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COMPOSITE WITH RECYCLABLES LOADS FOR MANUFACTURE OF BLOCKS WITH GREATER THERMAL RESISTANCE TO BUILD HOMES POPULAR

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Abstract. *It was built the Space Science in a state school in the city of Natal, using a composite consisting of gypsum, EPS, shredded tire, cement and water. Studies were conducted thermal and mechanical resistance. Inside the blocks were placed three types of fillings (EPS plates, beer and soda cans and bottles of mineral water 500 ml), in order to obtain inform a higher thermal resistance walls constructed, but also to give it an ecologically correct order, considering that both the tire and the EPS occupy a large space in landfills and require years to be degraded when released into the environment. Compression tests were conducted according to the rules of ABNT block seal, measurements of the temperature variation in the inner and outer walls using a laser thermometer and check the temperature of the indoor environment using a thermocouple attached to a digital thermometer. The experiments demonstrated the heat provided by the composite values from the temperature difference between the internal and external surfaces on the walls reaching levels above 12.0°C. It was also demonstrated adequate mechanical strength of such a composite for sealing walls. The proposed use of the composite can contribute to reducing the significant housing deficit of our country, producing popular homes at low cost and with little time to work.*

Keywords: *composite, low cost, thermal resistance, waste recovery, housing.*

1. INTRODUCTION

In Brazil, there are a large number of families living in inadequate conditions as to food, education, sanitation and habitat. Aiming to supply these deficiencies, many public programs have been created with the aim to build and provide social housing, with the minimum desirable for low-income families (SANTOS, 2008).

For this purpose we developed a new type of block using composite material in order to reduce the cost of building a house, and contribute to existing efforts to reduce the housing deficit. This block contains in its composition zest tire, gypsum, EPS, cement and water. Apart from a filling plate which can be recycled EPS, aluminum cans and bottles of mineral water. In this paper we present results for the blocks with such fillings.

The composite shows good homogeneity, the blocks produced are easy to manufacture and assembly and low thermal conductivity, and can be used for different manufacturing techniques mainly social housing scheme joint effort. There may be mentioned as another advantage of the composite produced their rapid healing process after partial undercut, about 10 minutes, permitting considerable flexibility of the constructive process.

The block has studied in its formulation cement, plaster, Styrofoam, shaving tires, and filling plates recycled EPS. These blocks have a width of 26 mm, length 80 mm and thickness 10 mm. This enables greater speed in the construction of housing in relation to conventional bricks (ceramic block eight holes) due to its greater area.

This block has the following main features low cost, good compressive strength, low thermal conductivity, good aesthetics, low weight, versatility and easy manufacturing processes and assembly. Another major advantage of the composite produced is its rapid healing process allowing considerable flexibility of the construction process. It should be noted, though, the good workmanship of the block produced by decreasing the cost of labor by not requiring finishing.

2. REVIEW

2.1. The ceramic composites in LMHES

The ceramic composites for manufacturing housing, thermal insulation, solar prototypes represent one of the main research lines of the LMHES UFRN, having been the subject of numerous scientific papers published in various national and international conferences and nine Masters dissertations and theses two Doctoral developing. The following are some of those jobs that are part of the history of this line of research in LMHES.

Souza et al., in 2008, presented in V CONEM Salvador, a solar collector alternative low cost and easy construction for heating water for residential applications. A collector's box was made of a composite material based on gypsum, ground EPS and water. The collector area corresponds to 1.2 m² and the heat reservoir to store the water heated by the collector is made from a polyethylene drum 200 liters. The heating system was easy construction and assembly and has a low cost are important factors for the socialization of the same. Test results were shown with thermal heating system that will demonstrate their viability thermal, economic and material.

Gomes, in 2010, in his Dissertation at PPGEM/UFRN, built a housing unit using a composite made of gypsum, cement, EPS, scrapes tire, sand and water and conducted studies of thermal comfort and materials. Used the technique of constructing the launch spot. Inside the mold PET bottles were placed in order to obtain thermal and mechanical resistance walls constructed, but also give you an end environmentally friendly. It demonstrates the comfort provided by the composite from the difference in temperature between the internal and external surfaces of the walls up to 11.4°C. Demonstrated the appropriate mechanical resistance to the composite closure walls. The use of composite proposed would contribute to reducing the housing deficit of our country, producing income housing at low cost and with little time to work.

