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Design and Materials undera Socio-Technical Perspective: Sustainable Plastic Manufacturing with Rice Husks

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Abstract: Thisarticle aimstoshowtheapplicationofricehuskasasustainableadditiveforanewcompositematerialofgypsumto generate incomeofa small handicraft company inAparecidacity. In the field of materialstudies, rice husks were collected, crushed and thegrains was granulometricly analyzed, scanning electron microscopy was used to analysis thecomposite interface and, finally, compression resistance tests of the samples.A sociotechnicalanalysis of the small company studied was carriedoutand,fromthisunderstanding,anadaptation ofthescientificmethodsusedtodevelopthecompositefortheempiricalmethodsperformedbythecraftsmen,besidestheeconomicviabilityoftheapplicationofthiscompositewascarried out. This research revealed that it is possible to use crushed rice huskin gypsum in an artisan context, saving up to 10% of the gypsum used in production.

Keywords: Design, Materials, Rice Husk, SociotechnicalAnalysis.

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I. INTRODUCTION

According to Law [1], knowledge is a social product, differentiating itself from a production carried out by means of a privileged scientific method. In this sense, it is revealed the importance of nonhumans as full actors in collective, due to the fact that they are not included as a social component by means of current world view [2]. According to Bijker [3], the different actors in this context can (re) define problems and more important stabilization processes of artifacts, therefore, different usage practices may interfere with design of artifacts, in which can come from social actors not so involved in technical process.

The fact is that designers have the ability to integrate possible networks and to promote distinct connections, that is, to relate all material and immaterial aspects, making them capable of recognizing and connecting values and converting them into measurable attributes for innovation [4]). According to Andrade [5], the innovative agent needs to control both the social context in which the practice takes place and its own adaptation. It is no longer possible to generate technologies that do not meet the requirements of environmental sustainability, with the risk of generating embargoes, boycotts and legal mechanisms of interdiction [6].

An interactive network begins to be established between the scientific and technological field as articulators in emergence of new concepts, new paradigms, desires and projects of individuals and societies disposed of means more and more efficient to materialize them, and interdisciplinarity comes as a complex theme that breaks down boundaries between content and methods [7], it has the challenge of partially restoring the character of totality and hybridity in real world, in which there is an interaction among different actors [8].

According to Meyer [9], when it comes to a design and network approach, it is first said about the focus of interest in design, which is qualified only for solidity of mediations promoted in a given network and, secondly, for impossibility of placing the designer as sole agent responsible for construction of an artifact. According to the author, the action of multiple actors interferes directly in construction of an artifact, in which it depends on a set of interests of several actors in which they can alter their primary objectives. Therefore, from this perspective, the author raises a question regarding the way of thinking the design that permeates amongst improvements for the user (human) or for the artifact (nonhuman), to think of another way: "what element most contributes to the strengthening of the network?" [9].

Krucken [4] argues that there is a tendency to drive design by adding value to products, strengthening and stimulating the identity of a particular place and especially in emerging economies, where design catalyzes innovation and the creation of products and services directly linked to territory in which they were produced.

The Paraíba Valley region, in São Paulo State interior, Brazil, has a high potential for development due to its distinct cultural practices and abundant natural resources, with rice being the main agricultural product grown in this region [10]. Gypsum organizations in artifact area are prominent in the economy of cities dependent on tourism. Aparecida city, for instance, with a little more than 35 thousand inhabitants, has an intense tourism, mainly religious. According to data from portal G1 [11], in the year 2016 a mark of about 12 million tourists was reached, arousing the interest of local artisans in production of sacred images in plaster, which has contributed to the income generation of the municipality population.

Based on the above, the aim of this work is to evaluate the feasibility of rice husks addition to gypsum for manufacture of sacred artifacts in Aparecida city, São Paulo. In this sense, this work of interdisciplinary character is framed in a crossroads of different scientific looks, proposed by Raynault [8], starting from the assumption that approaches a vision of design, materials engineering and social sciences of technology of symmetrical form in order to solve a social demand.

