cement is a binding material that adheres to other materials to hold them together. When water and cement are combined, the cement hardens, binding other materials together. Concrete is formed from cement blended with sand and gravel, whereas mortar for masonry is made from cement blended

with fine aggregate. OPC of 53 grade cement is utilized after conducting a specific gravity test (As per IS 4031, Part 11, 1988)

Lime

By heating limestone, a chemical substance called Lime is produced. When lime is applied in the right amount to mud block, it will react with the clay particles to create a cementitious product that binds the particles and boosts the block strength and plasticity. In this project, lime water is employed by the technical recommendations of the Bureau of Indian Standards IS (712, 1984).

Water

Potable water is used as per the optimum moisture content of the mix.

B. Mix Proportions

The most common method of casting stabilized mud blocks adapted the use of soil composed of 60% sand and 40% clay.

Here discusses the various mix proportions used in the making of stabilized C and D blocks. The number of various components used to make the requisite amount of a block is known as the mix proportioning. Calculations and tests were done on mixtures containing varied amounts of quarry dust, C and D waste, cement, and lime. Different mixes were created, keeping the Brunt clay brick, cement, and lime constant while replacing some of the quarry dust and C and D waste.

TABLE II: PROPORTION OF MATERIALS TAKEN FOR DIFFERENT SETS

SI no	INGREDIENT USED	S-1 (%)	S-2 (%)	S-3 (%)	S-4 (%)	S-5 (%)	S-6 (%)
1	QUARRY DUST	50	40	30	20	10	0
2	C&D WASTE	0	10	20	30	40	50
3	CEMENT	5	5	5	5	5	5
4	LIME	5	5	5	5	5	5
5	BRUNT CLAY BRICK	40	40	40	40	40	40

C. Tests on Materials

The basic properties of materials are very important in understanding their behaviour and their compatibility with other materials. Hence, all the materials procured, like cement, C and D waste were tested for their physical properties. All tests were conducted as per the IS codal specifications.

The additional tests were performed on quarry dust, cement, and C and D waste, and brunt clay brick.

- Specific gravity
- Sieve analysis
- Standard proctor test

D. Experimental study on properties of 1:4 mortar mix

An experimental study on the properties of a 1:4 mortar mix involves the careful preparation of mortar samples, testing them for various properties, and analyzing the results to assess their suitability for specific construction applications.

Test on fresh mortar (IS: 2250-1981)

Only one test, namely the consistency test popularly known as the flow test, was conducted.

Consistency Test

According to IS: 2250- 1981, a flow table test was used to fix the mortar mix consistency. For this, a conical mold with a base diameter of 75mm and a height of 150mm is employed. The mold is positioned in the middle of the flow table and filled with two layers of mortar mixture, each of which is tamped ten times using a rubber tamper.

A trowel was used to remove the extra mortar from the top of the mold, and the mold was then carefully removed. After removing the mold, the flow table was then hit with 25 blows in 15 seconds. The mortar spread's diameter was measured twice, and an average value was calculated. The process was repeated using various w/c ratios until a flow of 100–115 percent was attained. The figure shows the consistency test in progress.



Figure 2: Consistency test

Compressive strength of mortar



Figure 3: Casted mortar cubes and de-moulded

E. Experimentation on Stabilized Mud Blocks

An investigation on stabilized mud blocks by experimentation typically involves conducting various tests and experiments to evaluate their properties, strength, and suitability for construction. Below are some common experiments and tests conducted on stabilized mud blocks.

Tests on stabilized blocks

The blocks were cast by varying mix proportions. These blocks were manufactured as per the IS 1725-2023 codal specifications.

- Dimensionality test.
- Block density.
- Water absorption.
- CS.

Dimensionality test

To conduct a dimensionality test of stabilized mud blocks, six full-size blocks were considered to measure length, breadth, and height. Measurements of the individual blocks were read to the nearest division using a steel tape. Height on both faces and the midpoint of each face was measured, as well as length along the longitudinal center line of each face and breadth across the bearing surfaces. Then the average of all the blocks tested gave the respective dimensions of the block.

Average dimension = 231.67mm x 190.6mm x 100.5mm

Block density

Three stabilized blocks of MS-6 were randomly selected from the sample, and the blisters and loose particles were removed from the surface. The length, breadth, and height of each block were measured using a steel tape, and the volume of each block as calculated with the measured dimensions. Then each block was weighed using a weighing balance in kilograms to the nearest 10g. Hence, the density of a piece block was calculated using the below-mentioned formula, and the average density of six blocks was determined as per IS 1725-2023.