Silva, in 2010, in his Dissertation at PPGEM/UFRN, built a house from blocks made using a composite made of gypsum, EPS, cement, scrapes tire and sand. Were made from blocks of various compositions and performed preliminary tests of mechanical and thermal resistance, choosing the most appropriate proportion. Studies were conducted thermal performance to check comfort conditions. The blocks were seated inside each other as if they were pieces of "lego". PET bottles are used within the walls to provide thermal resistance. Above the house, an analysis was made of thermal comfort, checking the temperatures outside and inside the walls and the ambient temperature, among other variables, such as wind speed and relative humidity. The block had made good thermal environment, with walls, differences of up to 11.7°C between the outer and inner faces.

Silva, in 2010, in his Dissertation at PPGEM/UFRN studied a block of composite material made from cement, gypsum, crushed EPS, sand, boiler ash from the burning of residues from the extraction of palm oil and water, for the construction of residences were manufactured several popular models of blocks and the block was chosen that had the dimensions: L = 800mm, H = 260mm and B = 100mm. Inside the blocks can be placed plastic bottles, beer cans and soda, Styrofoam plates. The composite can be formulated to various mixing ratios and can be used for manufacturing the blocks to be used in building a house for low-income families. Tests were performed compressive strength for various composite formulations that met the standard specific. It was also investigated the thermal conductivity of the composite. It was demonstrated the feasibility of using the composite for the proposed end formulation chosen and more efficient.

Leite, in 2011, presented in the Master's Dissertation PPGEM/UFRN, two block models manufactured from composite material composed of cement, gypsum, EPS crushed, shredded tires, mud, sand and water for the construction of homes popular. Were made metal molds for the manufacture of blocks to be used in the construction of a residence for low-income families. Tests were performed compressive strength for various composite formulations that met the standard specific blocks used in construction. It was also evaluated the thermal conductivity of the composite for further study of thermal comfort generated in a residence built with composite proposed. The block had good thermal insulation made of the environment, obtaining differences of up to 12.6 ° C between the outer and inner faces. It was demonstrated the feasibility of using the composite for the proposed end.

Santana, in 2011, in his Dissertation at PPGEM/UFRN studied a new type of thermal insulation for hot water pipes drivers, which consisted of a composite of different formulations, to the base plaster, cement, crushed EPS, palm oil and water. Comparative results were presented for the thermal testing of pipes and materials proposed. Four formulations were used to manufacture tubes with three diameters 70, 65 and 42 mm. It was also tested elastomeric foam conventionally used for thermal insulation to 110°C, for a comparative analysis with the proposed heat insulating composite tube. It was demonstrated that the manufacturing cost of such tubing is competitive with alternative elastomeric foam tested, although the test results for thermal resistance of the composite tube for the temperature range

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tested, are lower. A plus factor of using the proposed composite tube would be the EPS recycling so damaging to the environment, representing an environmentally correct scientific application.

Barbosa, in 2011, in his Dissertation at PPGEM/UFRN studied a solar dryer direct exposure to food drying constructed from a scrap of light, coated with a composite consisting of cement, plaster, scrapes and tire water . The composite material used has the great advantage of their low thermal conductivity of around 0.20 W / mK, which provides a good thermal efficiency of the solar dryer proposed. Presented the processes of construction and assembly of this dryer, which allows the reuse of materials, constituting an environmentally friendly option of recycling.

Mota, in 2012, studied in the Master's Dissertation PPGEM/UFRN, a composite ceramic matrix composed of gypsum, cement, EPS, tire, PET and water to build prototype solar efficiency competitive with other conventional materials equipment already constructed and studied and lower manufacturing cost. Were built two solar ovens box type, a cooler to be cooled by solar energy, a solar dryer and solar cooker concentration. We determined the proportions of the constituent materials of the composite to the specific performance of each prototype designed and results achieved by the prototypes studied previously. Addressed the processes of construction and installation of such equipment and certain thermal and mechanical properties. We also evaluated the performance of each prototype constructed. This composite was feasible to manufacture such equipment, low cost and easy fabrication and assembly processes.

