

COMPRESSED BRICKS FROM INDUSTRIAL BY-PRODUCTS: A GREENER ALTERNATIVE TO CONVENTIONAL MASONRY

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Abstract

Burnt bricks, widely used for centuries, have high energy consumption and contribute significantly to CO₂ emissions. To address this, compressed stabilised earth blocks (CSEB) have gained attention as a sustainable alternative. With the growth of the M-Sand industry in India, large amounts of slurry waste are produced, leading to environmental challenges. This research focuses on repurposing this waste (size smaller than 150 μ) in dry powdered form, named as M-Silt, into eco-friendly building materials. Two brick types, Compressed M-Silt Bricks (CMB) and Compressed M-Silt Earth Bricks (CMEB), were developed and analysed. The study evaluates their properties, including compressive strength, water absorption, Initial rate of water absorption (IRA) and dimensional stability, highlighting the potential of M-Silt in sustainable brick production. Fig 1 represent the schematic representation of production of CMB bricks.

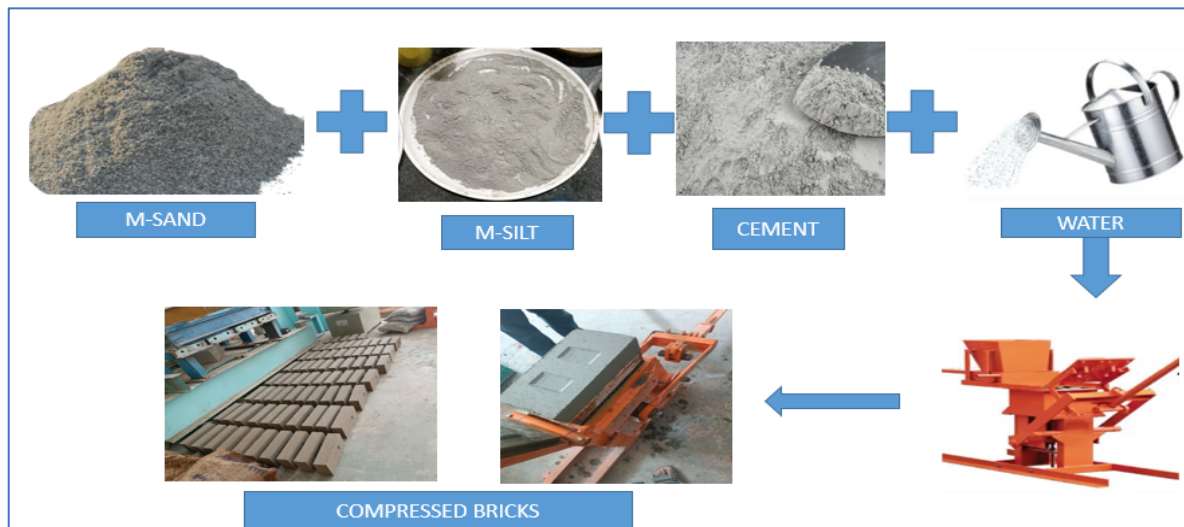


Fig 1 Production of CMB bricks.

1. Introduction

Burnt bricks have been the most commonly used masonry material since ancient times, valued for their availability, strength, and other key properties. However, their production process is highly energy-intensive and results in significant CO₂ emissions, contributing to global warming [2, 4, and 5]. In recent years, compressed stabilised earth blocks (CSEB) have become a popular alternative [1], made from naturally sourced soil. CSEB do not require burning and are produced

by compressing a mixture of soil and a stabilizing agent, typically ordinary Portland cement (OPC) or lime, using either manual or mechanical presses.

With the evolution of industrialization in developing countries, large amounts of waste are being generated as by products[6], prompting the need to repurpose this waste into useful materials. M-Sand industry is one of the fast growing industry in India [3]. During its production, after the washing process nearly 30-40% of its mass ends as slurry. This slurry is being dumped to open lands. Slurry when dried we get powder which we refer as M-Silt here onwards. Efforts are made to utilise M-Silt in production of compressed bricks.

In the Current research work two types of bricks are studied namely compressed M-Silt Bricks (CMB), Compressed M-Silt Earth Bricks (CMEB). The CMB bricks used M-sand, M-Silt and Cement as their raw materials whereas in CMEB bricks M-Sand is partially replaced with soil. The various properties such as dimensionality, compressive strength, water absorption and IRA tests are discussed in this paper.

