REVISTAMATÉRIA

V.29 N.3

ISSN 1517-7076 articles e20240179, 2024

Mechanical, water absorption, efflorescence, soundness and morphological analysis of hybrid brick composites

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ABSTRACT

Nowadays, Recyclability of huge quantity of waste materials generated in industries to form new materials. The current research is also focuses on utilization of waste materials produced by industry to form new hybrid brick for sustainable the environmental condition, technical aspects, and low production cost in construction field. In this paper hybrid brick specimens are manufactured using waste materials of clay, ceramic waste powder and sugarcane bagasse ash with various mix proportions. These bricks are tested in compression test, soundness test and water absorption test as per Indian Standards. It was observed that clay bricks incorporating ceramic waste powder (10%) and sugarcane bagasse ash (10%) exhibited high compressive strength, less water absorption, less efflorescence, good metallic ringing sound compared to other hybrid bricks leading to protect the environmental stability and keep away from hassle of ash disposal. The combination of ceramic powder and sugarcane bagasse ash residue increases the compressive strength of the clay samples (B2) to 27.2 MPa, and the composition of Brick B2 exhibits decreased water absorption percentage up to 11.4%.

Keywords: Clay; Ceramic waste powder; Sugarcane bagasse ash; Water absorption test; Soundness test.

1. INTRODUCTION

Large amounts of solid waste are being generated as a result of industrial activity (e.g. ceramic industries, marble and granite industries, paper and textile industries, petroleum refinery, urban waste, ashes, Al-rich sludge etc.). Industries have been on the search for technology that will help them optimize their processes and reduce waste [1, 2]. Fired clay bricks are essential components of masonry construction and have been widely used and manufactured for many years around the world. Burnt clay bricks are key parts of brick masonry and have been used and produced all over the world for many years [3, 4].

Plastic components (clays), fluxing components (feldspar), and inert components (feldspar) are the three most commonly utilized raw ingredients in traditional ceramic industries (quartz and sand) [5]. The red ceramic industry's clay ingredients come in a wide variety of compositions, allowing for the inclusion of a wide range of industrial waste products. Some wastes have a composition that is quite similar to the raw materials used in the manufacturing of ceramic products, and they frequently contain components that can be useful in the manufacture of ceramic products as well [6].

Corresponding Author: Balaji Venkatesan Received on 16/04/2024 Accepted on 05/06/2024

DOI: https://doi.org/10.1590/1517-7076-RMAT-2024-0179

Furthermore, in countries where substantial amounts of these wastes are produced and discharged in open fields, the trend of using biowastes from fuel sources in concrete, such as wheat bran ash, palm oil fuel ash, sugar cane bagasse ash and rice husk ash is growing significantly [7].

Bagasse is a byproduct of the sugarcane juice extraction process that is employed as a key energy source in some industries [8]. When Bagasse ash is used as a fuel, it produces a large amount of bulk ash. However, using bagasse ash waste as a partial replacement for cement in concrete has considerable economic and greenhouse gas reduction benefits [9]. However, using this bagasse ash residue in concrete as a partial substitute for cement has considerable cost and greenhouse gas reduction benefits. This is due to the high levels of amorphous silica and aluminium oxides in bagasse ash, both of which are required for pozzolanic materials [10]. The idea of adding bagasse into burnt clay bricks to reduce weight was developed, and the clay bricks' characteristics increased as a result of improved porosity and thermal insulation. Bricks are prepared from natural waste material which comprises of sugar bagasse ash and shown that maximum compressive strength can be attained. Bagasse ash bricks can reduce the seismic weight of building [11]. Recycling trash from industrial and agricultural processes as building materials looks to be a workable solution to both the pollution issue and the issue of cost-effective building design. Influence of marble and aluminum waste powder on the performance of bricks has demonstrated that the results of qualitative tests like the compressive strength test and the water absorption test are improved when marble powder and aluminium waste powder are added to the brick composition [12]. Bagasse is a type of industrial trash that is produced in nations like India, Thailand, China and Brazil. India in particular has a sizable area where sugar cane is cultivated. As a result, there is a surplus of bagasse waste of about 10 million tonnes annually. Seventy percent of bagasse is typically used as electric flue, in the paper sector, and in plywood, with the remaining 15 percent going to waste [13]. Amounts of cellulose, hemicellulose, lignin, and ash in bagasse range from 40 to 50 percent, 15 to 20 percent, and 15 to 25 percent, respectively. Silica (about 56 percent) is produced by the burning of bagasse [14]. Several groups have investigated the use of bagasse ash in ceramic products including the use of bagasse for reinforcement in composites [15].

