PONENCIA 41 DEVELOPMENT OF CERAMIC COATING WITH THERMAL COMFORT IN CONTACT

Luana Pacheco de Abreu
Ricardo A. Á. Silva
Fabiano Raupp Pereira
Orestes Estevam Alarcon
Humberto R. Roman
João A. Labrincha

Department of Mechanical Engineering - Civil Engineering and PGMAT – GDA, Universidade Federal de Santa Catarina, Florianopolis, Brazil
Departament of Engineering Ceramics and Glass, CICECO, University of Aveiro, Portugal

ABSTRACT

The sensation of thermal comfort of a individual to the built environment around him is related to the local environmental conditions and the properties of materials used. The adequacy of the microstructure and the consequent increase in surface roughness of tiles may lower its thermal conductivity. This work presents studies of the development of non-enameled tiles for indoor environments designed from the reuse of industrial waste. Reducing the density of ceramic bodies can be obtained by the inclusion of pores resulting from raw materials and processing conditions employed. Different compositions were prepared with residues of the cutting and polishing of tiles bunched by partial substitution on a mass. Respective matrices of comparison, without the incorporation of waste, were prepared in equal conditions of processing. Assessments of thermal comfort of tiles developed are described by their thermal and mechanical properties. The results show that the incorporation of the residue results in the formation of surfaces with higher roughness and also as the porosity and roughness increase, there is a significant improvement in comfort by contact.

Keywords: ceramic coatings, thermal comfort, industrial waste, development of products.

INTRODUCTION

In the last years, the increasing awareness for environmental issues has imposed tremendous pressure in order to minimize the negative impact of human activity on nature. Two objectives have deserved special attention: (i) reduction of energy consumption and (ii) reduction of waste or by-products, by the improvement of the production processes and / or the introduction of new technologies.

The absolute or relative reduction of the quantity of used materials and/or waste generated by the production process is associated with the globally premises of sustainable development. Within this context, the participation of design favors an improvement in product functionality, bringing new benefits to users, where through the consistent use of sustainable materials, guarantees innovation, promotion of material recovery, restoring their products in a new productive-economic cycle.

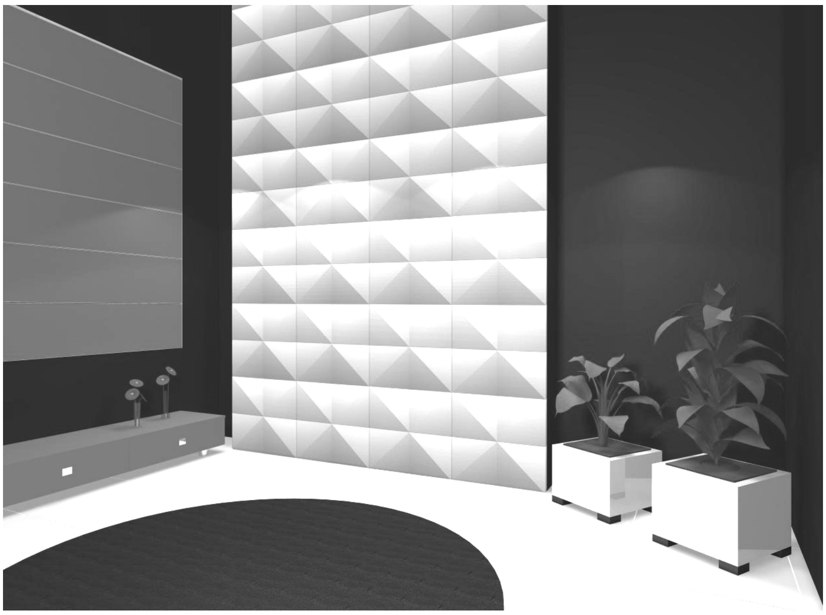

Figure 1 – Virtual Environment 01: Proposal coating with the use of waste.

Modern economies consume in a crescent way large amounts of raw materials in the production of goods and services. The counting of flows of natural resources, including processes of extraction, production, manufacturing, recycling and final disposal, reveals also a growing concern for the fact that the environment is the ultimate destination of all waste generated.

When discussing the problem of waste generation, we must consider several factors: the reduction/elimination of the waste source; the direct reuse; non-destructive recycling and waste management through measures “end-of-line". The first three factors are the only ones that are sustainable in a long term. The fourth factor is needed because of the current existence of waste without a short term solution and should only be applied in order to minimize the effects of inefficiency in waste management.