2. Experimental Programme

An attempt was made utilize M-Silt in the production of bricks. The proportions of M-Sand and M-Silt varied by keeping constant proportion of cement. The % of cement kept at 10% and the proportion of M-sand varied from 40-70% and M-Silt from 50% to 20% respectively with an interval of 10% as shown table 1.

Table 1. Trial mix Proportions

MIX ID	M-Sand (%)	M-Silt (%)	Cement (%)
C1	40	50	10
C2	50	40	10
C3	60	30	10
C4	70	20	10
C5	80	10	10

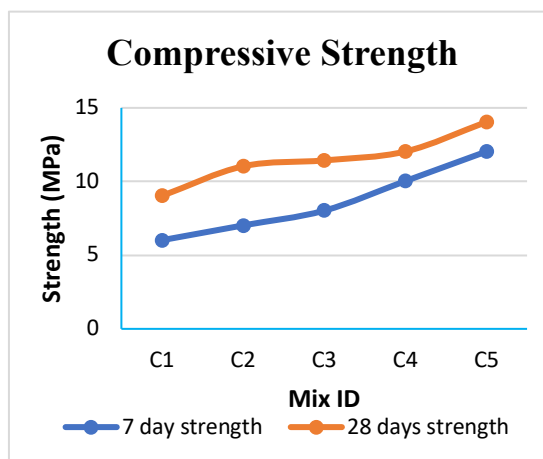


Fig 2 Strength of trial mixes of CMB Bricks

The trial mixes are done in mortar cubes of 70mm size and the results are shown in fig 2. from the results it is seen all the mixes satisfying the strength requirement as per IS: 1077-1992. Since amount of strength gain is more in C2 mix it is taken for further study. For the CMEB blocks M-Sand is partially replaced by natural soil. The properties such as dimensionality, compressive strength, water absorption and IRA are studied and are verified with codal requirements.

3. Materials

The material characterization plays a vital role in any research work.

3.1 Cement

53 grade OPC confirming to IS 12269:2015 [15] is used for the study. The results of various test conducted to know the physical parameters are shown in Table 2 and chemical analysis is done X-ray Fluorescence (XRF) and its result are shown in Table 3

Table.2 Physical properties of OPC

Tests Conducted	Results	Requirements as per IS 12269:2015
Normal Consistency (IS 4031:1988 Part-4)	27%	25%-30%
Initial setting time	35	Not less than 30 minutes
Final setting Time	310	Not more than 600 minutes
Specific gravity (IS 2720-2016 Part 3)	3.13	3.15
Fineness	4%	Should not exceed 10%
Soundness	1mm	Change in distance between the needles should be Less than 10mm

Table 3. Chemical Properties of Cement

Oxide Components	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	K ₂ O	SO ₃	P ₂ O ₅	Na ₂ O	TiO ₂	MgO
Percentage	16.34	6.95	5.38	60.84	2.73	1.99	1.67	2.73	1.50	2.32

3.2 M-Sand

M-Sand is a form of engineered sand, produced by crushing granite stones in quarries, and has emerged as a viable alternative to river sand, which is increasingly limited in supply and rising in cost. For this study, locally sourced M-Sand was utilized and rigorously tested in compliance with the IS 383-2016 code [16] to ensure its suitability for construction purposes. The properties of M-Sand is shown in table 4

Table 4 Physical properties of M-Sand

Sl. No	Property	Values for M-Sand	IS383 :2016 Value
1	Fineness Modulus	3.26	2-3.5
2	Specific Gravity	2.61	2.5-3
3	Bulk Density (Compact State)	1555 kg/m ³	1200-1750 kg/m ³
4	Bulk Density (Loose State)	1450 kg/m ³	

M-Sand is Confirming to zone II as per analysis and is used in surface saturated condition (SSD).