According to certain studies, bagasse's pozzolanic reactivity may increase various mechanical and durability-related parameters as well as the compressive strength of concrete [16]. Since silica oxide is the primary component of bagasse ash, many researchers have noted its potential application in concrete. The utilizing of 4% sugarcane bagasse ash as a partial substitute for cement boosted the concrete's strength metrics and showed a very similar pattern of strength improvement in different research [17]. 10% of sugarcane bagasse ash can be employed effectively without affecting the fundamental characteristics of concrete [18]. Using 15 percent sugarcane bagasse ash increased the strength and durability of concrete significantly. Experimental research on how to successfully recycle fly ash, as well as a novel brick-making method that can increase fly ash content by 50–80%. The basic materials used in fly ash brick production, as well as the major control points. It explains how to modify the technical parameters of an existing brick-making mechanical equipment, optimize parameter combinations, and increase device performance [19].

The primary goal of the current effort is to investigate the idea of adding burnt clay bricks with sugarcane bagasse and ceramic waste powder to reduce weight and enhance the mechanical and water-absorbing qualities of the clay brick. These uses help the environment because they make it possible to put waste materials to good use. Because of the finding of this research gap, this study creates innovative composites using ceramic powder and sugarcane bagasse ash residue. In this current work, handcrafted bricks (B1), (B2), and (B3) with varying compositions of ceramic powder and sugarcane bagasse ash residue are used. The compression test, water absorption test, efflorescence test, and soundness test of produced bricks are investigated. A morphological analysis is performed using scanning electron microscopy (SEM) images to better understand the distribution of fillers and matrix strength of bonds.

2. MATERIALS AND METHODS

2.1. Materials

In this research, clay (sieve size: 0.24 mm), ceramic waste powder (specific gravity 2.15 kg/m^3 materials are obtained from Institute of Ceramic Technology, Virudhachalam, Tamilnadu, India) and fine bagasse ash (density 2.25 g/cm^3 waste collected from Perambalur Sugar Mills Limited, Chennai, Tamilnadu, India) are shown in Figure 1 and Table 1.

2.2. Hybrid brick specimen preparation

The traditional procedure used in large-scale local brick manufacturing facilities is used to create hybrid bricks [20]. The weights of the brick clay, ceramic waste powder, and sugarcane bagasse ash are measured to create the

Figure 1: Raw materials used for brick manufacturing (a) clay, (b) ceramic waste powder and (c) bagasse ash.

Table 1: Raw materials used for brick manufacturing.

SL.NO.	INGREDIENTS	SOURCE	PROPERTIES
1.	Clay	Ordinary sand from ground	Sieve size: 0.24 mm
2.	Ceramic waste powder	Institute of Ceramic Technology, Virudhachalam, Tamilnadu, India	Specific gravity 2.15 kg/m^3
3.	Fine bagasse ash	Perambalur Sugar Mills Limited, Chennai, Tamilnadu, India	Density 2.25 g/cm^3

Table 2: Composition of hybrid brick specimens.

SPECIMEN	CLAY (Wt.%) (MATRIX)	CERAMIC POWDER (Wt.%) (REINFORCEMENT 1)	SUGARCANE BAGASSE ASH (Wt.%) (REINFORCEMENT 2)
Brick (B1)	90	5	5
Brick (B2)	80	10	10
Brick (B3)	70	15	15

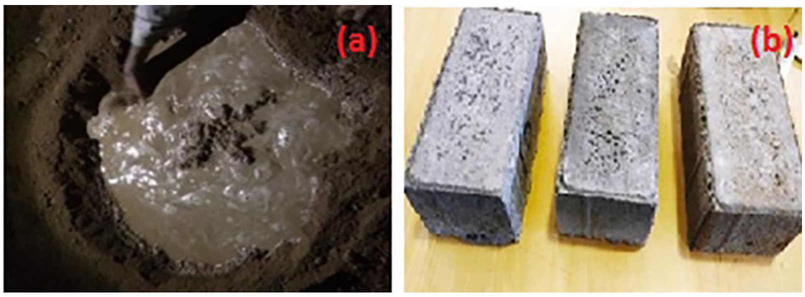

Figure 2: Specimen preparation (a) mixing of clay, ceramic powder and sugarcane bagasse ash and (b) brick specimen.

