Addition of alternative materials to ceramic slabs

(Incorporação de materiais alternativos em lajotas de cerâmica)

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Abstract

The construction market is very growing, leading to the emergence of new technologies and materials, and a growing need for sustainable products for the construction process, and the call for quality of life we present the description of a new option alternative materials for environments that require careful with the acoustics. The research covers the development and incorporation of new material in construction, with the potential acoustic, from tests and measurements with calibrated decibel meter called. We also used the ceramic tiles pre-molded, used for making floors or ceilings in buildings and homes. The methodology used for the development of this research was characterized as literature, exploratory, descriptive, qualitative and quantitative, alternative and affordable. How after the analysis results of the tests performed it can be seen that the incorporation of rice hulls of agglomerated to form ceramic tiles, possible reductions in noise levels on the order of 8 dB (A) than the traditional construction of the buildings, and then an excellent material. This research contributes to the construction so that presented a description of a new product developed from a conventional material, originating in agriculture, waste rice husk and its incorporation during the construction of buildings and home, with the potential acoustic observed from tests and measurements with calibrated decibel meter called.
Keywords: **c**eramic tiles, rice husk, environmental management.

Resumo

Esta pesquisa apresenta a descrição de um novo produto desenvolvido a partir de um material não convencional, oriundo da agricultura; os resíduos de casca de arroz. Procurar-se-á também apresentar o desenvolvimento e incorporação do mesmo material na construção civil, com potencial acústico, a partir de ensaios realizados e medições com aparelho calibrado denominado decibelímetro. Utilizou-se também o produto comercialmente conhecido pelas construtoras e incorporadoras de edificações, as lajotas de cerâmica pré-moldadas, usadas para confecção de pisos ou forros nos edifícios e casas. Esta pesquisa procurou apresentar uma nova opção de materiais alternativos para ambientes que exijam o cuidado com a acústica, bem como possibilitar a indústria da construção civil, novos estudos com materiais alternativos e que são muitas vezes rejeitados pela falta de informações ou desconhecimento pelos profissionais da área. A metodologia utilizada para o desenvolvimento dessa pesquisa caracterizou-se como bibliográfica, exploratória, descritiva, quali-quantitativa. Como resultados encontrados após as análises dos ensaios realizados, pode-se observar que a incorporação das cascas de arroz de forma aglomerada às lajotas cerâmica, possibilitaram reduções dos níveis de ruído na ordem de 8 dB (A), quando comparada a forma tradicional de construção nas edificações.
Palavras-chave*: lajotas cerâmicas, casca de arroz, construção civil, gestão ambiental.*

INTRODUCTION

Sustainable construction is understood as every constructive system which allows saving material and energy resources, satisfactorily meeting technical, social and artistic requirements and, also, providing, whether short or long-term, the building's energy balance [1]. The research aimed, therefore, the development of a new product, using rice husk as an alternative material added to hollow clay bricks and beams which, together, shape floors and ceilings in masonry houses and apartments. The main purpose of this research was giving a more noble nature to the residues coming from the rice husk and take advantage of it. This is an agricultural residue and it is found in great quantities in south Brazil.

The general goal here was to develop a new product for the construction industry based on the use of residues coming from the agglomerated rice husk to ceramic slabs - flooring blocks. The specific goals were: analyze the physicochemical characteristics of rice husk; understand the factors that may influence in the acoustic insulation in building constructions; experimentally evaluate the addition of agglomerated rice husk in ceramic slabs - flooring blocks - analyzing its potential when reducing the levels of noise in masonry houses and buildings; perform tests with conventional ceramic slabs and compare them to the one which have rice husk added to them. This study has been justified because of the need in developing alternative materials for the construction industry, in such a way it would allow them to save in materials and use waste, aiming the addition of green products during the construction process of houses and buildings. Global population growth combined to the technological advance reached in the recent years, has as consequence an enormous environment contamination, on both emission of toxic gases and production of great quantities of residues, with no appropriate place for its final disposal [2]. According to some investigators, the most effective way the construction industry has to turn into a green activity is through the addition of residues coming from other industries [3]. Several industries generate residues which could be potentially used in other industrial fields, because of their availability, technical potential and suitable costs, which, sometimes, could be limited to just the transportation of the product to the place it is going to be used [4]. The proper management of waste implies on the need for studying markets where it is possible to reuse it and, because it is an industrial field that consumes raw material of several different types, the construction industry may be great option for using recycled products and, also, byproducts from the industrial field [5].