Rodrigues, in 2012, presented in his Dissertation at PPGEMN/UFRN a block made of composite cement-based plaster, Styrofoam and ground water, with its interior filled with twelve plastic bottles of 500 ml, for the construction of a kiosk . The composite could be formulated to various mixing ratios and could be used for building walls for housing, gazebos, partitions and fixed to furniture designed. Tests were performed compressive strength for various composite formulations met the standard specific blocks used in construction. It was also investigated the thermal conductivity of the composite for further study thermal comfort generated in a masonry constructed with the proposed composite. It was built a kiosk modulated includes economics, aesthetics and respect for the environment.

Figure 1 sample some of the applications of the composites studied in LMHES in scientific papers, dissertations and Master's and Doctoral Theses PPGEM / UFRN.

Figure 1. Ceramic composites manufactured and tested in LMHES / UFRN.

3. MATERIALS AND METHODS

3.1. Composition of the blocks

The composite used in blocks presented the following proportions by volume: 1.0 gypsum part + 1.0 crushed styrofoam part + 1.0 cement part + 1.0 part craps tire + 0.4 part of the total volume of water. Fillings were used in blocks plates recycled EPS convenient packaging of air conditioning, cans of beers and soft drinks, Pets bottles of mineral water 500ml. The dimensions of the block were C = 80 cm, L = 26 cm and E = 10 cm, with an area of 0.21 m² and volume of 0.021 m³.

3.2. Manufacture the blocks

To manufacture the block with the fillings selected procedures were adopted the mold assembly; application of the release agent in the mold, dosage components for the manufacture of the blocks; dry mixing and homogenization of the components, homogenizing the mixture with water, filling the mold with the composite; placing of the filling, removing the mold components; monitoring the cure.

For the filling we used styrofoam plates from whole packs of split type air conditioners; bottles of soft drinks were twelve in number and cans of beer and soft drinks at number fifteen. Figure 2 shows the steps of manufacturing the proposed block.

Figure. 2. Manufacturing steps of blocks with three fillings used.

3.3. Construction of space science and technology

To test of thermal resistance built up a Space Science between a classroom and a library in the State School Raimundo Soares, located in Natal - RN, leveraging the two sidewalls that space. We used about 75 blocks in that building. Figure 3 shows some views of the walls of the built. Space Science had an area of 27.0 m² (6.28 m x 4.30m) and walls with a height of 2.44 me thickness of 0.10 to 0.13 m.

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Figure 3. Views of the walls of built space.

For the characterization of the composite tests were carried out for several formulations in order to determine the thermal conductivity, density, strength, percent water absorption and heat resistance.

The analysis of the thermal performance of residential units was made for daytime, considered the most critical period for the thermal performance of buildings considering the characteristics of the local climate.

Were collected directly in housing analysis, the temperatures of the internal walls, external sunny side (south) of the internal environment and every 15 minutes in at least eight hours, 8:00 to 16:00. Were also collected for the same period the thermal sensation of the external environment and global solar radiation.

To measure the internal and external temperatures of the blocks subjected to solar radiation used an infrared thermometer laser 31/2 digit resolution of 0.1°C, accuracy _+2, 0% of reading. The meteorological data was measured by a solar station installed in LMHES UFRN.

4. RESULTS AND DISCUSSION

The following presents the results of characterization of the composite with respect to physical, thermal and mechanical properties.

4.1. Determination of Thermal Conductivity

Table 1 shows average values of the thermal conductivity tests for all proportions of mixtures studied previously.

Table 1. Average thermal conductivity of the formulations studied, where CGI (cement, gypson and EPS), CGP (cement, gypson and tire scraper) and CGIP (cement, gypson, EPS and tire scraper).

COMPOSITION TYPE	**K (W/m.°C)**
CGI	0.20
CGP	0.37
CGIP	0.26

The composite used in this study showed low thermal conductivity, but higher than the other compositions tested already. The introduction in the composite scrapings tire brought an increase of 30% compared with the composition of crushed styrofoam, plaster and cement with both elements as bases.

The conductivity of the composition was investigated on the nearest gypsum (0.4W/m.°C) than that on polystyrene (0.036 W/m.°C) and tire scrapings (0.04 W/m.C).

