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Study of the Thermomechanical Behavior of the Compressed Earth Bloc when Adding Plastic Bag Slices

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ABSTRACT

Plastic waste management is a complex problem that has negative effects on the environment, society, and the economy. The development of science has made humanity use plastic materials a lot, and because it does not cost to manufacture and is recyclable, it is used in most industries. Plastic contains polyethylene, most of it does not biodegrade and remains in the environment for long periods, and its abundant accumulation leads to many environmental and health hazards to humans. This research, which aims to recycle plastic bags in the field of construction, is of utmost importance in addressing the pressing issue of plastic waste management. The plastic will likely increase the durability of structures mechanically and increase thermal insulation. In this research, the plastic bag segments are integrated in a ratio of 0% to 0.7% in the compressed clay bricks. Which consists of sand, clay, and gypsum. Some physical, mechanical, and thermal properties of the samples are measured. Preliminary results show that the addition of these strips reduces the value of the bulk density between 3.21% to 13%. The speed of sound transmission also decreases between 2.17% and 21%. The stress strength increases between 5.4% to 25.53%. The thermal conductivity value also decreases between 5.26% to 23.68%. This leads to the clay brick becoming lighter, more solid, and better thermal insulation. Thus, we combine the improvement of the properties of clay structures with a significant reduction in environmental impact, inspiring a more sustainable future.

Keywords: compressed earth block, plastic bag strips, mechanical properties, thermal properties, waste management.

INTRODUCTION

Plastic is widely used in our daily life. Such as cleaning agents, paint, medicines. It enters by 8% into the use of Petroleum. And petrochemical industries that produce polymers [Goosey, 1999]. It is important in our modern life because it is used in the manufacture of synthetic rubber from which car wheels, plastic bags, glue, paints, shoes and others are made. Most waste plastic products, especially plastic bags, cannot be easily disposed of. This is what causes harm to humans and other living organisms living with US [Legesse and Diriba, 2011]. Because plastic materials do not wear out, do not corrode and are not resistant to high temperatures. It is the most important factor in polluting open and public places inside and outside cities. Damage to wild animals is caused by the volatility of plastic bags and their prevalence in pastures and rural areas. Their response also leads to damage to the soil and it becomes non-buildable [Muthu et al., 2009]. It contains polyethylene, and this is a dangerous substance if it decomposes in soil and groundwater. Or when burned, it causes air pollution with toxic gases and vapors such as carbon dioxide and C6H5CHO. CO.and NH3, which cause various diseases such as allergies and shortness of breath [Harman et al., 2001].

In this regard, this research suggests an idea to get rid of plastic. By cutting it into slices or adding it inside a pressed clay brick. Because Clay is an environmentally friendly material that is available and does not contribute to emissions. [Shubbar et al., 2019]. It is used in the manufacture of pottery, cement and urban building materials. It is added to sandy soil to improve it. As for its problem, it is fragile and not resistant to climatic factors such as wind and rain [Pawar. et al., 2014].

In previous studies, plastic waste has been used to promote improved strength behavior and soil swelling. Researchers get a good [Amena, 2022]. In a study by researchers Amena, and Kabeta. Plastic waste and marble waste dust were used to improve the engineering properties of the soil. An improvement in mechanical properties was observed [Amena and Kabeta, 2022].

In this research, we are trying to combine getting rid of plastic bags, treating the fragility of clay bricks, and finding a solution to environmental pollution. Where we add sand and gypsum to the clay to make it more cohesive. And reduces the permeability of clay to water. It is used by humans in making molds and fixing fractions, and mortar is used in the construction of buildings. In our research area, we mix 50% clay with 33% sand and 17% gypsum with a measured amount of water. Plastic bag segments are added in different proportions 0% 0.05% 0.1% 0.15% 0.2% 0.25% 0.3% 0.4% 0.5% 0.6% and 0.7%. The samples are compressed with a hydraulic press under a pressure of 2.5 MPa. Then it is left to dry for 28 days and some physical properties are studied, such as the change in bulk density, sound transmission speed, pressure strength and thermal conductivity. The research focuses on the effect of adding plastic bags on the mechanical behavior of compacted clay bricks. The research among the authors is divided into three sections. The first group describes the substances used in the experiments. The mother of the second group makes samples and conducts experiments. While the third group analyzes the results and shows conclusions. The results of the research can set a general picture of the recycling of plastic bags in the field of building materials. And this is in to preserve the environment.