Bibliographic review

The environmental impacts coming from the flow of materials during the generation of the built environment are clear. The building construction uses up to 75% of resources taken from nature, with the aggravating factor that most of them are not renewable. From the point of view of Ref. [6], the practice of reusing existing components are revised for their use when trying to reduce environmental impacts, as attributes of processes consistent with the indicated use. The manufacturing, transportation and use of these products contribute for the global pollution and emissions of greenhouse gases and pollutants from internal environment within buildings, which are equally relevant [7]. There are many factors justifying the need for a green architecture like: population growth, industrialization, heavy consumption of non-renewable products and considerable waste production.

The construction materials have a significant impact on the environment, thus, they require greater attention when choosing and/or using those materials [8]. A more sustainable construction relies on the right choice of materials and components, what may be defined as the selection of products. When it is combined to the right details of the project, it results in low environmental impact and great social benefits, within the limits of economic viability in each situation [7]. When selecting green materials three aspects must be taken into consideration: environmental, economic, and social, therefore, it is important to minimize the use of non-renewable resources and seek for a maximum recovery of materials, avoiding, this way, residue generation; Efforts must be made to promote a fair distribution of costs and benefits and improve the quality of life among society, not making the construction aesthetical aspects unfeasible. The draftsman acquires, at this moment, a key position between society and construction industry [9]. Both of them have influence on less energy-consuming, less polluting and more reusable choices, while, at the same time, they must be very economical and functional.

The construction field is, very often, focused on short-term goals for projects, rather than having a long-term business strategy and organizational relations [10]. The environmental policy instruments applied in the world nowadays are from two different orders: regulatory instruments, like Command and Control; and Instruments of Economic Incentive or Market [11]. The first group is related to obligations, rules and standards which must be wisely met, aiming to identify specific environmental problems followed by a set of penalties for those who do not meet them. Secondly, there comes the group that stimulates the access to environmental resources and technologies, subsidizing activities which involve environmental management, reducing incentive to those ones having an environmental negative impact. It is a set of procedures which should help the organization to understand, control and decrease the environmental impacts of their activities, product and/or services.

In order to obtain an environmental management plan in a certain enterprise, it is stated that it is necessary to identify needs and problems based on the analysis of natural resources, their tendencies, potential for action impact and socio-cultural values [12]. In the rural areas, the rice-growing sector stands out among the ones that have been worried about the environment. In agriculture is the pollution produced by solid waste plants and animals, but which may be reusable in other activities [13]. In the case of the rice sector has been implementing environmental impact reduction procedures, since they come from productive system externalities [14]. Among all residues coming from an agro-industry where the production of rice is processed, there are rice husk and ashes. Those are considered to be the main residues found in this kind of industry and may be able reduce socio-environmental impacts. Some farmers have already used rice husk as a fuel burning it in boilers and, others have used it in their own properties. According to Ref. [15] composting is one of the most used destinations for this residue. The next step would be reusing residues generated after the manufacturing process of other products and using them in other areas like inputs (rice husk) [14].

In the recent years, the interests on public policies, which talk about residues coming from the construction industry field, have been increasing with debates on environmental matters. Among all alternatives, the most effective one, when trying to reduce the environmental impacts caused by civil construction waste, is reducing waste generation. Besides, it is the best alternative from the economical point of view. Therefore, many industries in the construction field are associating environmental matters to their productive processes through the Environmental Management System (EMS). The success of EMS of a company relies on the relation between products, services and environmental aspects linked to manufacturing processes [16].

According to Ref. [17], in an EMS, it is necessary to look at a system from three different perspectives. One of them is related to coercive means (regulations,

Table I - Level of evaluation criteria - LEC - for outdoor environments, in dB (A).
[Tabela I - Nível de critério de avaliação - NCA - para ambientes externos, em dB (A).]