3.3 M-Silt

It is the fine powder obtained after drying the M-sand slurry whose size is smaller than 150μ and is confirmed by the particle size analysis done using hydrometer and is as shown in Fig 3 below. The M-Silt is shown in Fig 4

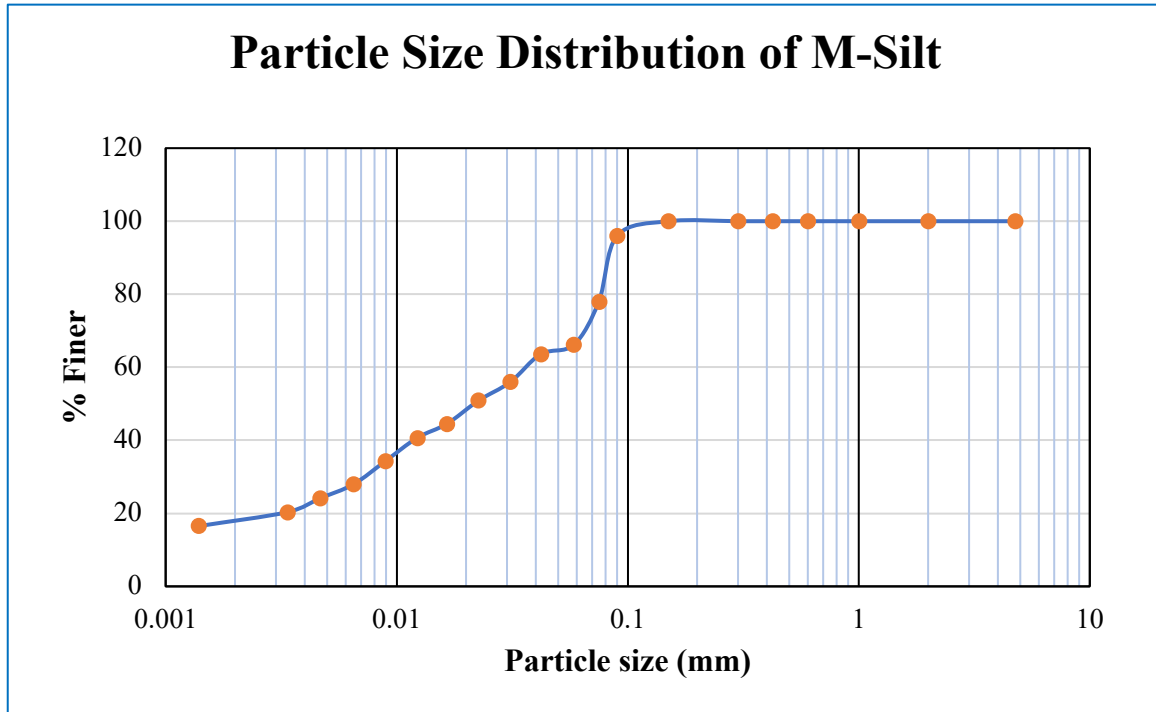


Fig 3 Particle size distribution of M-Silt



Fig 4 M-Silt

The results of various tests conducted at laboratory to understand the physical property are shown in table 5. The chemical properties are analysed by XRF and are as table 6

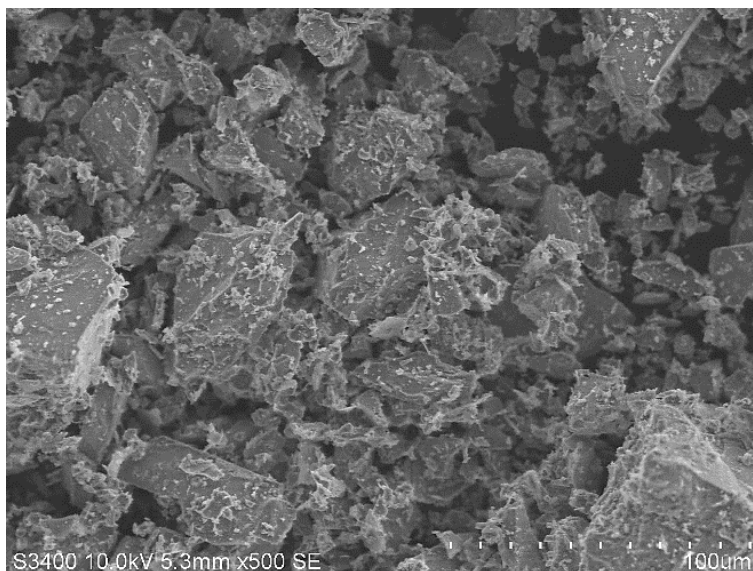
Table 5 Physical Properties of M-Silt

Test Conducted	Specific Gravity	Fineness	pH
Results	2.5	6	7.53

Table 6 Chemical Properties of M-Silt

Oxide Components	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	K ₂ O	MgO
Percentage	66.4	14.9	3.66	2.43	1.21	3.94

Scanning Electron Microscopy (SEM) is a high-resolution imaging technique that uses electron beams to analyze the surface morphology and microstructure of materials. The SEM image of M-Silt is represented in fig 5. X-ray Diffraction (XRD) is a powerful analytical technique used to identify and quantify the crystalline phases in materials. It works by measuring the diffraction patterns of X-rays interacting with the atomic lattice of a sample, providing insights into its mineralogical composition, crystallinity, and structural properties. XRD graph plotted for 2-Theta angle is shown in fig 6. From XRD analysis it is observed that M-Silt is rich in quartz with secondary items feldspar and clay minerals.