MATERIALS AND THE METHOD OF WORK

Materials

Clay

We use local clay from Adrar, southern Algeria Figure 1. Granule diameter 5 mm. It is distinguished by the density of 2.7 g/cm. The chemical properties are in Table 1 and physical properties in Table 2.

Sand

We use dune sand, Adrar region, Algeria. It is characterized by density 1.4 g/cm^3. The chemical composition in the Table 3 and physical properties in Table 4.

Gypsum

We use gypsum from the Ghardaia region, south of Algeria. Physical properties in Table 5 and chemical composition Table 6.

Plastic bags

Cut the plastic bags into strips The length is 10 cm and the width is 01 cm. The chemical composition is shown in Table 7.

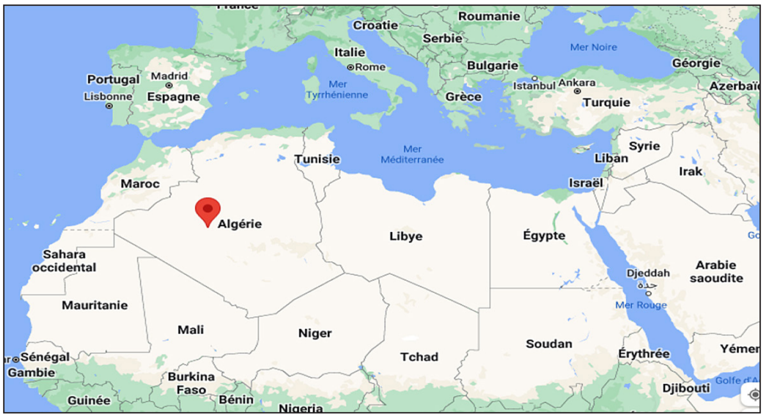

Figure 1. Location of Adrar, Algeria

Table 1. Clay chemical composition

Elements	SiO_2	Al_2O_3	MgO	K_2O	Na_2O	Fe_2O_3	CaO
Percentage %	75	10	0.95	2.5	0.27	4.5	0.85

Table 2. Clay physical properties

Density	Liquid limit	Plastic limit	Sand	Silt	Clay
2.7 g/cm³	81%	34%	8%	55%	36%

Table 3. Sand chemical properties

Elements	Fe_2O_3	AL_2O_3	SO_3	Ca CO_3	$CaSO_4$ $2H_2O$	Cl^-
Contents (%)	0.25	0.4	0.91	1.3	2.78	0.63

Table 4. Sand physical properties

Apparent density (kg/m3)	Absolute density (kg/m³)	Equivalent to sand visually (%)	Sand equivalent per piston(%)	Modulus of fineness (%)
1423.6	2675	97.74	96.58	1.22

Table 5. Gypsum physical properties

Apparent density	Density of the dry product	Shore A	Expansion	Recommended mixing rate	Prefabrication -moulding	Simple compressive strength 7 days
0.68 kg/l	1.15 kg/l	80	1 mm/m	g/w = 160 - 180 % w/g = 55 - 62 %	w/g = 0.75 volume	20.40 kg/cm²

Table 6. Gypsum chemical composition

Elements	Fe_2O_3	AL_2O_3	SO_2	Ca O	MgO	Cl^-	KO	Na_2O	SiO_2
Contents(%)	0.08	0.1	44.95	32.15	0.53	0.002	0.03	0.09	0.7

The method of work

Preparing the bricks

The ASTM d698 standard is used to determine the water content according to the proctor test [Spagnoli and Shimobe, 2020]. The ratio of clay and sand is calculated according to a laboratory experiment. The ratio of clay and sand is changed and the resulting density of the bricks is measured after drying

Table 7. Chemical composition of plastic bags

Elements	Percentage (%)
Polyethylene	41.5%
Polypropylene	24.3%
Poly ethylene terephthalate	12.8%
Poly vinyl chloride	2.9%
Poly lactic acid	0.2%
Poly styrene	6.6%
Others	11.7%

The best ratio that gives the bricks the highest durability is 60% clay 40% sand. When gypsum is added to the composition, the proportion of clay becomes 50%, sand 33 % and gypsum 17 %. The wet mass of the brick is 2000 g. To calculate the percentage of gypsum, the proctor test is used. The ratio of water and gypsum is changed every time. and the bulk density is calculated. The best ratio of water and gypsum is the one that corresponds to the highest value of the bulk density. Figure 2 shows how to find the ratio of water and gypsum.