Types of area	Day	Night
Farm and Ranch areas	40	35
Strictly residential urban area or places with schools and/or hospitals	50	45
Mixed area, mainly houses	55	50
Mixed area, mainly commercially and administrative orientated areas	60	55
Mixed areas, mainly recreational oriented areas	65	55
Area where industries are predominant	70	60

Source: NBR 10151, 2000

penalties, non-charged trade barriers, external pressure, etc.). Generally, companies treat their non-compliances in a reactive way. Another perspective is the economical one, when companies spot competitive opportunities through environmental preservation. The third perspective is related to environmental awareness (ethical and environmental responsibility). Usually, companies incorporate these views to their strategies, this happens in a pro-active way. The EMS must be implemented in such a way it would be integrated to the global management of a public or private organization. EMS action must not happen separately from the company's management. The environment should not be restricted to one room, department or set of people who work isolated from others inside the company. It should permeate throughout the organization. This shows the strategic importance that environmental considerations are taking inside companies [18]. In an EMS, the waste management is considered a complex activity, which contemplates since a whole process, starting from mapping the residues generated and going all the way to the verification of technical and economic feasibility in preventing and minimizing the generation of each one of these residues including: segregate, classify, identify and properly store them until their transportation to the final destination. Mapping the waste generation is one of the first steps taken and must be performed using spreadsheets, identifying and characterizing the waste generated in each sector and the destination given to it [19]. Good management of the waste generated is a concern for the authorities, the risk that can bring health and human security [20]. The recovery of waste, besides having environmental advantages, may help in manufacturing materials that could be developed at the lowest possible cost, decreasing economical costs and having the same comfort in housing [1]. The studies on environmental acoustics in urban areas say that noise may cause major problems to buildings, degrading the population's wellbeing and quality of life. One of the highest levels of complaints because of the transmission of noise from impacts through tiles come from impulsive noise, which results from footsteps, objects falling on the tiles, mainly during the evening [21]. The NBR 10151 [22] describes the levels of noise for the evaluation of different outdoor environments as it is described in Table I, where the time limits for day and night periods can be defined by authorities according to the population habits. However, the evening period should not begin after 10:00 pm and it should not finish before 7:00 am in the next morning. In case the next day is a Sunday or a holiday the end of the night period should not be before 9:00 am. For indoor environments, the level shown in Table I must go through a correction of 10 dB (A) for open windows and 15 dB (A) for closed windows.

Table II - dB (A) and NC values, noise evaluation curve.
[Tabela II - Valores dB (A) e NC, curva de avaliação de ruído.]

Places	dB (A)	NC
Hospitals		
Apartments, Sick bays, nurseries , Operating rooms	35-45	30-40
Laboratories, Areas for public use	40-50	35-45
Services	45-55	40-50
Schools		
Libraries, Music rooms, Drawing rooms	35-45	30-40
Classrooms, Laboratories	40-50	35-45
Hallways	45-55	40-50
Houses		
Bedrooms	35-45	30-40
Living rooms	40-50	35-45
Hotels		
Apartments	35-45	30-40
Restaurants and Living rooms	40-50	35-45
Gatehouse, Reception, Hallways	45-55	40-50
Auditoriums		
Concert halls, theaters	30-40	25-30
Conference rooms, Movie theaters, Multi-use rooms	35-45	30-35
Restaurants	40-50	35-45
Offices		
Meeting rooms	30-40	25-35
Churches and Temples (contemplative services)	40-50	35-45
Places for sports practice		
Private Concert Venues and sports centers	45-60	40-55

Source: NBR 10152, 1987

The NBR 10152 sets noise levels suitable for acoustic comfort in different environments, according to the information in Table II, where the lower values represent the sound levels for comfort; higher values indicate a reasonable sound level for the purpose, those higher levels can be considered uncomfortable and do not necessarily cause any risk of detriment to human health [23].

In order to ensure comfort while performing a specific task, it is necessary a minimum physiological effort over sound, light, heat and ventilation [24]. Every element in nature has acoustic properties and the absorption capacity depends on the type of material this element was made of. When choosing the materials for the acoustic, it is also important to pay attention to the occupancy rates, maintenance, lifetime, stability and fire resistance of that ambience. Absorption capacity takes place when, through the transformation of vibrations in thermal energy, material is able to dissipate the noise energy falling upon it. In this case, the use of very light and stringy materials like polyester, ceramic fibers, fabrics and other ones is indispensable [25].