various mixes shown in Table 2. Water is consistently added to each composition (10–15 percent of conventional brick weight). The clay mixture's consistency made it possible to create the bricks. The mixing, casting, and burning of the bricks were done using a commercial brick manufacturing technique. Making the mixture moldable allowed for manual tempering. The 190 × 90 × 90 mm handcrafted bricks were manufactured using techniques used in the region's brick production as shown in Figure 2. The bricks were cast using moulds without any pressure being applied to them. In India, the bricks were left to dry in the sun for two days at a temperature of 35 to 40 °C. For an 800 ºC firing, these bricks were placed in the centre of the brick kiln. Before being taken out of the kiln, the bricks were allowed to cool for five days. Laboratory tests for the bricks were performed after two weeks. Before doing each test, the actual sizes and any potential evident faults of the bricks are inspected.

2.3. Hybrid bricks characterization

To know the quality of bricks following 6 tests can be performed. In these tests some are performed in laboratory and the rest are on field as shown in Table 3.

Table 3: Testing of hybrid brick specimens.

LABORATORY TEST	FIELD TEST
Compressive strength test	Efflorescence test
Water absorption test	Soundness test
SEM – (EDX analysis)	Size and shape

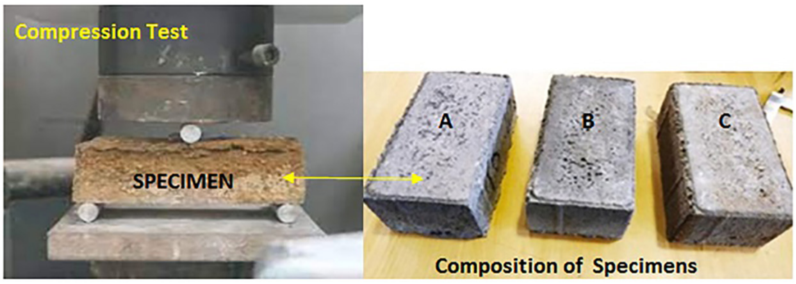

Figure 3: Universal testing machine with specimen and composition of specimens (Brick B1(A), Brick B2(B) and Brick B3(C)).

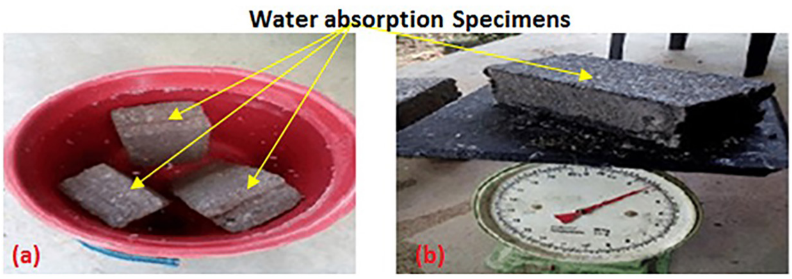

Figure 4: (a) Bricks are immersed into water and (b) bricks are weighted after 24hr immersion.

2.3.1. Compression test

Compressive strength test was performed on Microcomputer Controlled Electro-Hydraulic Servo Universal Testing Machine available at Met Mech Engineers Laboratory, Chennai as per ASTM C67-03. Displacement controlled monotonic loading (displacement rate of 0.01 mm/s) was applied on the bricks in wet condition to determine the compressive strength as depicted in Figure 3.

2.3.2. Water absorption test

Let us consider the Weight of the Brick is W1 and the testing specimen (A, B & C) are dried in an hot oven at 60 to 70 ºC till it secure a constant mass for 2 hours. Then it is kept Immerse in the brick in the cold water contained in the container for one day with room temperature as shown in Figure 4. It is weighed again to determine the weight of water absorbed W2 and the water absorption is calculated as follows

$$\text{Water absorption} = (W2 - W1) / W1 \times 100\%$$

Where, W1 = Weight of dry brick

W2 = Weight of water absorbed brick

2.3.3. Scanning Electron Microscopy (SEM) analysis

The JEOL (JSM- 6360) electron microscope is used to carry it out. The samples of ceramic powder and sugarcane bagasse ash were placed on a carbon strip attached to a SEM brass in order to be imaged by SEM to determine their size and shape. Blotting paper was used to remove any extra dust and the item was then placed under a mercury lamp for five minutes to dry.