When analyzing Figure 2, it is clear that the highest density is 1.9 g/cm^3, which corresponds to 17% gypsum and 15% water. 50% clay and 33% sand are mixed with 17% gypsum 15% water. An electric mixer was used to obtain a homogeneous mixture. Mixing is carried out for two minutes. Add the slices of plastic bags and mix for two minutes. Plastic bags are cut, carefully with a length of 10 cm and a width of 01 cm, which ensures homogeneity. Plastic strips are placed longitudinally on the inside of the brick.

Water is added in the specified amount and then mixed. The proportion of plastic bag parts is changing; Table 8 shows how samples are made and installed:

- the mixture is pressed into the mixture using a hydraulic machine with a power of 2.5 MPa.
- 03 samples are made from each percentage of plastic bag segments. The samples are left to dry for 28 days.

RESULTS AND DISCUSSION

Bulk density calculation

Bulk density is calculated using ASTM C134 standard [Sutcu et al., 2012]. The apparent density is calculated by weighing the sample and measuring its dimensions. The experiment is shown in Figure 3. Relation 1 is used to calculate the bulk density:

$$\rho = \frac{m}{v} \tag{1}$$

The measurement results are shown in Figure 4. Figure 4 represents the change in the value of the bulk density when adding plastic strips of different proportions. When analyzing the shape, it turns out that the higher the percentage of

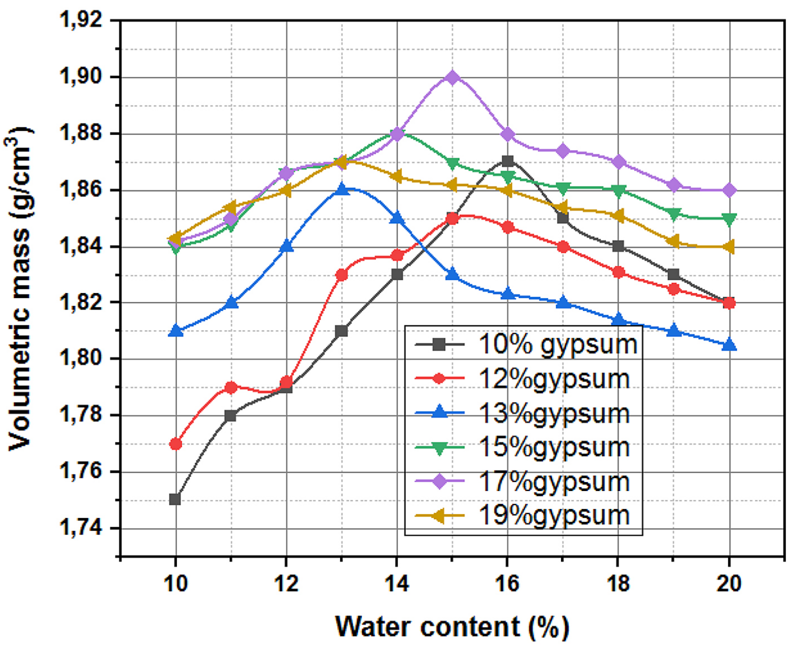

Figure 2. Water content 15% (Gypsum 17%)

Table 8. Sample preparation

Clay %	Gypsum %	Sand %	[PBS] percentage %	Water (ml)	Code
50	17	33	00	300	AP00
50	17	33	0.05	300	AP0.05
50	17	33	0.1	300	AP0.1
50	17	33	0.15	300	AP0.15
50	17	33	0.2	300	AP0.2
50	17	33	0.25	300	AP0.25
50	17	33	0.3	300	AP0.3
50	17	33	0.4	300	AP0.4
50	17	33	0.5	300	AP0.5
50	17	33	0.6	300	AP0.6
50	17	33	0.7	300	AP0.7

plastic slices, the lower the density value. When adding strips of plastic bags, the density decreases from 3.2% to 13%. (1990–1731) kg/m^3. This is explained by the fact that plastic strips increase the number of pores inside the brick and it is concluded that the more pores, the lower the density of the brick and therefore it becomes lighter. This is consistent with previous research [Kazmi et al., 2018]. This is also consistent with Sreekumar research [Sreekumar, 2021].

