Composite with Recyclable Loads for the Manufacture of Blocks to Build Popular Houses

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Abstract: The science space in a state school in Natal city was built using a composite consisting of gypsum, EPS (expanded polystyrene), shredded tire, cement and water. Mechanical and thermal resistances were evaluated. Inside the blocks, three types of fillings (EPS plates, aluminum cans and 500 mL bottles of mineral water) were placed in order to obtain a walls with higher thermal resistance, 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. The experiments demonstrated that the temperature difference between the internal and external surfaces on the walls reached levels above 12.0 °C. It was also demonstrated that the proposed composite has adequate mechanical strength to be used for sealing walls. The proposed use of the composite can contribute to reduce the significant housing deficit of Brazil, producing popular houses at low cost and with little time to work.

Key words: Solar composite, low cost, thermal resistance, mechanical resistance, materials reuse, 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 [1].

For this purpose, a new type of block was developed using composite material in order to reduce the cost of building a house, and contribute to existing efforts to reduce the housing deficit [1-5].

This block contains in its composition shredded tire, gypsum, EPS (expanded polystyrene), cement and water. The fillings of the blocks can be EPS plates, aluminum cans and bottles of mineral water. In this paper, the authors present the results for tests with such

fillings.

The composite has good homogeneity, the blocks produced are easy to manufacture and assembly and present low thermal conductivity and can be used for different manufacturing techniques.

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

This block has the following main features: low cost, good compressive strength, low thermal conductivity, good esthetics, low weight, versatility and easy manufacturing and assembly processes.

Another major advantage of the produced composite is its rapid complete drying process allowing considerable flexibility of the construction process. The advantage of good surface finishing of the

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produced block should also be noted

The paper is organized as follows: Section 2 presents the materials and processes used to manufacture construction blocks and space science; Section 3 presents results and discussions; and Section 4 gives conclusions and presents future work.

2. Materials and Methods

The composite used in the 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. EPS recycled plates, cans of beers and soft drinks, and pets bottles of mineral water 500 mL. The dimensions of the block were $L = 80$ cm, $W = 26$ cm and $H = 10$ cm, with an area of 0.21 m^2 and volume of 0.021 m^3 [1-3].

To manufacture the block with the fillings, selected procedures were adopted: the mold assembly; application of the release agent in the mold; dosage of the 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, styrofoam plates from whole packs of split type air conditioners were used; bottles of soft drinks were 12 in number and cans of beer and soft drinks 15 in number. Fig. 1 shows the steps of manufacturing the proposed block.

To test the composite's thermal resistance, a science space was built in a state school located in Natal-RN (Rio Grande do Norte). About 75 blocks were used for that building. Fig. 2 shows some views of the walls of the built science space that has an area of 27.0 m^2 ($6.28 \text{ m} \times 4.30 \text{ m}$) and walls with the height of 2.44 m and 0.10 to 0.13 m thickness.

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

Fig. 1 Manufacturing steps of blocks with three fillings.

Fig. 2 Views of the walls of the built space.

The thermal performance analysis of residential units was made for daytime. The temperatures of the internal walls, external sunny side (south) of the internal environment were collected directly at every 15 min in at least eight hours, 8:00 a.m. to 04:00 p.m. It was also collected for the same period the thermal sensation of the external environment and the global solar radiation.

3. Results and Discussions

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

3.1 Determination of Thermal Conductivity

Table 1 shows average values of the thermal conductivity.

The composite showed low thermal conductivity, but higher than other tested compositions. The introduction of the tire scrapes caused an increase of

Table 1 Average thermal conductivity.

Composition type	K (W/m $^{\circ}$ C)
CGE	0.20
CGT	0.37
CGET	0.26

C: cement, G: gypsum, E: EPS and T: tire scrapes.

30% in relation the crushed EPS. The thermal conductivity was closest to the gypsum's than to the polystyrene's and the tire scrapes.

3.2 Determination the Specific Mass of the Composite

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

The composite is much lighter than common brickwork (density of 1,600 kg/m ^{3}), which is a very positive factor during the laying of the blocks.

3.3 Test of Compression Resistance

Table 3 shows the values of compressive strength obtained for all tested configurations after 7, 14 and 28 days of curing.

The compression strength was 35.0% above the one shown by the standard, but it is clear that the mixing EPS-Tire does not produce a high mechanical strength. The other studied composites compositions showed higher levels in this parameter.

3.4 Thermal Resistance Test

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

The maximum temperature difference achieved between the external and internal walls occurred in the third test day, corresponding to 12.4 $^{\circ}$ C at 01:30 p.m. It should be noted that this day had a higher rate of incident global radiation.

The average temperature difference between the external and internal wall was significant, reaching an average value of about 4.0 $^{\circ}$ C.

In relation to other blocks manufactured in the same geometry, the results achieved were higher, especially

Table 2 Specific masses of the tested formulations.