II. MANUFACTURING AND CHARACTERIZATION OF COMPOSITES

Today's social and environmental problems induce a more appropriate consumption form, which makes the quest for sustainable products more and more frequent. Junior et al. [12] comment on the emergence of sustainability problems due to the removal of ecological barriers raised between the unrestrained exponentiality of humanity and other forms of life. The authors raise a series of questions and critics about valorization of environmental resources, capitalization and mercantilization of nature.

According to Sartori et al.[13], sustainability definition is not limited to raising awareness about environmental problems, economic crises and social inequalities, as defined throughout a historical process. For the authors, because it is a complex and continuous concept, different approaches emerge, characterized by a wide variety of themes, subjects in different activity areas, in which it places the need for projects to become increasingly aligned with the Triple Botton Line.

In a constructivist view, the scientific knowledge becomes fundamental for construction of discourses about sustainability, being this a construct formulated by production of knowledge and perception of risks for society [14]. According to the concept of sustainable development defined by Sachs (2004), it is necessary to design a strategy that isbased on three pillars: 1) socially inclusive; 2) ecologically sustainable; and 3) valued from the economic point of view.

According to Krucken [4], sustainability-based innovation requires a high degree of social participation, in order to promote the design of sustainable solutions, it is necessary to develop a systemic vision and integrate competencies from diverse actors.

Aiming to meet these three pillars, researchers have directed their attention to the study methods that use agroindustrial and natural waste to obtain new materials. According to Carvalho [15], efforts to promote longevity of natural materials are only beginning, where works made from natural leftovers can bring a reflection that induces the importance in creative process of an artisanal work, in which it generates very relative aggregate value.

Besides the search for sustainable products, consumers also want these to be captivating or differentiated, and it is up to designer to solve this demand. Advances in the area of materials allow progress in industrial design, and can generate new behaviors, experiences and architectures. According to ASHBY [16], materials play two important roles in design area: (i) provide technical functionality and (ii) create personality for the product.

Materials engineering and product design can also be seen as a functional combination between art and science, where importance of process is placed in search for solutions that generate meaning for people, provide new experiences, and create impact on society. In this sense, materials play an essential role in product design process, since they concretize the ideas, concepts and designs created by designers [17].

According to Kindlein [18], creative specification of materials and production processes is of fundamental importance in order to concretize projects, bringing intrinsic and extrinsic benefits to their production. According to the authors, the engineering approach to making decisions on the aesthetic properties of a product without design concepts becomes a usurpation of functions. Thus, the designer must acquire maturity and knowledge in the areas of materials and manufacturing processes so that he has the authority to decide together with the engineering what adaptations should be suggested for contribution in development of the project. "The choice of materials and manufacturing processes then rises as a characterizing factor of the concept of product, not limited to a problem of engineering alone" [18].

Gypsum composition consists of hemihydrate calcium sulphate and its natural production basically takes place in four stages: 1) gypsum extraction; 2) preparation for calcination; 3) calcination; 4) selection.

Gypsum is a sedimentary rock that basically presents in its composition gypsum, anhydrite and some impurities, usually clay-minerals, calcite, dolomite and organic material. There are several studies that try to improve the mechanical resistance of gypsum hemihydrate, since this one, despite the good appearance offered when used in civil construction, has very low resistance, which limits its application [19]. An excellent alternative to improve gypsum properties is by means of addition of fillers or reinforcement in the material. With the use of small amounts of additives, it is possible to improve both the mechanical and physical properties of the plaster paste in fresh state as well as its physical properties in the hardened state in order to meet the specifications desired for each type of use [20].

Addition of small cellulose fibers in gypsum, from recycled paper, contributes to increase the induction time by approximately 100% [21]. The authors confirmed in their research that the fibers increased the mechanical properties of composite, in which the best result was with 12.5% cellulose, with a 160% increase in its mechanical resistance compared to gypsum without fibers.