Figure 3. Samples weight

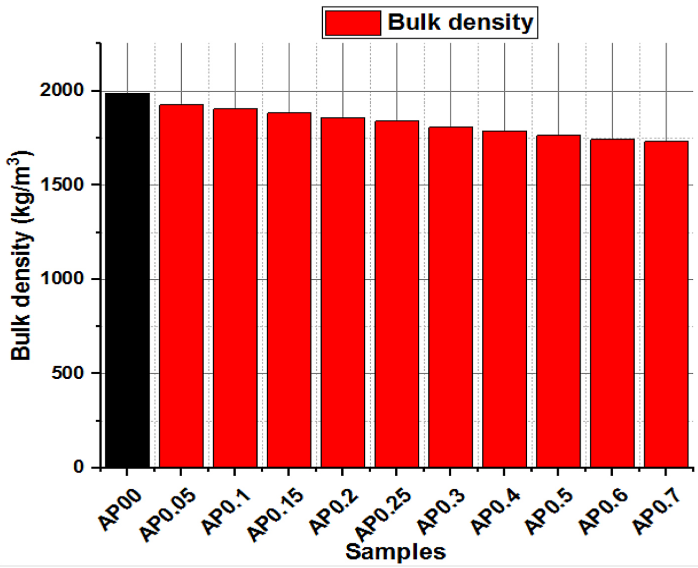

Figure 4. Bulk density calculation

Calculate the speed of sound

The ASTM c597 standard is used to measure the speed of sound transmission [Sathiparan. et al, 2023]. To measure the speed of sound transmission through samples. The device shown in Figure 5 is used. It is a device that provides the experimenter with the time needed to cross the sound by the second. The speed of sound transmission is calculated by knowing the distance and time according to Equation 2.

$$v = \frac{D}{T} \quad (2)$$

The results of measuring the speed of sound transmission are shown in Figure 6. Sound is considered to be a mechanical wave. The speed of sound varies depending on the medium or material in which it propagates [Oelze et al., 2002]. It is influenced by the temperature and the physical state of the medium [Bohn, 1988]. The speed of Sound Propagation in solid objects is faster [Curle, 1955].Based on the analysis of Figure 6, a decrease in the speed of sound transmission is observed when strips of plastic bags are added.

Compared to the Strips-free sample the speed decreases between 2.17% and 21% (690–545) m/s. The decrease in the speed of sound transmission is explained by the fact that the brick has become more porous due to the addition of plastic Strips. And the addition of slices can be associated with increasing the number of pores. The speed of sound transmission decreases due to a decreasing intensity value. These results are consistent with previous research [Abdelkader et al., 2023] [Teixeira et al., 2020].

Figure 5. Measure the speed of sound

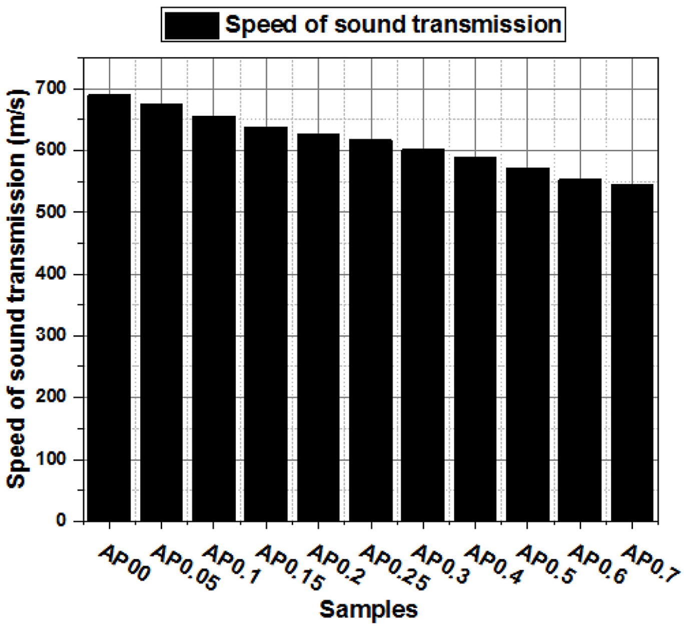

Figure 6. The results of measuring the speed of sound

This decrease is proved by testing non-destructive waves. Where the researcher Abdul Manaf noticed a decrease in the speed of sound pulses when adding plastic to concrete [Manaf, 2022]