**Fig 5. SEM image of M-Silt**

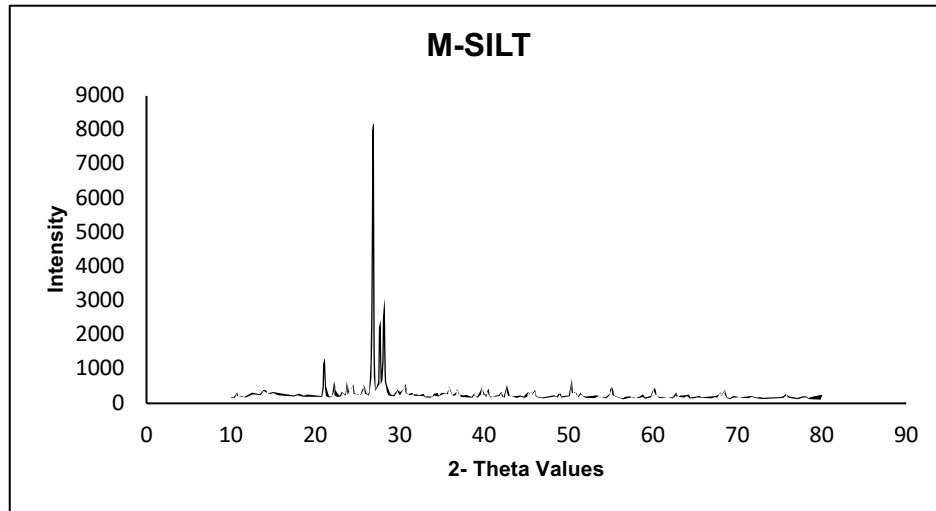


Fig 6. XRD pattern of M-Silt

3.4 Soil

Soil is a natural ingredient used in production of compressed bricks and it is collected from nearby site. The use of soil makes the brick more sustainable and economical. Its particle size distribution is shown in below fig 7 and other properties are shown table 7.

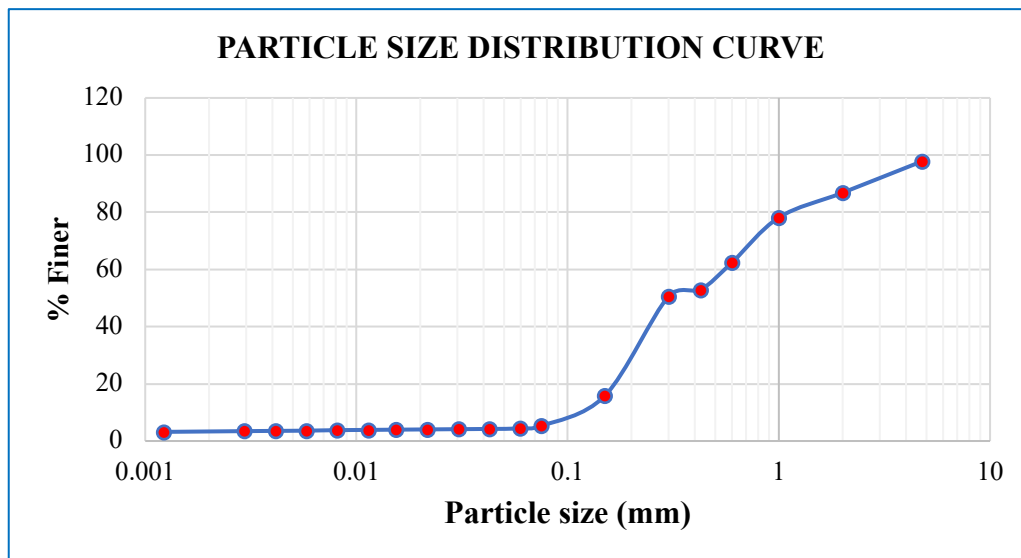


Fig 7. Particle size distribution of Soil

Table 7 Properties of Soil

Test Conducted	Results
Specific Gravity	2.58
Liquid limit	33.60%

Plastic Limit	20.22%
Plasticity Index	13.38%
Density 1.Core Cutter Method	Bulk Density = 2049 kg/m ³ Dry Density = 188 kg/m ³
2. Sand Replacement Method	Bulk Density = 1857 kg/m ³ Dry Density = 1590 kg/m ³

Water

Tap water which is colourless and odourless is used for the preparation of alkaline solution and also for casting work.