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4.2. Determining the specific mass of the composite

Table 2 presents the mass of each of the composite formulation and their specific gravities.

Table 2. Specific masses of all the formulations tested.

ELEMENT	MASS (Kg)	SPECIFIC MASS (Kg/m³)
CGI	172.9	882.1
CGP	249.3	1271.9
CGIP	179.2	914.2

It was observed that the composite had specific MASS of less than 39% in the composition specified mass of greater specific mass, GCP and was just above the composite foam triturated CGI 3.5%. The composite is much lighter than common brickwork, density of 1,600 kg/m³, which is a very positive factor during the laying of the blocks.

4.3. Test of resistance to compression

Table 3 shows the values of compressive strength obtained for all configurations tested after 07, 14 and 28 days of curing.

Table 3. Compressive strength of the formulations studied.

COMPRESSION STRENGTH (MPa)			
COMPOSITION	**07 DAYS**	**14 DAYS**	**28 DAYS**
C.G.P.	3.10	*4.18*	4.31
C.G.I.P.	*1.5*	1.84	2.02
C.G.I.P.A.	2.70	*2.80*	2.90

The compression strength was 35.0% above the one shown by the standard, but it is clear that the mixing polystyrene-tire, does not produce a high mechanical strength. The other composites shown and has studied showed higher levels in this parameter. However, despite the lower strength, the block is made above the minimum standard for the sealing block.

4.4. Thermal resistance test

Tables 4, 5 and 6 show the values of the three days of diagnostic tests for thermal comfort for the three types of filling.

Table 4. Average of three days of testing for thermal comfort - EPS filling.

DAYS	**$T_{wall\ external}$ (C°)**	**$T_{wall\ internal}$ (C°)**	**ΔT (C°)**	**ST (C°)**	**I_g (W/m²)**
DAY 1	37.2	32.6	4.6	35.5	720.0
DAY 2	37.7	33.2	4.5	36.0	732.6
DAY 3	39.1	33.4	5.7	36.0	752.5

The maximum temperature difference achieved between the external and internal walls happened to the third day of trial, corresponding to 12.4°C at 13:30 hours. It should be noted that this day had a higher rate of global radiation incident.

The average temperature difference between the external and internal environment of the Space Science built was significant, reaching an average value of about 4.0°C.

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In relation to other blocks of the same geometry made the results achieved were higher, especially for the period between 13 and 14 hours, with temperature differences of around 10°C. These findings are relevant to obtaining a good thermal comfort in the interior of dwellings made of the composite studied.

Solar conditions of days tested were very good, recording solar radiation peaks around 1000W/m², and average above 730W/m² and average relative humidity around 60%, maximum 70% and minimum of 50%.

Table 5. Average of three days of testing for thermal comfort - filling cans.

DAYS	$T_{wall\ external}$ (C°)	$T_{wall\ internal}$ (C°)	ΔT (C°)	ST (C°)	I_g (W/m²)
DAY 1	36.8	32.6	4.2	35.5	720.0
DAY 2	36.8	33.1	3.7	36.0	732.6
DAY 3	38.0	33.4	4.7	36.0	752.5

The maximum temperature difference achieved between the external and internal walls happened to the third day of trial, corresponding to 11.5°C at 13:30 hours. It should be noted that this day had a higher rate of global radiation incident.

The average temperature difference between the external environment and the internal space Science constructed was significant, reaching an average value of 4.2°C.

In relation to other blocks of the same geometry made the results achieved were higher, especially for the period between 13 and 14 hours, with temperature differences of around 9°C. These findings are relevant to obtaining a good thermal comfort in the interior of dwellings made of the composite studied.

Table 6. Average of three days of testing for thermal comfort - filling bottles.

DAYS	$T_{wall\ external}$ (C°)	$T_{wall\ internal}$ (C°)	ΔT (C°)	ST (C°)	I_g (W/m²)
DAY 1	37.0	32.4	4.6	35.5	720.0
DAY 2	37.1	32.9	4.2	36.0	732.6
DAY 3	38.4	33.2	5.3	36.0	752.5

The maximum temperature difference achieved between the external and internal walls happened to the third day of trial, corresponding to 11.7°C at 13:30 hours. It should be noted that this day had a higher rate of global radiation incident.

