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Study and manufacture of thermally insulating concrete blocks using sustainable insulation materials

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ABSTRACT

This study summarizes the process of constructing lightweight hollow concrete blocks used as partitions in construction instead of load-bearing walls. Heat-insulating hollow concrete blocks are used to reduce the thermal effect inside the building by creating gaps of different dimensions, sizes, and shapes that allow for extending the path of heat transfer and thus significantly reducing the effect of thermal bridging in the wall. and significantly improves their thermal resistance. The compressive strength of the blocks and their thermal properties, such as density and absorption, were examined. One type of concrete wall unit incorporates irregular rectangular overlapping openings, while the other two types incorporate two and three parallel square openings. The thickness of the hollow block shell and the width of the openings were expected to be 30, 35, and 40 mm. The primary objective of using overlapping openings was to expand the heat transfer channel through the wall. Therefore, this new technology limits the number of openings, which impacts and reduces its thermal performance. Additionally, foam material is used, which aids in heat insulation and is utilized effectively. The primary materials used are cement-sand mortar. All of this contributes to reducing energy consumption costs and maintaining a sustainable, clean environment.

Keywords:hollow concrete blocks insulating, hollow, thermal , foam concrete

دراسة وتصنيع بلوكات خرسانية عازلة حرارياً باستخدام مواد عزل مستدامة

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ملخص

تلخص هذه الدراسة عملية إنشاء بلوكات خرسانية مجوفة خفيفة الوزن تُستخدم كقواطع في البناء بدلاً من الجدران الحاملة. تُستخدم بلوكات الخرسانة المجوفة العازلة للحرارة لتقليل التأثير الحراري داخل المبنى من خلال إنشاء فجوات بأبعاد وأحجام وأشكال مختلفة تسمح بتمديد مسار انتقال الحرارة، وبالتالي تقليل تأثير الجسور الحرارية في الجدار بشكل كبير، وتحسين مقاومتها الحرارية بشكل ملحوظ. دُرست قوة ضغط البلوكات وخصائصها الحرارية، مثل الكثافة والامتصاص. يتضمن أحد أنواع وحدات الجدران الخرسانية فتحات مستطيلة متداخلة غير منتظمة الشكل، بينما يتضمن النوعان الآخران فتحتين أو ثلاث فتحات مربعة

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متوازية. كان من المتوقع أن يكون سمك غلاف البلوك المجوف وعرض الفتحات 30 و35 و40 ملم. كان الهدف الرئيسي من استخدام الفتحات المتداخلة هو توسيع قناة نقل الحرارة عبر الجدار. لذلك، تُقلل هذه التقنية الجديدة من عدد الفتحات، مما يؤثر على أدائها الحراري ويُقلل من فعاليتها. بالإضافة إلى ذلك، تُستخدم مادة رغوية تُساعد في العزل الحراري وتُستغل بفعالية. المواد الأساسية المستخدمة هي ملاط الأسمنت والرمل. كل هذا يُسهم في خفض تكاليف استهلاك الطاقة والحفاظ على بيئة مستدامة ونظيفة.

الكلمات المفتاحية: كتل خرسانية مجوفة عازلة، مجوفة، حرارية، خرسانة رغوية

1. INTRODUCTION

Insulation against heat is an important topic so when it comes lowering power use and its consequences on structures. Given that Arab countries like Iraq have hot, dry summers & cold, rainy winters, it is one of the most important topics that must be discussed in this study. With a relative humidity level of at least 60%, summer temperatures can surpass 45 degrees Celsius. These days, solid or hollow blocks of concrete make up the exterior walls of most buildings in developed countries [1]. One of these walls' distinguishing features is their low heat resistance. During the summer Without air conditioning, the temperatures inside these structures are rather high. Therefore, electrical energy may be used to run air conditioners. This situation could persist for over five months in a year. It is better to design buildings with adequate thermal insulation [2]. Its objective is to reduce cooling expenses and environmental pollution. The only structures that use insulating materials are government buildings and commercial complexes. Concrete has been shown to have a substantially higher heat conductivity than air. By including holes or air spaces, the heat conductivity of the concrete mass can be reduced. The larger the air spaces, the more insulation there is.