4. Results and Discussion

The CMB and CMEB bricks are casted as per optimum mix obtained in trial mix. The proportions of M-Sand-Silt and Cement were in the ration of 5:4:1 respectively in CMB bricks. CMEB had M-Sand, Soil, M-Silt and Cement in the ratio of 2.5:2.5:4:1 respectively. The amount of water to be added is determined using standard compaction test and the results found to 13.8 % for CMB bricks and 15.2% for CMEB bricks (Fig 8).

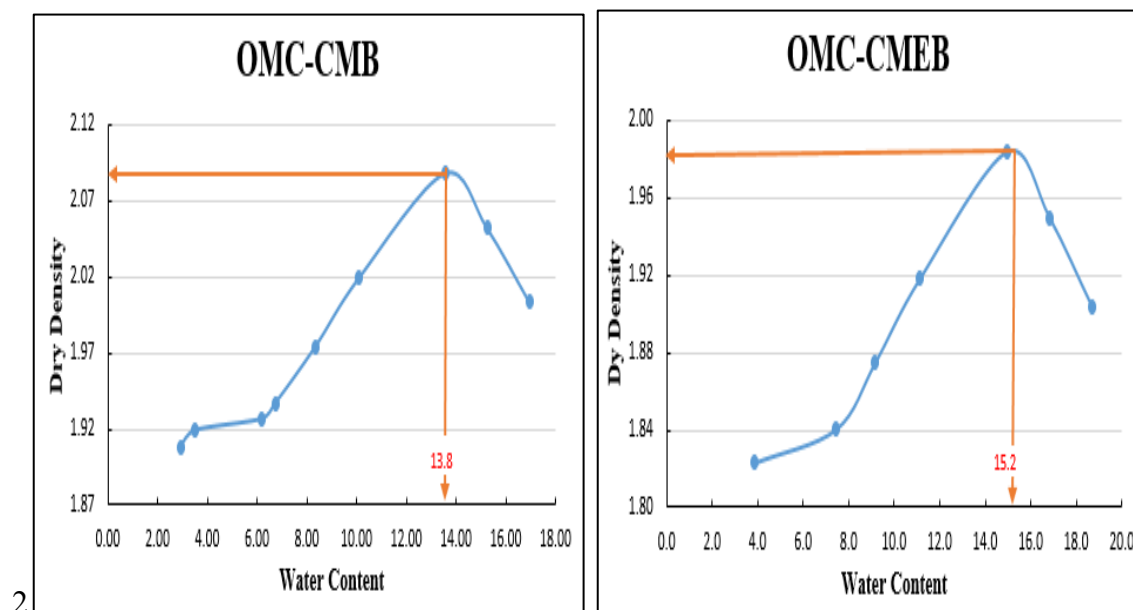


Fig 8. Values of OMC for CMB and CMEB bricks

4.1 Dimensionality test

Twenty bricks were selected randomly and were cleaned from any blisters or loose particles. This test is very essential to assure the shape of structure. The test is conducted as per IS 1077-1992 [9]. Selected bricks were arranged in a line on a flat surface in contact with each other as shown in Fig 9



Fig 9 Dimensional test

The results are found to be within the range mentioned the code book and are tabulated in table 8. And it was observed that all the bricks possessed sharp edges without any damage.

Table 8 Dimensionality test results

Types of Brick	Sides	No. of units	Dimension (mm)	Average Dimensions (mm)	Variation in Dimensions (mm)	IS 1077:1992 (mm)
CMB	L	20	6000	6018	+18	± 80
	W		2800	2809	+09	± 40
	H		1400	1410	+10	± 40
CMEB	L	20	6000	6017	+17	± 80
	W		2800	2807	+07	± 40
	H		1400	1411	+11	± 40

4.2 Compressive Strength

IS 1077-1992 [9] guide lines are used for the testing of bricks. The compressive strength of CMB and CMEB are shown in Fig 10