Rice husk is a protective coating formed during grain growth, low density and high volume. It is a fibrous material, characterized with small fibers, whose major constituents are cellulose (50%), lignin (30%) and inorganic residues (20%). Inorganic wastes contain, on average, 95 to 98% by weight of silica in hydrated amorphous form, making up 13 to 29% of the total shell [22].

Rice husk (RH) is one of the most abundant agroindustrial residues, with 23% of the bark being husked and 4% being ashes for each ton of rice in the husk [23]. Rice production in Brazil in 2012 was 11.5 million tons, reaching 9th place in ranking of the highest world production, according to data from FOA [24]. If all the rice husk ash produced in Brazil were produced in white (or light gray) and with high reactivity, it could be commercialized at the price of active silica (U$ 600.00/ton), which would generate a billing of US$280.8 million per year [25].

Kumar [26] describes several applications for the use of rice husk ash, including: (i) Steel industry; (ii) Pottery industry; (iii) Silica fountain and (iv) Cement and construction industry. Ashes from rice hulls have been widely used in the manufacture of refractory bricks and in manufacture of low-cost lightweight insulation boards due to their insulation properties.

With the increase in rice husk supply, the problem of the use of rice husks is the lack of stoichiometric capacity of the clinker process to receive more residues [27]. Therefore, in this work, the crushing process of the in-nature shells was used for its use in the composite.

The rice husk used was collected in Alto dos Marins rice processing on a farm in Canas City, São Paulo. Shells were ground in a JF 2-D shredder which contained a 90 μm aperture sieve. Gypsum used in this research was gypsum casting that follows the standard NBR-13207, composed basically of calcium sulfate hemihydrate and with impurities below 2%. Water used for the manufacture of composite plaster/rice husk was potable water supplied by the public network.

Firstly, a granulometric analysis of the crushed rice hulls was carried out according to the norm NBR 7217 - Aggregates: determination of granulometric composition [28]. It was used sieves with the following apertures in mm: 90, 75 and 63. The analysis revealed a percentage of powdery materials with a size less than 0.075 mm equal and 7.9% of the total. This process assisted in the removal of irregular particles and possibly harmful to the strength of composite.

The test specimens for compression tests were manufactured with dimensions in accordance with ASTM C28 [29], and the methodology can be described in three steps: 1) weighing gypsum, water and rice husks; 2) homogenization in a Moema planetary mixer for about 1 minute and 3) the mixture is poured into the mold and allowed to stand until partial drying to allow removal.

After preparation of test specimens, they were submitted to the drying process in a greenhouse at 105º C for 24 hours for later weighing, in order to evaluate mass reduction associated with addition of the rice husk. Finally, the parameters for the compression tests followed the requirements of the ASTM C472M standard [30], using a universal EMIC 3000 machine in an air-conditioned room at 23.8°C and 38% humidity. A comparative analysis was carried out among pure gypsum, the addition of 5% and 10% of ground crushed rice hulls in the mixture. Results of compression tests can be found in Table 1.

Table 1 – Results of compression tests in different test specimens.

Samples of materials	Maximum force (N)	Deformation (mm)	Compression Resistance (Mpa)
Pure Plaster	3700.45	0.60	1.48
Crushed Husk 5%	2636.32	0.65	1.05
Crushed Husk10%	1928.48	0.46	0.75

Source: The author.

Values obtained for pressure in compression of test specimens tested with 5% of addition of rice husks plus pure gypsum, ordered in its sociotechnical application. Already the additions of 10% of crushed rice hulls a greater fall in the resistance of the material, but still applied in a handmade context.