The average temperature difference between the external and internal environments of Space Science built was significant, reaching a mean value of 4.7°C.

In relation to other blocks of the same geometry made the results achieved were higher, especially for the period between 13 and 14 hours, with temperature differences around 9.5°C. These findings are relevant to obtaining a good thermal comfort in the interior of dwellings made of the composite studied. The table 7 shows the average temperature measured for the three types of fillings used.

Table 7. Parameters average for the diagnosis of thermal comfort of the blocks with different types of filling.

TYPE OF FILLING	ΔT_{MAX} (C°)	$\Delta T_{AVERAGE}$ (C°)	ST (C°)	I_g (W/m²)
EPS	12.4	5.0	35.5	720.0
CANS	11.5	4.2	36.0	732.6
BOTTLES	11.7	4.7	36.0	752.5

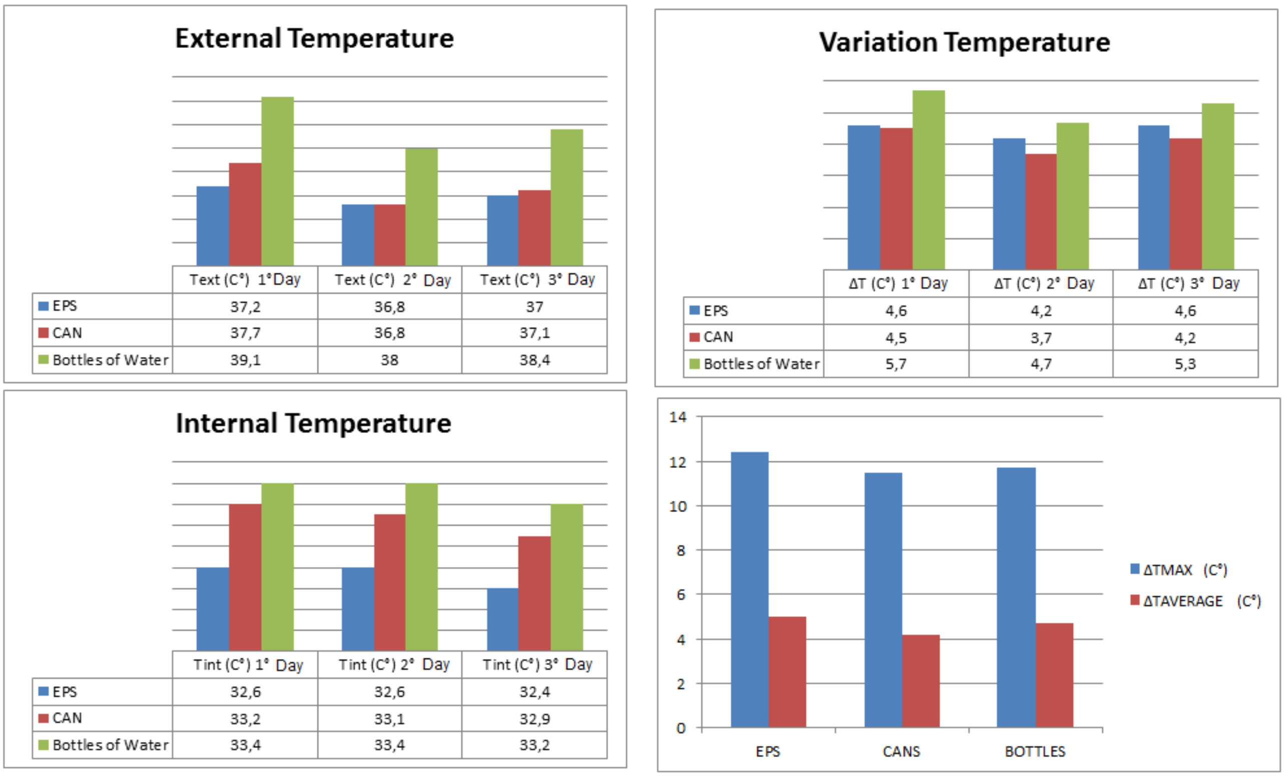
The highest thermal insulation provided by the boards of EPS, although other fillings also proved efficient to provide adequate thermal comfort conditions in our region inside homes.

All fillings are elements harmful to the environment if left exposed, so their use constitute an important factor for the preservation of nature.