2. PROBLEM STATEMENT

By adding as many gaps in air or holes as feasible to the block or even wall unit, the influence of thermal bridges on walls can be greatly diminished, greatly increasing the resistance to heat of the masonry unit. There are three different kinds of concrete wall units: one with square apertures and another with parallel rectangular openings. The cover has a thickness of 30, 35, or 40 mm. Creating a conduit for heat to travel through the wall is the fundamental concept underlying the use of voids in the blocks. Its thermal characteristics must therefore be compressed.

3. RESEARCH OBJECTIVES

the study concentrated on creating lightweight blocks of concrete with various hole configurations. A more affordable option may be offered by producing lightweight concrete blocks using a variety of lightweight basic materials with low heat conductivity [3]. Lightweight material can be utilized as raw materials, treated as natural resources, or processed as a by-product. Because of its inferior mechanical qualities, lightweight concrete is only appropriate for non-load-bearing walls, despite its better qualities like light weight and strong thermal insulation. Such materials are considered as waste, which are discarded without useful reuse. Development of LWC blocks with high thermal insulation properties using by products and waste materials as lightweight aggregates can have dual benefits, reducing the cost of construction and providing an alternative safe way of utilizing a waste material [4].

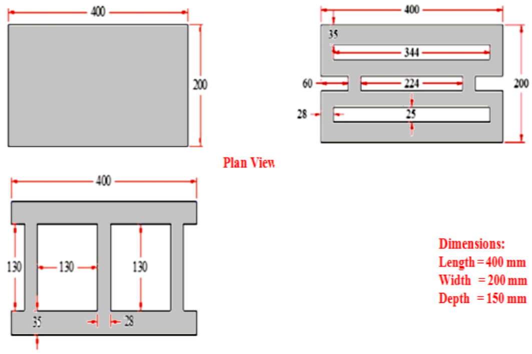

Figure 1: Formation, size and dimensions of concrete blocks

4. LITERATURE REVIEW

A few LWFC studies have been conducted. It is well acknowledged that LWFC has advantages such exceptional fireproofing, heat insulation, and acoustic insulation—all of which are robust, lightweight, and free-flowing. LWFC's freedom of flow allows her to fill holes without the need for vibrations.

Because of this, LWFC mix have recently been approved for use in a number of applications, such as void filling and wall construction. It takes a significant amount of time, money, and effort. The result is retained as intuitive. This is why LWFC exists. It is commonly regarded as a cost-effective alternative to traditional concrete mixes.

In a few earlier experiments, Mydin used the Hot-Guarded Plate technique to evaluate the heat conductivity at foamed concrete with varying densities of 650, 700, 800, 900, 1000, 1100, and 1200 kg per cubic meter. components that influence heat conductivity. The findings demonstrate that less dense foamed concrete transmits heat less efficiently. Porosity determines the density of foamed concrete; a larger porosity is indicated by a lower density. Air is the weakest conductor of solids and liquids due to the structure for molecules, which drastically alters the porosity of foam concrete. As a result, heat conductivity is significantly altered [5,6].

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Zhao et al. looked into the foamed concrete's compressive strength & thermal insulation properties utilizing granulated slag that was taken out of blast furnace slag. A foamed mortar with a mass density of 1300 kg/m^3 was produced. The optimal ratio of cement to water was determined to be 0.56. Two mix samples were created: one with cement and foam mortar (CFM) & the other with a slag and foam mortar (SFM), where a half of the weight of cement was replaced by slag. The experimental findings suggest that replacing 50% of the cement with slag could enhance the foamed the concrete's performances in terms of both compressive strength & thermal conductivity [7].

According to Jalal et al., foam concrete's ideal strength makes it a viable alternative construction material for industrialized building systems. For a combination with a low density, the foam concrete There is hardly much strength. The increase in cavities created by foaming throughout the sample lowers the density of the concrete, which lowers the compressive strength. High levels of insulation from heat, freeze-thaw resistance. This is and fire protection are offered by foam concrete [8].