Micrographs were obtained using the Scanning Electron Microscopy (SEM) technique of fractions retained in sieves. The equipment used was the Zeiss EVO MA15 electronic microscope, located in the Structural Characterization Laboratory of the Institute of Mechanical Engineering (IEM) of the Federal University of Itajubá (UNIFEI) and also the Proac X-based anacom Scientific microscope. Samples were fixed with adhesive carbon tape, followed by metallization with gold and the electron detector was used to obtain the images, Figure 1.

Fig. 1 - (a) rice husks after grinding process by UNIFEI MEV (b) gypsum crystals after their hydration by scanning electron microscopy by the bench MEV.

Morphological analysis of rice husk revealed that the hulls had a morphology of the type wrinkled on its surface and smooth with continuous fibers in its interior. Besides its rough surface, morphology of rice husk also presents small capillaries coupled to its surface, which were discarded in the sieving process. Thus, morphological analysis of bark reveals that the surface roughness of rice husk can aid in mechanical adhesion of composite, causing the plaster to be anchored in the shell.

Plaster is a ceramic material and forms a large amount of bubbles and pores depending on its reaction with the amount of water and its mixing time. In a larger microscope, it can be observed that after hydration, the gypsum forms small thin crystals that intertwine with each other. Spaces in which crystals can not interlace are identified as pores. These pores, in turn, are formed by bubbles of water that did not mix to the plaster enough, dried and dissolved, Figure 2.

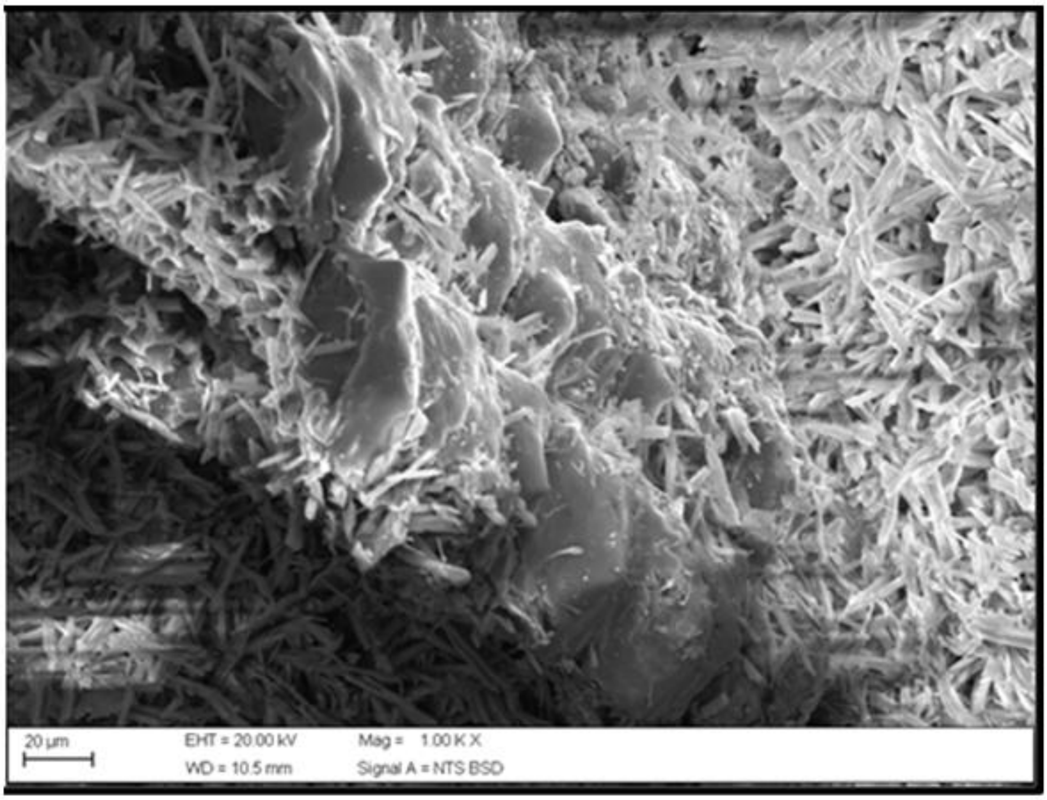

Fig. 2 - Analysis of composite interface between gypsum and crushed rice husks by scanning electron microscopy.