Calculation of compressive strength

The ASTM c67 standard is used to measure the compressive strength [Latha et al., 2023]. To calculate the tensile strength, a hydraulic compression machine is used. It is a machine used in civil engineering to measure the stiffness of structures. The device is set according to the initial conditions:
- compression speed 0.6 MPa/s.
- initial pressure 10 kN.
- determine the area where the force is applied, 20 × 10 cm^2.

The results obtained are shown in Figure 7. Figure 7 shows the change in the pressure force applied to the samples when plastic strips were added. The pressure force is observed to increase to a ratio of ٠.% then decreases. Compared with strip-free samples, the compressive strength increases between 5.4% and 25.5% (4.7–3.5) MPa. This is explained by the fact that plastic strips increase the durability and hardness of earthen bricks. This corresponds to previous research [Lamba at al., 2021]. The ratio of 0.25% of plastic strips is considered the best ratio in terms of hardness. It reduced compressive strength after a ratio of. The strips' effect is limited and in specific proportions. The oversized proportions of plastic make the earthen brick brittle and easily break [Awoyera et al., 2021]. In a previous study, added Kabeta plastic strips by 0.2%, 0.3%, and 0.4% of the soil weight, and the pressure resistance test showed an increase in soil strength by 138% [Kabeta, 2022].

Thermal conductivity calculation

Representing heat is a form of energy. While thermal conductivity is a physical property of materials, it represents the ability of a material to transfer heat [Popov et al., 2003] measured in Watts/meter-kelvin. Previous studies concluded that the lower the conductivity, the better the material is for thermal insulators. Thermal radiation varies from material to material and is affected by the following:
1. Cross-sectional area.
2. Temperature difference.
3. Sample length.
4. Types of material.

There are three types of heat transfer: radiation, conduction, and convection [Dehghan and Behnia, 1996]. The study of thermal conductivity is facilitated by a specialized device-the thermal needle. This device plays a crucial role in our understanding of thermal properties. The thermal needle is a practical device designed for swift and accurate measurements of the conductivity and thermal