Scientists Mohammad Faisal Khalil & Eethar Thanon Dawood evaluated the effects of partially substituting environmentally friendly mineral additives for conventional Portland cement (OPC) in their earlier study, The Effects of The use of Eco-friendly Materials in the Manufacture of High Strength Mortar. These included limestone (L), silica fume (SF) [10], and calcined clay (CC) [9] in the production of high in strength mortar (HSM) [11,12]. Utilizing these resources helps to reduce the environmental impact of cement production by conserving natural resources and reducing carbon dioxide emissions. To achieve the required strength, different mixtures were made using the super plasticizer (SP) type of G [13,14] by decreasing the water-to-binder ratio (w/b) and increasing the binder ratio. The mechanical behavior and strength of the blended cement were evaluated., and the optimal mixture was determined using the results of experiments on mechanical behavior, strength, and fluidity. The results showed that Mix F32, which consists of 8% SF, 4% L, & 13% CC with a roughly 35% increase, is the best mixture for the best mechanical properties to control the mix's strength. The results of the study indicate that the mechanical, durability, & service life of modern concrete/mortar mixes can be improved by partially substituting CC, SF, and L for OPC [15,16]. The results of this study can be expanded upon in future concrete mix design research. [17, 18].

The impact of foam material on cement & foamed concrete was also investigated by another researcher, Li Houa, Jun Lib, Zhongyuan Lub, and Yunhui Niub [19]. The agent for foams is a necessary component when creating foam concrete using prefabricated foams. In this study, four types of foaming agents were used to create foam concrete. The effects of the agent that foams on the

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properties in both fresh and hard foaming concrete [20,21], the interaction between the foaming agent and cement, and the gas–liquid interaction of foam concrete were examined. It has been observed that the interaction between the the cement & the foaming agent had a greater impact on the development of foam concrete. The gas-liquid interface property of foam concrete was the most important factor affecting its performance [22, 23]. which evaluated the stability of fresh foam concrete, the products of the pore walls for hard foaming concrete, and the pore structure. Finally, the process by which foam forms in freshly mixed foam concrete was investigated [24, 25].

The researcher(Alla Sai Krishna, Rakesh Siempu, G.A.V.S. Sandeep Kumar)also studied the properties of fresh and hardened concrete containing fly ash. Cellular lightweight concrete, or concrete made with foam with fly ash substituted, has been the subject of a research to investigate its fresh state and hardened state qualities. There are three main degrees of fly ash replacement: 25%, 50%, and 75% by cement weight [26]. Twenty different mixes in total were made with different densities between 800 and 1600 kg/m3. Nine 40 mm by 40 mm by 160 mm prismatic beam examples were cast and tested for each combination Using a mini slumping cone for workability and a mini V-funnel for uniformity, fresh state properties were discovered. The properties of the hardened state, including flexural and compressive strength, were assessed after seven and also twenty-eight days of age [27]. Consistency: It is found that the flow time lowers as the amount of fly ash in the foam concrete increases. The workability, or slump, of foam concrete has increased along with the quantity of fly ash added [28]. As fly ash replacement has increased, both the compressive and flexural strengths have significantly decreased [29].

Additionally, the researchers examined Hasan Mohammed Ahmed, Dr. Alyaa Abbas Al-Attar, and Ahmed Radhi Taha. This study illustrates how different restrictions affect the compressive strength of geopolymer concrete composed of fly ash mixtures that have been tuned using the Taguchi technique and the Minitab software. The primary goal is to determine the optimal ratios that might produce the best compressible strength for geopolymer concrete. For twenty geopolymer concrete mixture combinations with five mixtures of ordinary concrete, the effects of the addition of Alkali-Activator for the binder ratio (AA/B), the concentration of NaOH (M), its effects of Na2SiO3 for the NaOH ratio (SS/SH), and the influence of binder contents (B) were assessed. A variety of molarities were used in this investigation, include 8, 10, 12, 14, and 16.. In order to create geopolymer concrete, flay ash is utilized as a waste material in the following ratios: 15, 17.5, 20, 22.5%, and 25%. It is replaced with 90% regular Portland cement.. Additionally, sodium hydroxide and sodium silicate are used in ratios of 1, 1.5, 2, 2.5, & 3. Sodium silicate, hydroxide of sodium, and water were combined in the following ratios to create the alkali activator: 0.3, 0.35, 0.4, 0.45, & 0.5. In place of regular coarse aggregate with diameters of 19 mm, fine aggregate, one kind of local crushed coarse aggregates was utilized. One aspect of mechanics that has been studied is compressive strength. The findings show that the geopolymer concrete exhibits The maximum strength at compression was attained when the alkali-activator to binder ratio was 0.45, the binder content is 25%, the alkali-activator to binder ratio was 1, and the concentration of NaOH was 16. Furthermore, the findings showed that compressive strength rises with curing age. Scanning electron microscopy was used to evaluate the microstructure of geopolymer-based concrete [30].