It is observed a good mechanical anchoring between the roughness of rice husk and crystals formed by the plaster, revealing a good interface amongst the different materials that conform the composite.

III. SOCIOTECHNICAL ANALYSIS

Bijker [3] states that not only engineers or researchers, but all relevant social programs contribute to the construction of a technology. "Technique is a social construct, just as the social is technically constructed". In the author's view, the sociotechnician is not only treated as a combination of technical and social factors, in this sense, the social is not defined by technology as technology is not determined by society - both emerge from both sides of a sociotechnical construction of facts, artifacts and relevant social groups. In this sense, technological determinism inhibits interventions and the development of a democratization of technology control.

The concept of Social Technology (ST) is a recent development [31] and has contributed to poverty reduction, job generation and income, promoting local and sustainable development, among others. According to the authors, these technologies would not be determined by scientific and technical criteria, this technology would be socially constructed, by means of a surplus of feasible solutions to a given problem, where social actors would be responsible for the final decision influencing all the way to produce this technology. According to Dagnino (2009), it is part of the result of an action taken by a collective of producers about a work process. This action, based on a specific socioeconomic context and a social agreement, allows a modification in the product generated, which can be appropriated according to the collective decision [32].

ST, from Novaes[33], brings together characteristics such as:
• Adapt to small producers and low power consumerseconomic;
• Not to promote the kind of capitalist control of segmenting, hierarchizing and dominate the workers;
• Be oriented towards satisfaction of human needs (production of use values);
• Encourage the potential and creativity of the direct producer and users;
• Be able to economically make feasible enterprises such as popular cooperatives, agrarian reform settlements, family agriculture and small businesses.

According to Dagnino [31], a sociotechnical approach (STA) can be understood as a process that seeks to promote an adequate scientific and technological knowledge (whether already incorporated in equipment, inputs and forms of production organization, or still in the intangible and even tacit form) not only to the requirements and purposes of a technical-economic nature, as has hitherto been the usual, but also to the set of socio-economic and environmental aspects that constitute the relation among science, technology and society (STC).

The STA proposal would be a direction for deconstruction and subsequent reconstruction (or reprojection) of more than adequate technological artifacts, indispensable for the growth and radicalization of associative movement and self-management (cooperatives arising from settlements, recovered, popular cooperatives, etc.) [33].

In this sense, technical visits were made to the JB company, a small family company that manufactures handicrafts in plaster, in order to understand the technical and social procedures for the development of artifacts in this small company. This work was documented by means of audio recordings, videos and photos in loco, a field notebook for general annotations, unstructured questionnaires and the approximation of the empirical mode of production to the scientific mode.

To validate scientifically and to approximate the results of the laboratory to the handmade methods, a culinary scale with capacity of 1 kg was used to make the measurements and to define some approximate patterns to reproduce the experiments in laboratory. The measurements were standardized from the methods that are used by artisans, which are hands and a pot of margarine.

In order to evaluate the economic viability of artifact produced, especially the image of Our Lady of Aparecida, it has been analyzed the average amounts of gypsum used to make different types and sizes of artifact. Then formulations were analyzed with addition of rice husks and reduction of resources used for their development. Finally, the impact of gypsum reduction on the gross total income of the company was evaluated.

In general, artisans use an average of 2 kg of plaster to develop 4 saints that are sold at a price of R$ 3,50 per unit (approximately US$ 1.00). The use of plaster weekly by the company is 10 bags of 40 kg each, totaling 400 kg of plaster per week. The total rent in the relation between use of plaster and the commercialized images is on average R$ 2.800,00 reais per week (approximately US$ 760.00). In order to evaluate the possible reductions in gypsum consumption and, therefore, the savings generated in the process, a comparison was made between the traditional process used by the artisans (pure gypsum) and the alternative, using the material proposed in the present study (added plaster of rice husks), Figure 3.