A wide variety of waste can replace conventional materials, both for economic reasons as environmental and social reasons. These facts lead the industry to develop alternative technologies, at the processing level and even at the consumption of raw materials, in order to save resources for future generations and preserve the environment.

The natural mineral resources are non-renewable goods that require an adequate and controlled extraction to satisfy the needs of consumption and environmental conditions favorable to industrial development. In this scenario, there are crescents quantities of waste produced by the manufacturing industry, particularly by the existence of various forms of processing, making the development of alternative ways of use in a big technical, scientific, economic and environmental challenge.

Finding the appropriate treatment and reuse of waste as alternative raw material, the ceramic industry has shown interest in a wider application of design techniques in developing of new products. Searching for the best form, functionality and esthetics, of coatings to be manufactured, making them viable through the rationalization of production, the developed technical peculiarities and the potential marketing of the innovator product.

The commercial and economical viability of production of ceramic tiles using industrial wastes as raw material should be related to the production of products that add value through technical and innovating aspects.

Figure 2 – Virtual Environment 02: Proposal coating with the use of waste.

The theory of thermal comfort is based on the level of heat transfer of materials and property that expresses the rate of heat transfer on the surface of solids is called effusivity. This property shows the changes in the temperature of a body with the variation of atmosphere temperature. The presence of porosity in ceramic materials implies a low thermal effusivity that can be directly correlated with low conductivity, density and a consequent reduction in mechanical strength.

The residues from the process of polishing and grinding are basically made of the components of the support and glazed ceramic layer and the abrasive material is removed in the process. This material received a classification prior to the treatment and final disposal, as waste that doesn't show health hazard. The reuse of these materials allow the obtaining of materials that present high porosity, resulting in a low density and excellent thermal and acoustic insulation. This feature is due to the decomposition of the abrasive agent (silicon carbide, SiC), coming from the polishing sandpaper, with oxygen during thermal processing of the new developed product. The SiC decomposition generates gas, causing volume expansion of the piece.

Based on these results, it is proposed through the intervention of the design, the development of new concepts for ceramic tiles, where, from the use of alternative materials, suggests a new type of interaction between the User and the product, showing a greater importance for the technical surface characteristics, involving new paging arrangements through the composition made of different pieces and elements, emphasizing the contrast and the three-dimensionality of the environment.

The floor coverings must show differentiated textures, giving value to the surface, favoring the composition of spaces so that the visual effect sharpen the curiosity and encourage the contact. Parts with vertical settlement should be used as a resource for the decomposition of the form in order to take advantage of the generated effects of light and shadows. Thus, with the simple interactions of these principles for a practical reality of production, it creates an opportunity for the development of innovative products.

THERMAL COMFORT (MATERIALS AND METHODS)

Thermal comfort was evaluated correlating the contact temperature of the human body with the coating sample. The lower effusivity of the ceramic coating, the greater integration between the contact and body temperature, resulting in a greater comfort. The thermal effusivity is directly related to the thermal conductivity and density of the material. Materials with low conductivities and densities can be obtained by the inclusion of pores. It can be consider that the thermal conductivity of ceramic materials decreases with increasing the porosity.

For the conductivity and flexural strength test were prepared ceramic samples, with variations in the quantities of waste, which after burning process showed different degrees of porosity and surface roughness. Industrial experiments were made with sample composition of 40, 50 and 60% of waste polishing and grinding, adding to an atomized mass of semi-stoneware (percentages established in preliminary tests, small samples, 100x30mm). These compositions were evaluated at temperatures of 1100, 1120, 1140 and 1150 °C. The characterization of prepared pieces followed the industrial parameters: firing cycle of the industrial furnace of 45 minutes with four ramps of about 5 minutes in the burning zone.

RESULTS AND DISCUSSION

The effect of heating temperature on the sintering process and the interaction effect between the two raw materials used in this work is visually evidenced, observing the appearance of the samples surfaces with the variation of the firing temperature and the percentage of waste. Figure 3 presents samples containing 20 and 50% of waste incorporated into the atomized mass and sintered at 1120 °C and also the obtained bodies via double pressing, where in the support was used a mono-porosity mass and on the cover was used mono-fired mass with 40% of waste. With this process, the development of a ceramic coating of rough surface was obtained through a permanent basis (mass with minimal size change all over the temperature increase), which served only of support to avoid distortion coming from the expansion of gases included within the material due to oxidation of silicon carbide. However, this permanent basis must have agreement with the coverage (since both are permanently intertwined), where the basis retracts and then expands to exceed the support area without compromising the planarity, but guaranteeing the desired quantity and morphology of pores, which also difficult the production of this product in an industrial scale.