With respect to the manufacturing process of the blocks there is an additional complication to the use of all fillings tested. The filling which exhibits greater ease of manufacturing or the plate.

A Thesis is in development where all these fillings will be tested along with different proportions between the constituents of the composite and a house will be built and will be evaluated thermal comfort generated by these blocks. The tests performed in this work indicate a viability of generating significant thermal comfort.

The graphs of Figure 4 show the behavior of the parameters analyzed during the tests.



	Text (C°) 1°Day	Text (C°) 2° Day	Text (C°) 3° Day
EPS	37,2	36,8	37
CAN	37,7	36,8	37,1
Bottles of Water	39,1	38	38,4

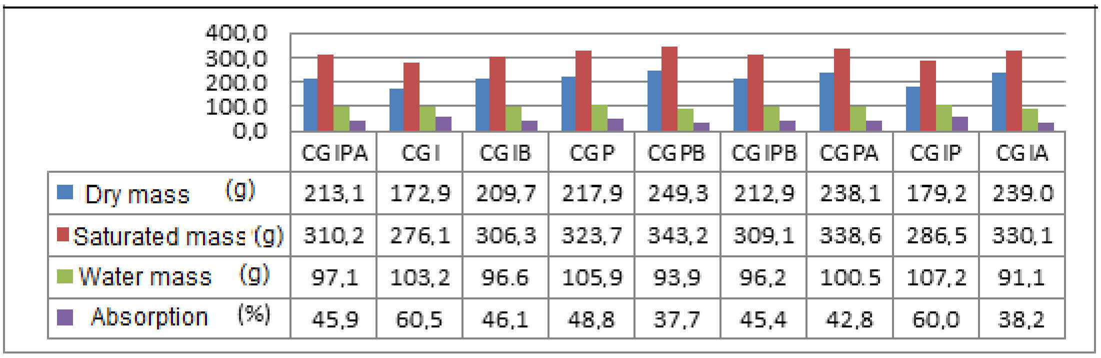
	ΔT (C°) 1° Day	ΔT (C°) 2° Day	ΔT (C°) 3° Day
EPS	4,6	4,2	4,6
CAN	4,5	3,7	4,2
Bottles of Water	5,7	4,7	5,3

	Tint (C°) 1° Day	Tint (C°) 2° Day	Tint (C°) 3° Day
EPS	32,6	32,6	32,4
CAN	33,2	33,1	32,9
Bottles of Water	33,4	33,4	33,2

Figure 4. Behavioral parameters analyzed during testing.

4.5 Water Absorption

The graph of Figure 5 shows the behavior of the parameters during the test to determine the percentage of water absorption of the composite.



	CG IPA	CG I	CG IB	CG P	CG PB	CG IPB	CG PA	CG IP	CG IA
Dry mass (g)	213,1	172,9	209,7	217,9	249,3	212,9	238,1	179,2	239.0
Saturated mass (g)	310,2	276,1	306,3	323,7	343,2	309,1	338,6	286,5	330,1
Water mass (g)	97,1	103,2	96.6	105,9	93,9	96,2	100.5	107,2	91,1
Absorption (%)	45,9	60,5	46,1	48,8	37,7	45,4	42,8	60,0	38,2

Figure 5. Behavior of parameters in water absorption test.

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All formulations can be used as building elements with respect to water absorption. The most efficient formulation presents sand CGIA and with a percentage lower than 40.0%.

The percentage of polystyrene composites without sand or clay have high water absorption, about 60%, but significant absorption that does not compromise its use for the manufacture of plates, which are then sealed in a paint which provides a significant reduction of this problem.

5. CONCLUSIONS

1. The composite studied is feasible to be used as construction material;
2. Due to the good heat resistance of the composite blocks, it is expected a good thermal comfort in the interior of a house built with these blocks;
3. The manufacturing process is simple and can block its technology to be transferred to needy communities for people of any cultural levels;
4. A large block enabled a faster construction of space science, by its greater area, compared to brick red ceramic;
5. The reuse of materials harmful to the environment, such as Styrofoam and tire constitutes an ecological action of great importance to environmental preservation;
6. The residence manufacturing cost can be reduced since it significantly reduces the cost of labor.

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