By altering the geometry of CFRP, a reinforcing material, researchers Hasan M. A. Albegmprli have been able to increase the strength at shear of concrete reinforcement corbels. The experimental study focused on the size and breadth of CFRP installations and investigated the use of CFRP with specific geometry. The diameters (1/3, 2/3, and full), height, cross-section, & magnitude are all represented by multi-layer CFRP. Based on the testing data, the primary cause of the increase in shear was the CFRP performance at the neutral axis, which accounted for 33.6% of the middle third compared to 46.25 percent for fully reinforced. Furthermore, because of the strip' debonding with the concrete's surface happened before they ruptured, the results showed that the second layer of CFRP was less effective than the first [31].

The researchers also Eethar Thanon Dawood and Alyaa Abbas Alattar and Waleed Abdulrazzak Abbas and Yahiya Ziad Mohammad, conducted a study The behavior is concrete with foaming reinforced with one or both carbon and polypropylene fibers under high temperatures is illustrated in this work. To strengthen the foamed concrete mix, different volumetric percentages of carbon fiber (0.5, 1, and 1.5%) were utilized. Additionally, 1%CF + 0.5% PPF with 0.5%CF + 1% PPF hybrid fibers were made using carbon fibers (CF) with polypropylene fibers (PPF). Finally, the foamed concrete mix was reinforced with mono polypropylene fibers at a 1.5% PPF content. The compression strength, splitting tensile and flexural strength, and flexural toughness tests were performed on these various mixtures. In addition, the samples were heated to several temperatures—200, 250, 300, 350, and 400 °C—to complete the heating process. The findings showed that when the temperature rose, lightweight foamed concrete's (LWFC) compressive & flexural tensile strengths dropped. However, after the temperature reached 400 °C, the strongest effects of these strengths were apparent. Because polypropylene fiber has a low melting point, LWFC mixes reinforce with it are more susceptible to high temperatures as LWFC mixes reinforce with carbon fiber **[32].**

Table. 1 Typical properties of LWFC [33]

Dry Density (kg/3)	Compressive Strength (MPa)	Thermal Conductivity (W/m K)	Modulus of Elasticity (GPa)	Drying Shrinkage (%)
400	0.5----1.0	0.1	0.8-----1.0	0.3----0.35
600	1.0-----1.5	0.11	1.0------1.5	0.22----0.25
800	1.5-----2.0	0.17---0.23	2.0--2.05	0.20----0.22
1000	2.5------3.0	0.23----0.3	2.0-----3.0	0.18---0.15
1200	4.5---5.5	0.38---0.42	3.5-----4.0	0.11----0.09
1400	6.0------8.0	0.5----0.55	5.0------0.6	0.09---0.07
1600	7.5----10	0.62---0.66	10-----12	0.07----0.06

Table 2. Density Classification Requirements (C129 – 17) [34]

Density Classification	Density Classification Oven-Dry Density of Concrete, lb./ft3 (kg/m3) Average of 3 Units
Lightweight	Less than (1680)
Medium Weight	than (1680 to 2000)
Normal Weigh	(2000) or more

5. MATERIALS

In reference to the materials employed in this study, their functioning mechanism was understood and their qualities were examined and analyzed. The following lists the characteristics for the materials used to make foamed concrete

5.1 OPC, or ordinary Portland cement

is the type of cement used? All cement properties are in accordance with Iraqi Requirements No. 5/1984 [35], which were adopted for this research.