Industry has developed new materials with coefficient of acoustic insulation e/or noise absorption. They are more efficient than the ones which had so far been considered as 'acoustics'. Thereby, it has been possible to obtain, through variations in their composition, satisfying acoustic results that could meet the user's. Nowadays, using recyclable materials in environmental acoustics and the continuing uprising of reusable or recyclable products - in this area - have gotten bigger and bigger. This field has been using insulations basically made of textile fibers, cellulose, waste tires, besides other alternatives coming from recyclable processes, creating, this way, solutions for using waste and contributing for a better environmental development of certain materials. Aiming to produce insulating materials with low environment impact, fibers coming from plant and animals (wool) can also be used. Rice husk is made up by 2% proteins, 0.3% fat, 34.5% fibers, 13.2% proteins and 22% carbohydrates; it has high hardness, fibrosis and abrasive nature. It has high levels of silica, 50% cellulose, 30% lignin and 20% silica anhydrous based [2].

Pure or mineral silica is a mixture highly used in inorganic chemical manufacturing, especially in ceramic industries as a raw material for producing glasses, refractories, Ceramic sleeves, thermal insulators, and abrasive products [26]. On the construction industry, it is used as an additive for cements, concrete and mortars. In those cases, silica is vital because it is responsible for ensuring the product's resistance, stickiness, and curing time. As a rice husk based product, it has also been used, together with clay, when manufacturing bricks and roof tiles that have a good thermal insulation and lightweight concrete [27].

The incremental innovation relates to any improvement performed in a product, process or ways of organizing the manufacturing process inside of a company, what may bring profitability, quality and also improve technical efficiency. Optimizing production processes, designs and decreasing the amount of material and components used during the manufacturing process a good may be called incremental innovations [28].

The innovations brought by the construction industry to Brazil in the early 90's added to the evolution in the construction sector as far as it allowed the construction companies to import products and technologies [29]. During this period, several construction companies invested in the modernization of productive resources, watching the increasing industrialization on work sites. To this extent, Ref. [30] defines technological innovation as a technological improvement resulting from the company's internal or external research and development activities, applying their findings to the buildings' production process aiming performance improvement, quality or cost of a building of part of it. The innovations in the construction industry can also be set by advantages related to traditional processes, complexity, compatibility, and experimentations [31]. The evolution of innovation in this sector may be found in different stages: in finished products, in the ones supplied to the construction and in the internal organization of companies which belong to this field.

MATERIALS AND METHODS

Methodology

After the research and comprehension about the subject chosen for this study, researchers performed new insights, which worked as the kick start for data collection. They created a sample for a new product, inserting the rice husk (Fig. 2) inside the commercially obtained hollow clay brick (Fig. 1). The rice husk was all glued together with Tenaz (white glue) so it could form a single block capable of being inserted in the interspaces of the hollow clay bricks. After the prototype for acoustic hollow clay brick (Fig. 3) assembling had been finished, some tests were performed trying to evaluate the real efficiency of this new product.

Figure 1: Conventional hollow clay brick.
[Figura 1: Tavela convencional.]

Figure 2: Rice husk.
[Figura 2: Cascas de arroz.]

Figure 3: Hollow clay brick with agglomerated rice husk inside it (acoustic hollow clay brick).
[Figura 3: Tavela com casca de arroz aglomeradas internamente (tavela acústica).]

Technical sheet for cheaper conventional hollow clay brick (Fig. 1): H x L x D: 2.75" x 11.81" x 7.87", Weight (Ib): 6.063 Parts/1150 in²: 13 unit, Resistance (bending): ≥ 0.7 KN, Water absorption (Aa): 8 - 22%.