Fig. 3 - Mixture of composite (a) and artifacts developed with gypsum and in-nature rice husks (b) at JB company.

It was possible to make an approximate measurement and to calculate the yield when making the artifacts, therefore for 4 molds of saints of 25 cm of height, it was used 1.5 pots of water and 8,5 hands of plaster. For 5 molds of saints of 20 cm of height, 1 pot of water, 6.5 hands of plaster was used - an average total mass of 2,500 g. In this case, each final image was weighed at 500 g totaling and verifying the specified values.

After checking the values, the first tests were carried out on mixtures of rice hulls and gypsum. In the first mixture, the values adopted were maintained and rice husks were added. In this case, they were 1.5 pots of water, 9 hands of plaster and 3 hands of rice husks for 4 molds of saints of 25 cm. The result was satisfactory and it can be observed that they could increase the results.

In this way, a second mixture was made, reducing the gypsum and adding peels, being these 1.5 pots of water (900 g), 4 hands of gypsum (1000 g), 6 hands of in nature husks of rice (100 g) for 5 molds of 20 cm. It was observed that more mixing remained than usual, however, drying of the artifact was faster and the average weight of a saint was reduced by 50 g. The workers were surprised by the yield of the shells to make the saints and, according to them, the image was lighter. This result is relevant because it could solve the difficulty of producing larger saints that are heavier and more difficult to handle. Moreover, in none of the molds did the saint's crown collapse, as it is often the case in some molds of pure plaster - perhaps because of the fiber's ability to hold plaster.

The total reduction in gypsum consumption and, consequently, total cost was estimated at 39.39%. Each piece had its total weight of gypsum reduced from 330 g to 300 g, which may represent an advantage for logistic reasons. Thus, monthly production of 4848 units, consumption of plaster leaves from 1599.48 kg to 969.60 kg, which represents a reduction in costs from R$775,68 to R$436,32 (approximately US$210.00 to US$120.00).

TRADITIONAL MATERIAL 1 piece (20 cm high image) consumes:
- 330 g of plaster;
- costs US$0.04 per piece.

PROPOSED MATERIAL (RICE HUSK) 1 piece (20 cm high image) consumes:
- 200 g of gypsum;
- 100 g of rice hulls;
- at the cost of US$ 0.02 (US$ 0.02 of plaster + US$ 0.00 of rice hulls).

IV. CONCLUSION

The study of materials in this research served as a contribution to identify the feasibility of application of this composite and allowed to evaluate its applicability in an artisan context based on its mechanical properties. It is concluded that the collection and crushing of the rice hull was an effective procedure and can be used in this context. The sieving sessions aided in characterization of material and the removal of irregular particles and harmful to the development of composite. Scanning electron microscopy and dispersive energy spectroscopy helped to characterize and analyze the interface between the matrix (gypsum) and reinforcement (rice husks), revealing a good adhesion due to the mechanical anchoring of this mixture. Finally, the compression tests showed that it is possible to use the crushed rice hulls to make the composite, without significant loss of resistance to an artisan application.

Socio-technical research revealed unidentifiable results in the materials lab. The sociotechnical analysis showed the different stages used in the process of making handicrafts, from the reception of the raw material to its finishing, besides addressing the interest of the craftsmen in using this composite.

From the results obtained in this work, it is concluded that it is possible to use crushed rice husks as an additive to gypsum in a handmade context, generating savings of up to 10% in the use of gypsum. The addition of crushed rice hulls considerably affects the mechanical properties of the gypsum mixture, however, it is known that, in a handmade context, these properties are not relevant - what is relevant is the malleability and the conformity of the mixture in order not to affect the final product.

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