5.2 Fine Aggregate

The sieve examination of fine aggregate, which had an acceptable maximum measurement of 4.75 mm that was reasonably priced in the local market, was done for this investigation. Table 3 lists a sieve analysis of sands in accordance with ASTM C330/C330M-14 [36]. The fine aggregate had an absorption of 2.7% and a specific gravity of 2.63

Table .3. The Sieve Analysis of fine aggregate ASTM C136

Sieve size(mm)	Passing%	ASTM C330[36].
9.5	100	100
4.75	92	85-100
2.36	73	-
1.18	61	40-80
300	17	10-35
150	14	5-25

5.3 Mixing Water

During the experiments and specimen curing, all of the mixes were made using the standard (tap) water that was accessible in the Concrete Laboratory

5.4 Foam Agent

Cemairin F300, an insulating foam material made by DCP, was utilized. The substance was diluted by combining water with varying amounts of foam in accordance with ASTM C 796-97 [37] requirements. The material was then subjected to resistance, density, absorption, and insulating tests, and the best one was chosen, as seen in the figure,2,

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Figure .2. Weight and mix foam

Table .4. physical properties of foam [37]

Type of foam agent	Compound foam agent
Foaming ratio Wet densities (kg/m design dry grades(kg/m3 >55	
Foaming densities (kg/m3)	40-60
Ph. value	7.04
Foaming bleeding rate	<20%
Increasing rate of wet density determined	

by defoaming test <10%

6. METHODOLOGY

6.1 Lightweight Foam Concrete

This study is different from the last one in that it focuses on the topic of our research, which is the creation of concrete blocks with various forms and cavities and the insertion of a percentage of foam for thermal insulation. After calculating the weights of the cement and sand pouring quantities, several experiments were carried out by casting & testing experimental samples in order to generate a lightweight foam concrete mixture. The ideal cohesiveness ratio was selected from among foam concretes that provide a reduced density while maintaining the required compressive strength. Six sand-cement mortar combinations were cast and tested. It was determined that the approved mix had a cement content of 532 kg/m^3 and a ratio of 1:2.5. To produce foamed concrete, different present of foam agents were added to the mix. There are six mixes (FC1-FC6) with varying amounts of foam agents (1.0, 1.5, 2.0, 2.5, 3.0, and 3.5 L/m^3). These proportions were added to the concrete mixes, and the mixes were then poured, cured, and tested for compressive strength, wet density, and absorption to select the optimal proportion.

6.2 Foam Concrete Block

Following a few minutes of mixing and blending using a mixer, the concrete with foam is then poured into molds made of cast iron of 100 x 100 x 100 cubic millimeters. Mineral oil is applied to the molds' inside surface before being poured in layers. A vibrating stick is used to compress each layer for a maximum of ten seconds. The samples are stored in the lab for around twenty-four hours after they are placed. According to ASTM C192[38], the samples are then taken out of the mold and placed in a water bath that is kept at 23±1˚C until the test date. Following several tests on mixture models, we were able to determine the typical density and appropriate compressive strength that allowed us to utilize the block solely as partition walls and not for a load-bearing structure. The FC3 combination was selected to create four distinct types of foamed concrete blocks, and adding foam in varying amounts to regular concrete resulted in a percentage drop in compressive strength. The foamed concrete's age, porosity, dry density, and compressive strength are all ascertained. Compressive strength is also influenced by other parameters, including cement/water ratios, curing, filler type, air void form, size distribution, etc. The primary concrete blocks, which are 200*200*400 mm in size and will thereafter be poured with cement-sand mortars with foam exclusively, are cast once the ratios have been established by a number of trial

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mixes. Gaps are created inside the foam blocks. In order to prepare it for a subsequent examination in which its pressure and insulation properties are tested, it is pressed thoroughly to minimize the appearance of bubbles caused by the foaming effect, filling all the spaces. It is then treated by submerging it with water for up to four weeks at temperatures of 23 Celsius inside laboratory tanks Figure 3 shows the stages of making and pouring the foamed concrete mixture