Tests elaboration

In order to perform tests on the new product, we built a wooden box measuring 19.69 in x 11.81 in x 7.87 in (H x L x D) open only on the upper side (Fig. 4) where a hollow clay brick measuring 2.76 in x 11.81 in x 7.87 in (H x L x D) was set. It aimed to represent the top part of apartments or the ceiling of a masonry house (Fig. 5). Tests were performed following the description below: wWe set a siren inside a wooden box. Right after it, we started measuring, from outside, the noise made by the siren outward it. This procedure was performed five times, we wrote down the values shown by the decibel meter (Fig. 6) so, later, we could obtain an average from these measures in two different moments: Firstly, we set a conventional hollow clay brick (Fig. 1) inside the wooden box, with no agglomerated rice husk in it, then we noted down the noise coming out the box. We made five different notes calculating the average between them and the standard deviation related to these readings. The second step was setting the hollow clay brick for floors with agglomerated rice husk inside the box and, then, performing the same procedure, in other words, with the siren inside the box we measured the noise coming outwards. We used the same distance as we did during the previous measurement and we noted down the noise made by the siren. Five readings were performed. The average between them and the standard deviation related to these readings were later calculated like we did during the first experiment. With all data collected, it was possible to compare the reduction of levels of noise which took place before and after the hollow clay brick replacement. The wooden box was used just to simulate any environment.

Figure 4: Wooden box.
[Figura 4: Caixa de madeira.]

Figure 5: Wooden box with hollow clay brick on the upper part.
[Figura 5: Caixa de madeira com tavela na parte superior.]

RESULTS AND DISCUSSION

As indicated, 10 measuring tests were performed during this study, 5 of them were performed using the conventional hollow clay brick and the other 5 used the hollow clay brick with agglomerated rice husk. For the conventional hollow clay brick, the following readings were found LTC1, LTC2, LTC3, LTC4 e LTC5 and the average between them was calculated as shown in the table below. For the hollow clay bricks with agglomerated rice husk the readings obtained were, LT2, LT3, LT4 and LT5 and the average between them was calculated as shown in the Table II. Based on these data, we obtained the standard deviation for both cases, as shown in Table III and IV, respectively.

Based on data obtained in this research, it can be noticed that the average of noise levels for the test proposed and performed, improved considerably, falling from 77.72 dB(A) without using rice husk to 69.24 dB(A) when rice husk was incorporated to the hollow clay bricks. A reduction of approximately 8 dB (A). If we pay attention to the Regulation Standards, the NR 15 which deals with noxiousness, it can be noted that a worker can be exposed, in a work environment, for a maximum period of 8 h with noise levels of up to 85 dB(A). If the noise levels rise to 90 dB (A), the exposition time, in the same environment, should be reduced to 4 h, thus, thinking about the results found, it can be noticed that there was a considerable decrease when this alternative material was added to the hollow clay bricks; results which meet the main goal of this research that was developing a new product for the construction

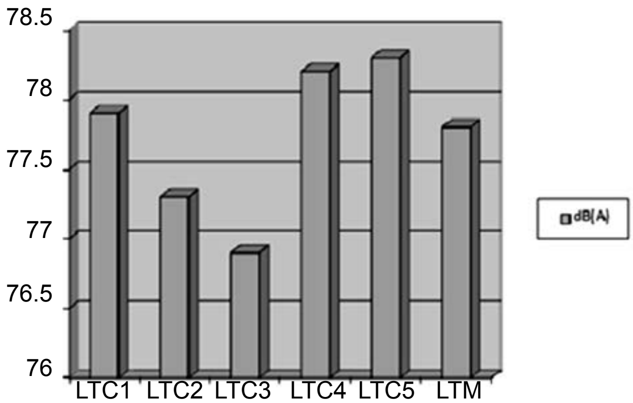

Chart 1: Measurements of the noise levels exposed in conventional hollow clay bricks.
[Gráfico 1: Medições dos níveis de ruído exposto em tavelas convencionais.]

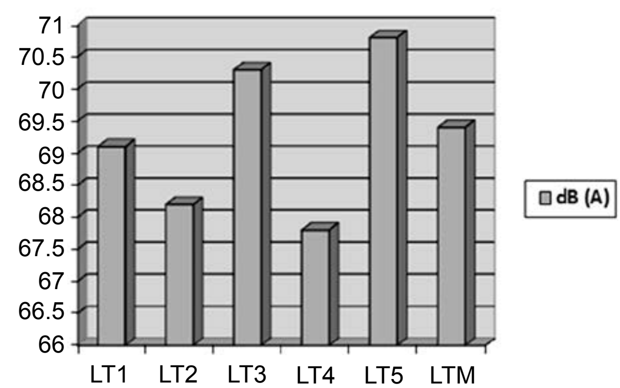

Chart 2: Measurements of the noise levels exposed in hollow clay bricks with agglomerated rice husk.
[Gráfico 2: Medições dos níveis de ruído exposto em tavelas com cascas de arroz aglomeradas.]