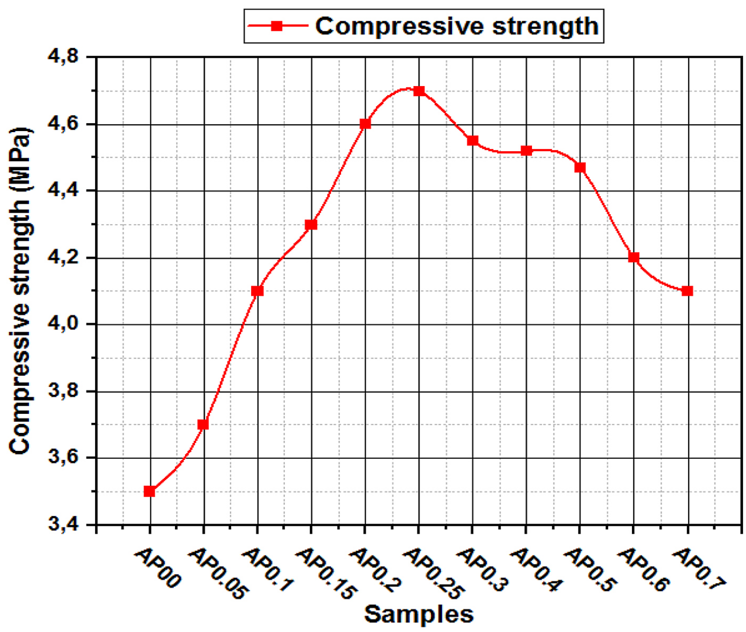

Figure 7. Stress applied to shatter the samples

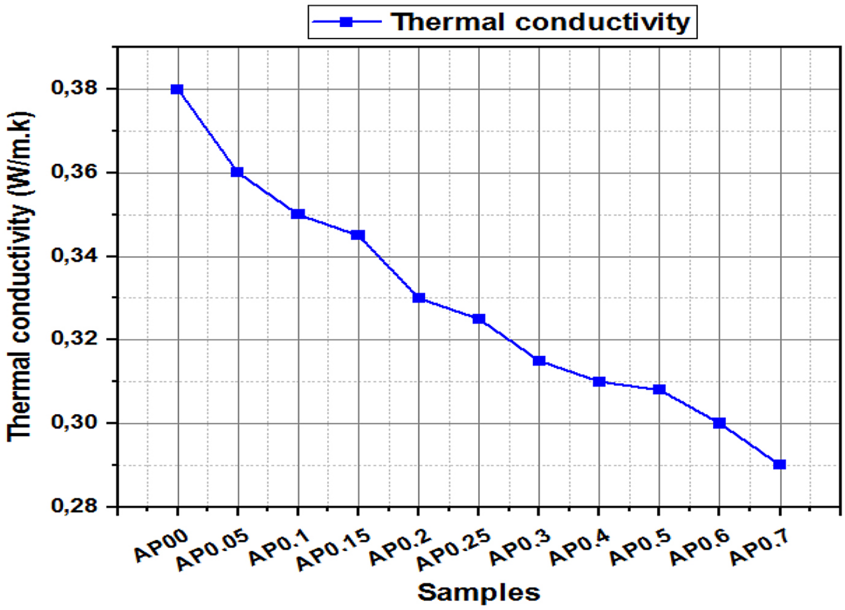

Figure 8. Thermal conductivity measurement results

resistance of soils [Humaish, 2020]. Its application in the field of materials science is invaluable.

This method uses a heating wire and sensors located at different points on the needle. We make a hole inside the sample and insert the needle into this hole. The measurement result is displayed on the console screen. The measurement result is generated automatically. The device independently processes input data related to the time, temperature and heating power set during measurement. The thermal conductivity is calculated according to the ASTM C90 standard [Ozturk, 2023]. The results obtained are shown in Figure 8.

Figure 8 represents the change of thermal conductivity in earthen bricks when adding plastic bag strips. It is noted that the value of thermal conductivity decreases with increasing ratio of strips.

Comparison with the strip-free sample

The value of thermal conductivity decreases between 5.26% to 23.68% (0.38–0.29) W/m.k. This decrease in thermal conductivity is explained by the fact that plastic strips impede heat transfer between the brick parts. This finding is consistent with previous research [Donkor and Obonyo, 2015][Jnr et al., 2018].

Plastic increases the thermal insulation of civil structures. This is what resulted from the research of Bozyigit et al. [Bozyigit et al., 2021]. The result of the research corresponds to a study by researcher Basha and others on the use of recycled plastics. In concrete, a decrease in the value of thermal conductivity was observed [Basha et al., 2020].

Importance of research

The accumulation of inorganic solid waste has led to a threat to the ability to bury and incinerate waste. The use of plastic bags for land stabilization purposes has also spread. Such as the protection of slopes and the construction of low-cost housing. The field of plastic bag recycling is ripe for innovation and experimentation, offering a canvas for creative solutions to this pressing environmental issue. Both in terms of new geometric shapes and new materials. The use of readily available resources is necessary to minimize the low environmental impact and ensure good construction performance.

In this research, plastic recycling was combined with increasing the durability of ground structures. This research, which combines plastic recycling with enhancing the durability of ground structures, promises a bright future from both environmental and mechanical perspectives.

CONCLUSION

The use of environmentally friendly materials preserves the environment because they do not produce heat in production or use. Clay is a substance present in most types of soils, and the addition of other substances to Clay changes its physical and mechanical properties. By incorporating strips of plastic bags into the compacted earthen bricks, along with gypsum, a unique and beneficial process is initiated. It makes it light because it reduces the bulk density 13%. Due to the increased number of pores inside the brick. This causes the voice transmission speed to decrease between 2.17% and 21%. The addition of 0.25% plastic bags is considered the best percentage to increase the hardness of bricks by 25.53%. Also, the thermal conductivity decreases between 5.26% and 23.68%, making the brick the best thermal insulation. This research introduces a novel approach to recycling plastic bags in compact floor structures, particularly suitable for self-build houses, thereby advancing the field of sustainable construction. This proposal combines improving the mechanical and thermal properties of earthen construction with preserving the environment through the recycling of plastics.

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