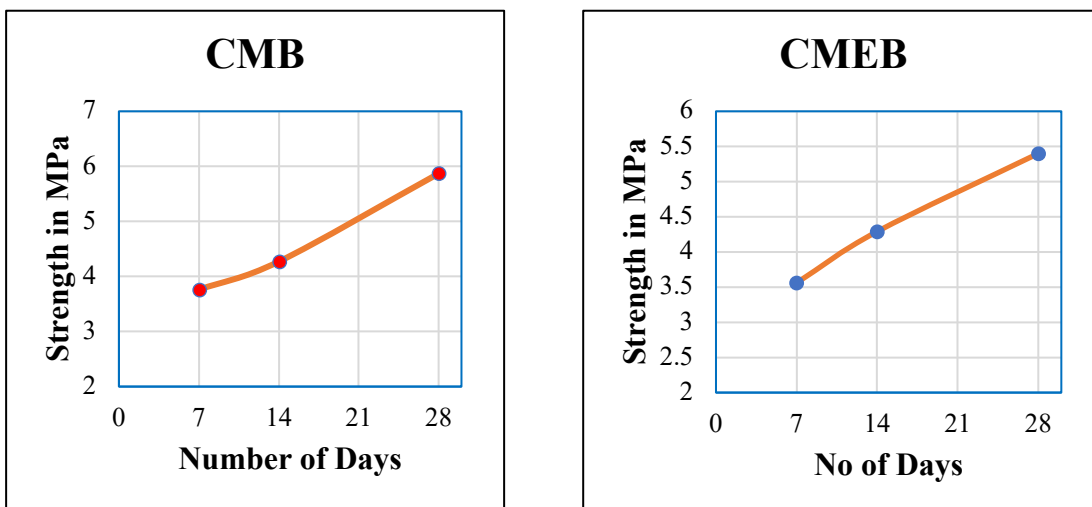


Fig 10 Compressive Strength of CMB and CMEB bricks

The minimum strength requirement for any bricks as per IS code is 3.5 MPa. The strength of CMB brick varies from 3.7 to 5.9 MPa and for CMEB it varies from 3.6 to 5.4 MPa. From the results CMB had higher strength than CMEB. The lower strength of CMEB is due to lower % of clay in natural soil used, however it has surpassed the strength requirement of brick to be used in construction. . XRD pattern of CMB and CMEB are as shown in fig 11 (a) and (b) respectively, the strength gain is majorly in line for to the formation of C-S-H gel.