Composition type	Specific mass (kg/m ^{3})
CGE	882.1
CGT	1,271.9
CGET	914.2

Table 3 Compressive strength.

Composition	Compression strength (MPa)		
	7 days	14 days	28 days
CGT	3.10	4.18	4.31
CGET	1.5	1.84	2.02
CGEC	2.70	2.80	2.90

C: clay.

Table 4 Average of thermal comfort tests—EPS filling.

Days	$T_{wall\ external}$ ($^{\circ}$ C)	$T_{wall\ internal}$ ($^{\circ}$ C)	ΔT ($^{\circ}$ C)	ST ($^{\circ}$ C)
1	37.2	32.6	4.6	35.5
2	37.7	33.2	4.5	36.0
3	39.1	33.4	5.7	36.0

ST: thermal sensation.

for the period between 01:00 p.m. and 02:00 pm, with temperature differences of around 10 $^{\circ}$ C. These findings are relevant for obtaining a good thermal comfort in the interior of dwellings.

Solar conditions of test days were very good, recording solar radiation peaks around 1,000 W/m ^{2} , and average above 730 W/m ^{2} , and average relative humidity around 60%.

The maximum temperature difference achieved between the external and internal walls occurred in the third test day, corresponding to 11.5 $^{\circ}$ C at 01:30 p.m. The average temperature difference between the external and internal wall reached average of 4.2 $^{\circ}$ C.

In relation to other blocks manufactured in the same geometry, the results achieved were higher, especially for the period between 01:00 p.m. and 02:00 p.m., with temperature differences of around 9 $^{\circ}$ C. These findings are relevant for obtaining a good thermal comfort in the interior of dwellings.

The maximum temperature difference achieved between the external and internal walls occurred in the third test day, corresponding to 11.7 $^{\circ}$ C at 01:30 p.m. The average temperature difference between the

Table 5 Average of thermal comfort tests—cans filling.

Days	$T_{wall\ external}$ (°C)	$T_{wall\ internal}$ (°C)	ΔT (°C)	ST (°C)
1	36.8	32.6	4.2	35.5
2	36.8	33.1	3.7	36.0
3	38.0	33.4	4.7	36.0

Table 6 Average of testing for thermal comfort—filling bottles.

Days	$T_{wall\ external}$ (°C)	$T_{wall\ internal}$ (°C)	ΔT (°C)	ST (°C)
1	37.0	32.4	4.6	35.5
2	37.1	32.9	4.2	36.0
3	38.4	33.2	5.3	36.0

Table 7 Parameters average for the diagnosis of thermal comfort of the blocks.

Filling type	ΔT_{max} (°C)	ΔT_{ave} (°C)	I_g (W/m ²)
EPS	12.4	5.0	720.0
Cans	11.5	4.2	732.6
Bottles	11.7	4.7	752.5

external and internal wall was significant, reaching an average value of about 4.7 °C.

In relation to other blocks manufactured in the same geometry, the results achieved were higher, especially for the period between 01:00 p.m. and 02:00 p.m., with temperature differences of around 9.5 °C. These findings are relevant for obtaining a good thermal comfort in the interior of dwellings. Table 7 shows the average temperature measured for the three types of fillings used.

The highest thermal insulation was provided by the EPS filling, although other fillings also proved themselves to be efficient in providing adequate thermal comfort conditions inside houses.

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

Regarding the manufacturing process of the blocks there is an additional complication to the use of all tested fillings. The filling that was easier to manufacture was to EPS plate.

A thesis is in development in order to test these fillings along with different proportions between the constituents of the composite. A house will be built and

Fig. 2 Behavioral parameters analyzed during test. **Fig. 3 Parameters behavior in the water absorption.**

the thermal comfort generated by these blocks will be evaluated. The tests performed indicate a viability of generating significant thermal comfort.

Fig. 3 shows the behavior of the analyzed parameters during the tests.

3.5 Water Absorption

Fig. 4 shows the behavior of the parameters during the tests to determine the composite's percentage of water absorption.

All formulations can be used as building elements with respect to water absorption. The most effective formulation was CGEC with a percentage lower than 40.0%.

The constitutions without sand or clay have high water absorption, about 60%, but this absorption does not compromise its use for the manufacture of plates. As they are sealed in paint, there is a significant reduction of this problem.

4. Conclusions

- (1) The composite studied is feasible to be used as construction material;
- (2) Due to the good heat resistance of the composite

blocks, a good thermal comfort is expected in the interior of a house built with these blocks;

(3) The manufacturing process is simple and its technology can be transferred to needy communities for people of any cultural levels;

(4) A large block enabled a faster construction of the science space since its area is greater if compared to a red ceramic brick;

(5) The reuse of harmful to the environment materials, such as EPS and tire constitutes an ecological action of great importance to the environmental preservation;

(6) The residence manufacturing cost can be reduced since it significantly reduces the cost of labor.

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