Average Block Density = 1820.67kg/m³

Compressive strength of the blocks

The stabilized mud blocks' CS test measures how much pressure they can withstand without crumbling. The kind of soil, quantity, and type of stabilizer used to produce the block all affect CS. Maximum strengths are achieved with optimal material combination. A block's CS is one of its most crucial technical qualities. It was determined that as the strength of stabilized blocks grows, so does their durability from the literature. Start the compressive testing machine by moving the lever into the holding position. Observe the specimen while gradually applying the weight without any shock. Applying the weight should be stopped when the specimen starts to break. Take note of the maximum load on the machine's display.

IV. EXPERIMENTAL INVESTIGATION ON BEHAVIOR OF STABILIZED MASONRY PRISMS WITH MORTAR MADE OF C AND D WASTE



Figure 4. C and D Block prism with C and D waste mortar joints

Masonry is a substance made of bricks and mortar that causes the composite to behave in an anisotropic way. Low estimations of the masonry wall's strength capability are caused by ignorance of the qualities of the composite material. The permissible stress and stiffness utilized in masonry design are greatly influenced by the assessment of CS and the distortion of full-scale masonry obtained from compressive tests of stack-bond masonry prisms and the examination of the findings acquired from prism testing. Although it may withstand lateral pressures brought on by wind, earthquakes, or other applied loading, the main purpose of structural masonry is to sustain compressive loads. Masonry has a reduced shear and flexural capacity, both of which depend on the applied normal stress, but it can withstand rather large compressive pressures. Due to frequent lateral pressures from Strong winds and earthquakes, most structures exposed to urban environments experience shear stresses in the structural walls.

In the present study, stack-bonded prisms with stabilized blocks and mortar made of C and D waste were cast. Masonry prisms were tested for compression strength under a loading frame. Masonry efficiency has been studied and discussed. Typical masonry prisms are shown in Figure 4.1. A mortar mix of 1:4 made with C and D waste was maintained.

A. Compressive Strength of Masonry Prism

Stabilized block masonry prisms constructed with five blocks measuring 230 x 190 x 600 mm were molded and cured for periods of 7, 14, and 28 days before undergoing testing. Once the curing period was completed, the specimens were carefully moved onto the UTM with a capacity of 1000kN for testing purposes. A constant load

was applied until the specimen failed, and the failure load was recorded. Three specimens for mortar created using the C and D waste materials were examined. As per the provisions outlined in IS 1905, a necessary correction factor is implemented. The test setup for assessing the CS of the prism is illustrated in Figure 4. 2. The CS was calculated following the formula provided below.



Figure 5: Test setup for the compressive strength of the prism

V. RESULTS AND DISCUSSION

Results from the experimental investigation are presented and discussed in this section. As discussed above, the following tests were conducted for blocks, and their results have been presented and discussed.

- CS of blocks
- CS of Mansory unit (prism)

A. Compressive Strength of Blocks

CS testing was performed on three samples. The specimen's surface was cleaned, and the load application area of the block was measured with a steel tape. The stabilized block was positioned under a UTM with a capacity of 1000KN, and steel plates were positioned on both the bottom and top of the specimen to ensure uniform loading. The weight was then applied gradually until the specimen failed. CS was calculated using the maximum failure load of the specimen, as outlined in the following equation. The results of the test are presented in the figure below.

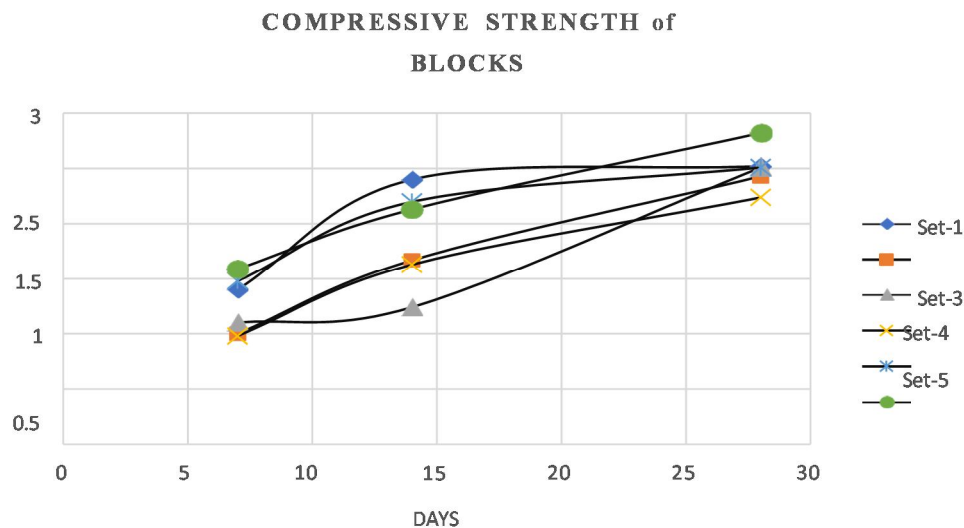


Figure 6. Compressive strength of blocks

B. Compressive strength of the prism result

The CS of a prism, typically referred to as the prism CS, is a measure of the maximum load a masonry prism can withstand before it fails in compression. It is an important parameter for assessing the structural integrity and load-bearing capacity of concrete or masonry elements.