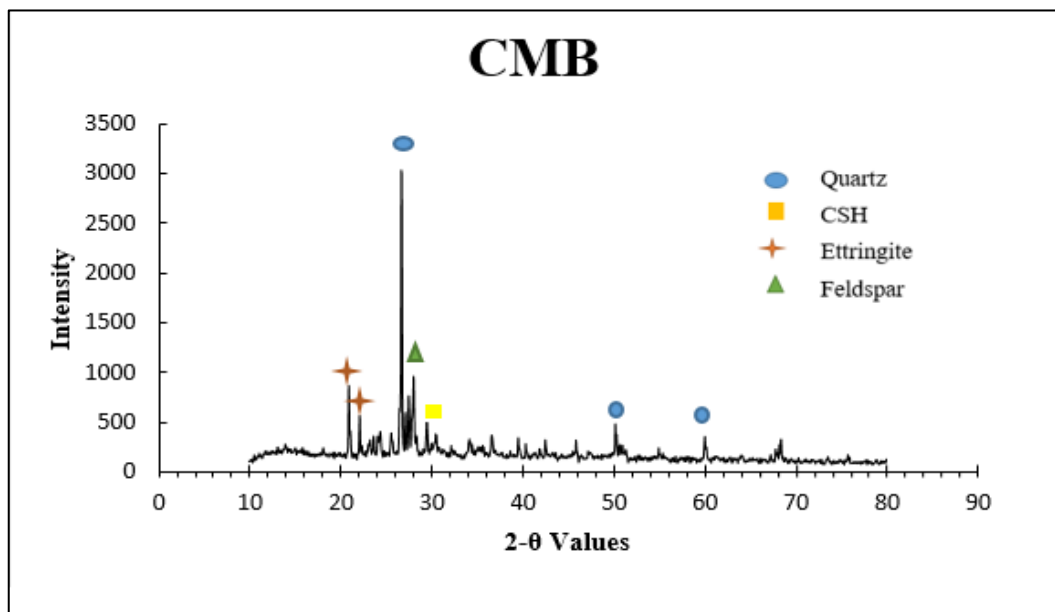


Fig 11 (a). XRD Pattern of CMB Bricks

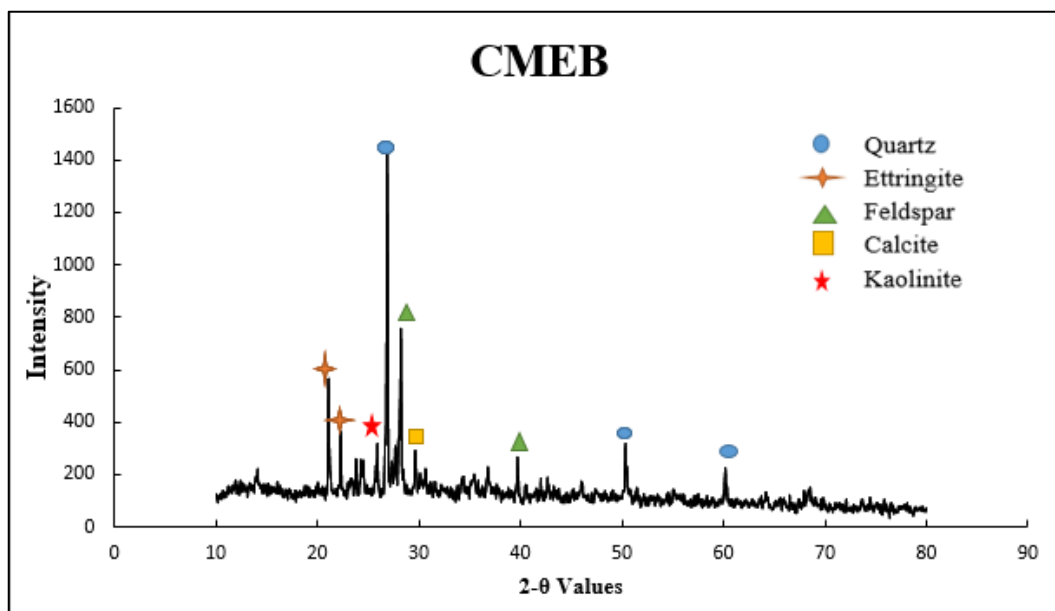


Fig 11 (b). XRD Pattern of CMEB Brick

4.3 IRA

The test is conducted as per ASTM C67 [14] guidelines. IRA indicates the suction capacity of a brick. It is defined as the weight of water that the brick's bed face absorbs in one minute when immersed in water to a depth of 25 mm. It is expressed in Kg/m²/min. The test results are shown in table 9. IRA value for burnt clay bricks ranges from 1.17 to 9.33 kg/m²/min [7, 8]. The value of IRA is found to be within range [7, 8]. IRA testing is shown in fig 12

Table 9. IRA Values

Type of bricks	IRA (kg/m ² /min)
CMB	6.88
CMEB	7.05



Fig 12. IRA testing

4.4 Water Absorption

The water absorption is carried out as per part 2 of IS 3495-1992 [10]. It is amount of water absorbed by the brick when soaked in water for 24 hours and is expressed in percentage. It indicates the particle density of brick. The water absorption of brick are shown in table 10. It is observed that the water absorption was in the range of 11.51-13.05%. According to IS 2185-2005 [11] the maximum water absorption for solid bricks is 20%. Both the bricks type CMB and CMEB satisfy this criteria.

Table 10. Water absorption Values

Type of bricks	Water Absorption (%)
CMB	11.51
CMEB	13.05

5 Conclusions

The effort is made to utilize M-silt as raw material to produce compressed bricks. The properties such as dimensionality, compressive strength, IRA and water absorption are evaluated and are verified with requirement of bricks to utilize for construction works. The results of various tests are summarized as below

1. Both CMB and CMEB bricks exhibit excellent dimensionality characteristics as per IS 1077:1992
2. Compressive strength of both the brick types were higher than the minimum standards mentioned in IS: 1077:1992 (greater than 3.5 MPa).
3. The water absorption value ranged from 11% to 13.05%, meeting the requirement of not exceeding 20% by weight as per IS 3495:1992
4. IRA is found to be 6.8 kg/m²/min for CMB and 7.05 kg/m²/min for CMEB satisfying the criteria.
5. Since both brick types meet the necessary standards, they can be effectively used as alternatives to conventional bricks

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