Table III - dB (A) and NC values, noise evaluation curve.
[Tabela III - Tavelas convencionais, sem casca de arroz.]

	Readings (dB)	Average	Deviation	Deviation table
LTC1	77.9	77.72	0.2	0.04
LTC2	77.3	77.72	-0.4	0.16
LTC3	76.9	77.72	-0.8	0.64
LTC4	78.2	77.72	0.5	0.25
LTC5	78.3	77.72	0.6	0.36
	Total			1.45

variance - 0.29, standard de viation - 0.5

industry based on the use of rice husk waste agglomerated to ceramic slabs - hollow clay bricks. When looking at Table II of NBR 10152, acceptable noise levels are set for different environments, it is possible to see that in houses, the values range from 35 to 50 dB (A), where a value lower than 35 dB(A) means a comfortable noise level and levels higher than 50 dB(A) are considered uncomfortable. These values, although low in dB (A), must ensure comfort for the user of those environments. With the system proposed, adding

Table IV - Hollow clay brick with rice husk.
[Tabela IV - Tavelas com a incorporação de casca de arroz.]

	Readings (dB)	Average	Deviation	Deviation table
LTC1	69.1	69.24	-0.1	0.01
LTC2	68.2	69.24	-1.0	1.00
LTC3	70.3	69.24	1.1	1.21
LTC4	67.8	69.24	-1.4	1.96
LTC5	70.8	69.24	1.6	2.56
	Total			6.74

Variance - 1.34, Standard deviation - 1.15

agglomerated rice husk to ceramic slabs, it was possible to reduce the noise level in nearly 8 dB (A). If the noise level gets to 50 dB(A) in the environment analyzed, the worst scenario shown in Table II, then, we could be close to what the standards set as comfortable, in other words, we would reduce the noise level to 42 dB(A) just with the use of rice husk.

Because of the results obtained, we suggest continuing this research through the incorporation of other alternative materials as sawdust, sugarcane straw, maize straw, etc.; benchmark the results and search for the best option for each environment built, with the right alternative material to be incorporated there, resulting, this way, in a good selection of green material that may bring even more significant and encouraging results for the construction industry.

CONCLUSIONS

It was possible to verify that the environment management practices in rural areas may help, not only for the quality of the environment and life, but also, it may offer important job opportunities and income for the rural population. Waste, which up until then caused environments impacts, can now become environmentally sound technologies, helping to spread the zero-carbon emission concept (University of Tokyo) and, also, be used in different industry fields. This research brought, this way, a great innovation for the environmental field, showing that the rice husk is a great opportunity for the construction industry to minimize environmental problems generated through the improper disposal of this waste, besides contributing for the improvement of acoustic insulation. Likewise, it is noticeable that the main goal of this study has been reached, because of the experiments performed and it is clear that agglomerated rice husk set on ceramic slabs - hollow clay bricks are very efficient alternative materials to improve the emission levels of acoustic noise. It can, also, be used as a new material, being a great new option for the construction industry, if used correctly agglomerated in logs. The physical-chemical characteristics of the rice husk were analyzed and it was concluded that the great amount of waste generated through this culture happens, after the rice crop, because its husk is built by silica and it has great fibrousness, hardness, and abrasive nature. It is inedible, because it does not have any nutritional value. However, according to what was studied in the literature review and exposed here, nowadays the rice husk has been used in different industries because of its high resistance and calorific value. As a specific goal, it was also analyzed the direct connection between acoustic isolation and some materials. They work in such a way they create a barrier, because of their hardness, not allowing the sound to escape, as it happens with the rice husk. An example that may be proved through comparative experiments performed with conventional ceramic slabs. Through those experiments, it was possible observe an average reduction of 8 dB (A), when comparing to the traditional way of building ceilings and floors with ceramic slabs; being considered, this way, in the researcher's view, the rice husk agglomerated in logs and set inside ceramic slabs, an excellent alternative material with low cost, capable of making a significant reduction in noise levels in buildings and masonry houses. Based on the results found, it was noticeable that the specific goals of this research were reached. As a suggestion for future projects, we suggest continuing the research in this same segment, adding other alternative materials to products available on the market, and compare the results, bringing new options of green materials.

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