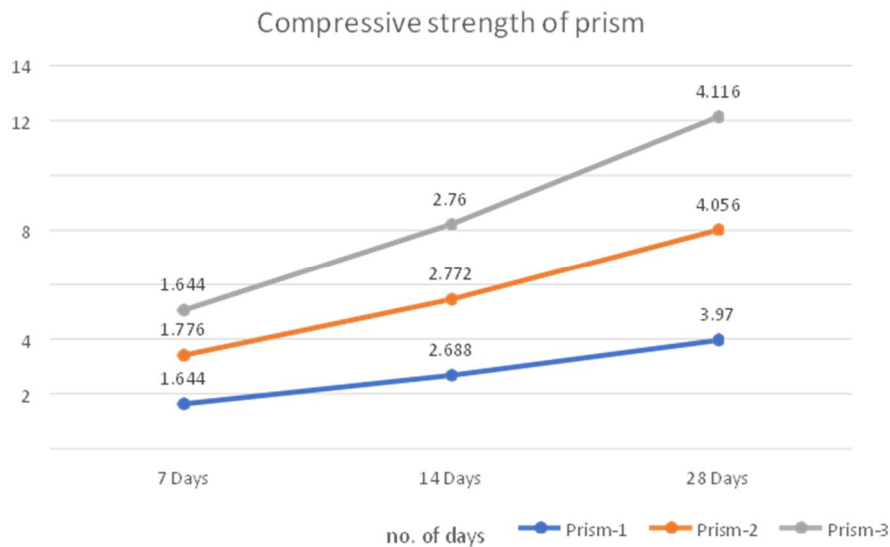


Figure 7. Compressive strength of prism

VI. CONCLUSION

The experimental results on different alternatives, namely C and D waste as soil in stabilized blocks and fine aggregates in masonry mortar, have led to the following concluding remarks

- The manufacture of C and D blocks considers sustainable construction practices. Landfills with C and D waste were identified. The collected and segregated materials were further processed using innovative crushing techniques.
- The sieve analysis indicates that the distribution of particle grains in the C and D waste alternative materials falls within Zone-II according to IS 383-2016.
- According to IS 1905-1987, the CS of mortar at a ratio of 1:4 should be 7.5 N/mm² for 28 days. However, the CS of the mortar mix made up of C and D waste at a ratio of 1:4 is 19.42 N/mm², exceeding the codal requirement.
- Under IS 2250-1981, the flow table test results demonstrate that a water/cement ratio of 0.95 results in a workability of 105%. The code required a flow between 100 and 115%, which was achieved.
- Varying mix proportions were cast. The casted blocks were tested for 7, 14, and 28-day CS. The set-6 CS is higher than all sets. For 7 days, 14 days, and 28 days, values are 1.59 N/mm², 2.13 N/mm², 2.82 N/mm²
- The water absorption test for the modified set was done, and the result was 10.46%, which stratifies the IS 1725-2023 codal requirement; it should not be more than 15%.
- The manufactured blocks of all sets were found to have a good finish and were made with less manpower and duration. The blocks could not fulfill the strength requirement as per IS 1725-2023. The strength might be achieved by adapting alternate binders and improving the process of mixing materials.
- The strength of SET-6 is approaching the code standards; it has been selected for the construction of prisms. The proportions of SET-6 materials have been modified by increasing the cement content by 10% instead of lime.
- The CS of the modified set-6 is higher than the set-6 proportions. For 7 days, 14 days, and 28 days, the values are 2.78 N/mm², 3.31 N/mm², 6.82 N/mm², respectively, and they achieve the strength as per IS 1725-2023.
- The masonry prisms with stabilized blocks were cast. Prisms are made with stabilized C and D blocks and mortar with C and D waste as a fine aggregate. The prism at 28 days was found to be 4.1N/mm²
- Masonry efficiency of the prisms made with the mortar of C and D waste, 60.1% for 28 days, is acceptable for block
- From the dissertation work carried out, it can be concluded that the C and D waste and burnt clay brick can be used as soil instead of sandy soil or quarry dust in stabilized mud blocks.
- From the work carried out, it can be concluded that the C and D waste can be used as fine aggregates instead of natural sand or M sand in masonry.

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