2.3.4. Experimental set up of EDX

The elemental compositions of sugarcane bagasse ash and ceramic powder were determined by Energy Dispersive X-ray (EDX) analysis (JEOL: 6360) utilizing a variable pressure scanning electron microscope equipped with INCA X-sight Oxford instrument facility, at an acceleration voltage of 25 keV.

3. RESULTS AND DISCUSSIONS

3.1. Energy Dispersive X-ray (EDX) analysis

It is conducted to analyze the elemental makeup of materials. The ordinate and abscissa of the EDX spectrum both show the counts and ionization energy, respectively. The presence of a specific element will be more at that place or area of interest if its counts are higher. Each element's quantity can be shown as a number of counts or as a weight %. Analysis of the sugarcane bagasse ash profile using EDX Figure 5(a) displays a strong signal for elemental calcium and other chemical signatures (Si, Al, C, O and Fe).

The optical absorption band in the Ash crystallites peaks at 4.7 keV. The stability of the produced Ash was strongly attributed, according to the results of the EDX investigation, to the several chemicals that were absorbed on its surface. Figure 5(b) from an EDX study of ceramic powder displays a high signal for elemental Ca together with other chemical signatures (Mg, Na, Si, K, Fe and Cl). The optical absorption band in the ceramic powder crystallites peaks at 2.7 keV. The resilience of the synthesized cement is strongly attributed to the numerous compounds that were absorbed on its surface, according to an EDX examination [21].

3.2. Compressive strength

The compressive test is crucial for determining a building material's technical excellence. As illustrated in samples B1, B2, and B3, the results (Figure 6) reveal that the strength is significantly influenced by the amount of sugarcane bagasse ash and ceramic powder in the brick. Because of improved density and decreased water absorption, the addition of ceramic powder and sugarcane bagasse ash residue increases the compressive strength of the clay samples (B2) [22].

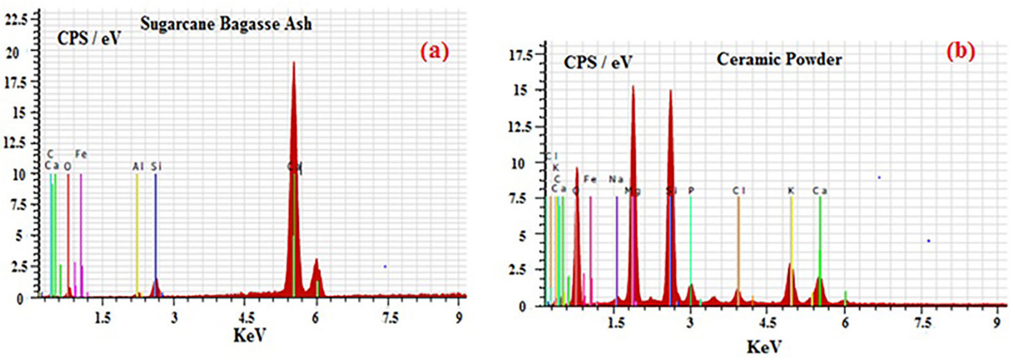

Figure 5: Chemical composition of EDX analysis (a) sugarcane bagasse ash and (b) ceramic powder.

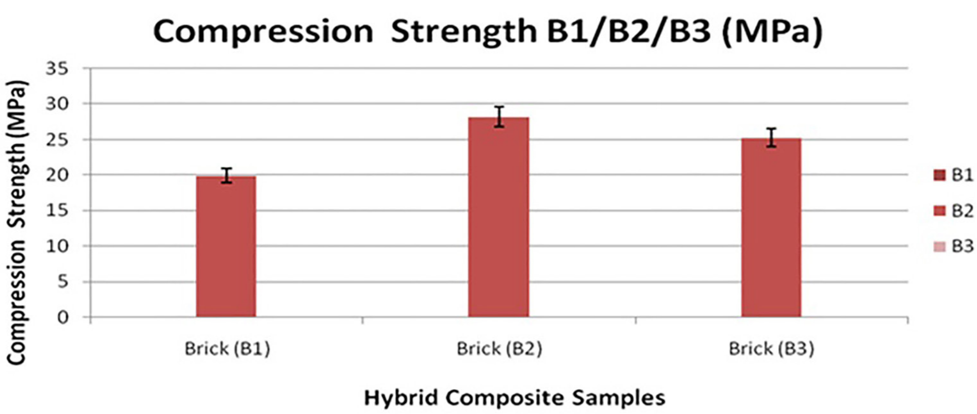

Figure 6: Compression strength of hybrid composites.