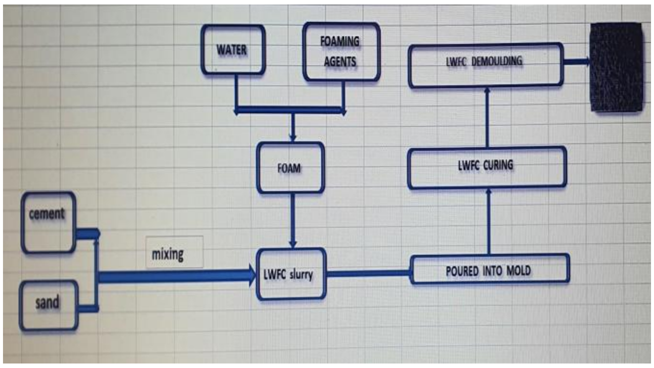

Figure 3: Stages of preparing a lightweight concrete block model

Figure 4 Details of the dimensions and shape of the cavities inside the concrete blocks

Lightweight cellular concrete blocks, [**41**] which are used to offer thermal insulation and are constructed as partitions inside structures rather than walls that bear loads, have a density ranging from 400 kg/m3 to 1800 kg/m^3 The density of foamed concrete is indirectly related to its thermal resistance [39]. The insulating properties of foamed cement were identical to those of ordinary concrete [39]. In concrete, removing 23% of air increased the thermal resistance by 25% and decreased the density of dry concrete of 100 kg/m3 by 0.04 W/(m.K) [39]. According to Medin, the thermal conductivity in this study was measured according to ASTM C177 standard [40]. A thermal conductivity test mold with a diameter of 40 mm and a thickness of 10 mm was used for measurements.

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7. MECHANICAL PROPERTIES OF CONCRETE BLOCKES

In addition to the other variables that affect the calculation and information, such as the density, age, porosity in it water-to-cement ratio, a foam type, treatment, design, dimensions, type of gaps, and other factors, [39]. compression strength is a crucial component and has a significant impact on the lightweight concrete, also known as foamed concrete [39]. Through the work we noticed that the mixture of fine sand and evenly distributed pores had better compressive strength, and the compressive strength of the mixture of coarse sand with irregular pores was lower Fine sand is properly dispersed between air spaces to make foamed concrete[41]. Results were obtained regarding the electrical conductivity of lightweight foamed concrete's mechanical and thermal qualities as well as the impact of the type of cavities that were employed inside the formwork[42] Three varieties of lightweight concrete—A, B, and C—are recognized. Type A concrete formwork, which has a density of 800–1200 kg/m3, is utilized for load-bearing walls. Our research did not address this. The other two categories, B and C, are solely utilized as partitions for non-load-bearing walls. According to IQS 1129 Specifications for Non-Load-Bearing Hollowed Building Unit and ASTM C-129[43]. Standards, gaps of various sizes and dimensions are created during casting to achieve enough compressive strength but less than Type A conditions.

8. CONCLUSION

This study investigated the mechanical and thermal properties of foamed concrete blocks. Using varying foaming agent ratios, several pilot mixes of cement and sand mortar were conducted, and the optimal sand-to-cement ratio of 1:2.5 was selected. Several pilot mixes were also conducted using foamed concrete, and a ratio of 2.0 L/m3 was determined to achieve the best compressive strength value of 23.7 MPa at 28 days for blocks used as partitions only, The above-mentioned ratios were used to cast lightweight hollow concrete blocks into smooth wooden molds measuring 200 x 200 x 400 mm. Cavities of various sizes and shapes, including two-, three-, and rectangular blocks with irregular cavities, were created within these blocks and filled with polystyrene. This increased the path of heat transfer and reduced thermal conductivity. These ratios provided the best thermal insulation, reaching approximately 60-70% of that of conventional blocks. It is clear that foam concrete blocks can be used in many public, private, and commercial buildings to create non-load-bearing partitions. The foam concrete specifications comply with ASTM C129 requirements for non-load-bearing foam concrete building units. The results clearly show that the concrete panels are lighter, they are more thermally insulating and sufficiently durable compared to conventional concrete blocks. This suggests the potential for future additions and development of new engineering projects using these insulated blocks, reducing the use of conventional heavy concrete blocks, increasing their reliability, and preserving a clean environment**.**

9. RECOMMENDATIONS

Through this study, we have a future idea that can be used later, which differs from its predecessors regarding the research topic above, as it is possible to develop more insulated and less expensive concrete models, and also the availability of raw materials in the local market. This contributes to reducing the consumption of electrical energy, which work has begun on in the advanced and most developed countries in the production of smart concrete blocks that also contribute to maintaining a clean and sustainable environment.

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