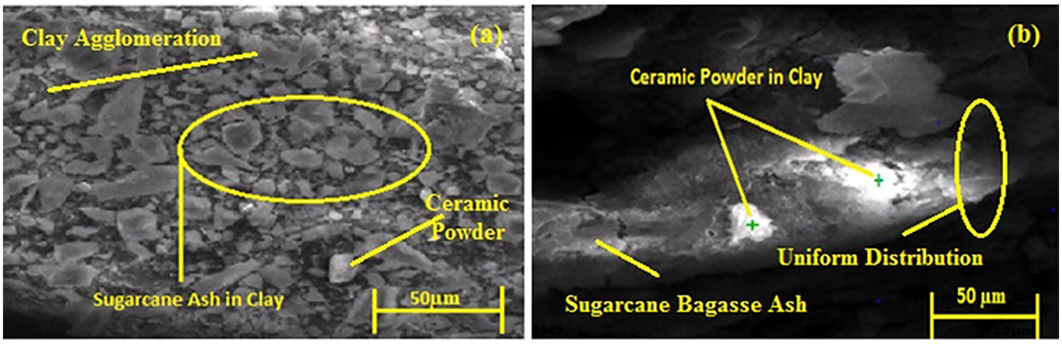

Figure 7: SEM images of hybrid composites (Brick B1 and Brick B2).

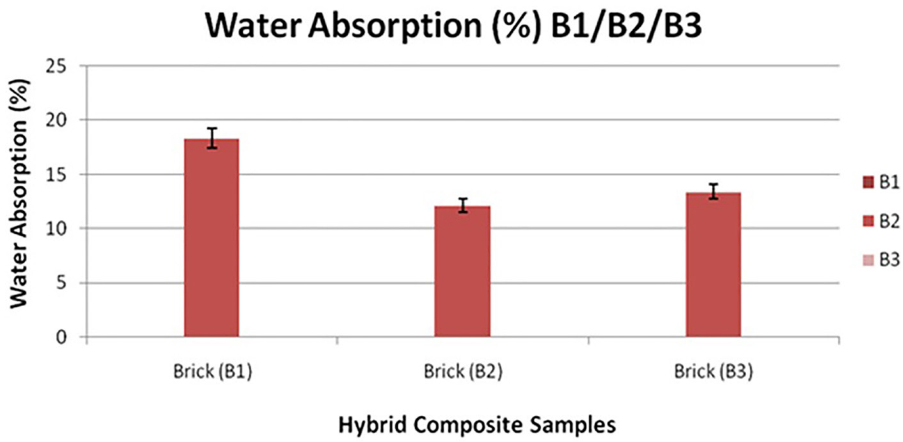

Figure 8: Water absorption (%) of hybrid composites.

3.3. Fractography observation

The SEM pictures of the Brick are displayed in Figure 7. According to Figure 7, the sugarcane bagasse ash and ceramic powder have irregular diameters and an uneven distribution in the clay for Brick B1. (a) According to SEM research, the distribution of the size of the ceramic powder and sugarcane bagasse ash in cement concrete is homogeneous (see Figure 7). (b) Concrete's durability performance is enhanced by the smaller sugarcane bagasse ash and ceramic powder particle sizes [21]. Filler reinforced bricks help to strengthen weak bricks by changing the failure mode from shear to stretching, and vice versa [23]. The covering of brick columns with filler improves their energy and ductility dissipation capacities [24].

3.4. Water absorption test

The consequence of water absorption for hybrid composites can be understood from Figure 8. The composition of Brick B2 shows less water absorption than all other percentages of replacement, which is an obvious conclusion [20].

3.5. Efflorescence test

The efflorescence test is used to determine whether groundwater has entered building foundations or has entered brickwork by capillary action. Typically, efflorescence contains magnesium sulphate, calcium sulphate, and sodium and potassium carbonates. A white crystal layer was deposited on the surface of the eco bricks during an efflorescence test, as depicted in the Figure 9. As can be seen from the test, the results are represented by a thin layer of salty material that covers less than 10% of the exposed area of the eco-friendly brick [19].

3.6. Soundness test

The soundness test of the Eco bricks is shown in Figure 10. Bricks are tested for soundness to determine their resistance to quick impact. In this test, two bricks are taken and joined together. The bricks should not break and should generate a clear metallic embrace sound, but Eco bricks produced a bland sound [20].

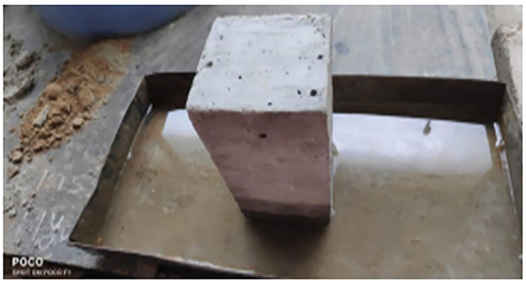

Figure 9: Efflorescence test specimen of brick.

Figure 10: Soundness test of brick.

Table 4: Hybrid brick specimen size.

SPECIMEN	LENGTH (mm)	WIDTH (mm)	HEIGHT (mm)
Brick (B1)	190.1	89.7	89.8
Brick (B2)	190	90.1	90.2
Brick (B3)	190.5	91.8	90

Table 5: Comparison between ordinary bricks and newly formed hybrid bricks.

SL. NO.	DESCRIPTION	CLAY BRICKS	HYBRID BRICKS
1.	Size, mm	190 mm × 90 mm × 90 mm	190 mm × 90 mm × 90 mm
2.	Volume, cm^3	450 cm^3	450 cm^3
3.	Density, kg/m^3	1700	1720
4.	Cost in rupees	10 (INR) per brick	8 (INR) per brick
5.	Compressive strength, MPa	15–20	20–28
6.	Water absorption	20–25%	11–17%

3.7. Size and shape

Randomly selected size and shape test bricks are laid out along their length, breadth, and height, and then those are measured to determine how widely the sizes deviate from the norm. Bricks are scrutinized thoroughly to ensure that their edges are clean, uniform, and straight. The various ratios of clay, ceramic powder, and sugarcane bagasse ash used to make the eco-bricks, such as types B1, B2, and B3, were tested for size and shape. The results are presented in the Table 4 below. The proportion and standard value of eco bricks apply to all brick sizes as well [19].

3.8. Scientific comparison between ordinary bricks and newly formed hybrid bricks

The scientific comparison between ordinary bricks and newly formed hybrid bricks are observed in Table 5. From that, it is observed that newly formed hybrid brick properties are good in compressive strength and water absorption for the same size, volume and density. Similar cost for manufacturing of hybrid brick is less in comparing with ordinary bricks.

4. CONCLUSION

The following conclusions are reached as a result of an experimental inquiry into the appropriateness of sugarcane bagasse ash and ceramic powder in the production of sustainable clay bricks.

- The experimental data demonstrates the considerable increase in the compression strength of hybrid composites (Brick B2) made of ceramic powder and sugarcane bagasse ash. Sugarcane bagasse ash and ceramic powder present in Brick (B2) reduce water absorption.
- The mixture of ceramic powder and sugarcane bagasse ash residue raises the compressive strength of 27.2 MPa and also reduces water absorption by up to 11.4% in the brick (B2).
- An EDX examination revealed that numerous compounds were absorbed on the cement's surface and are crucial to the stability of the synthetic cement.
- According to SEM analysis, cement concrete's durability performance is enhanced by the use of ceramic powder and sugarcane bagasse ash in smaller particle sizes.
- The hybrid brick B2 form has good properties when compared to other hybrid bricks, according to the efflorescence test, soundness test, and brick dimension. The study reveals enhanced mechanical qualities, more research is needed to assess the performance of these bricks in future structural applications, such as Clay Matte Grey London Brick, Soil Rectangular Red Brick, Clay Pillar Bricks, M Bricks, and others. This includes their performance under load and their incorporation into various types of building.

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