It can verify that the incorporation of the residue results in the formation of surfaces with greater roughness, as well as enhance the effect of expansion in higher temperatures. The presence of roughness favors in many ways the characteristics of thermal comfort.

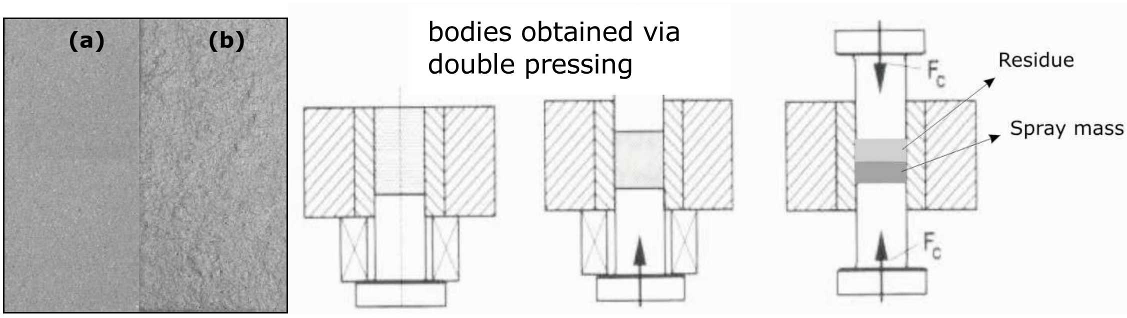

Figure 3 - ceramic substrates consisting of atomized mass with incorporation of 20 (a) and 50% (b) of waste at a temperature of 1120 °C and also bodies obtained via double pressing.

In Table 1, it can notice that the apparent density decreases with the increasing percentage of waste. This observation is due to the increased porosity of the bodies (see details in Figure 4).

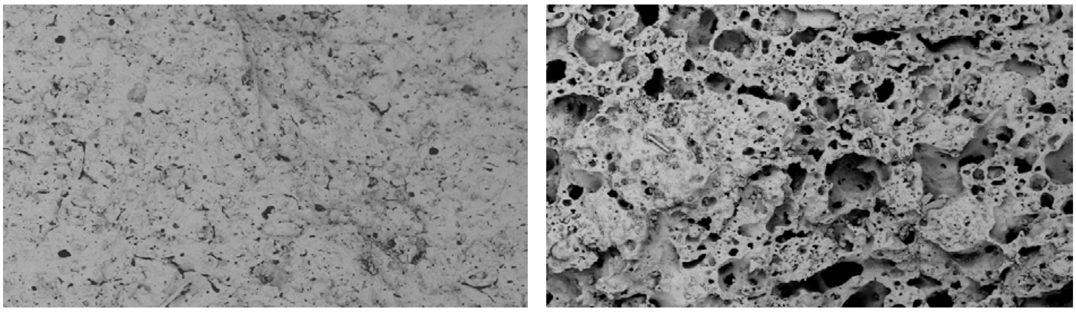

Figure 4. Microstructures (50x increase) of the fracture surface of the body spray without incorporation of residue (left) and mass with the addition of 40% residual (right).

For firing temperatures of 1100, 1120 and 1170 °C, the ceramic bodies presented module of flexural strength of 25, 27 and 39 MPa, respectively (Table 1). In addition, with the generation of porosity and the varying of the firing temperature, the samples with 20% waste firing at temperatures higher than 1100 °C presented module of flexural strength of 26 MPa. For 50% of waste, the flexural strength showed values of 20 MPa.

Table 1 - Results obtained for the mass spray (ref.) and compositions with the incorporation of waste.

	Linear shrinkage (%)	Loss on Ignition (%)	flexural strength (MPa)	T(°C)
Mass atomized	5,53	5,77	25	1100
	7,02	6,21	27	1120
	7,48	5,74	39	1170
	Linear shrinkage (%)	**Loss on Ignition (%)**	**flexural strength (MPa)**	**T(°C)**
Residue 50%	6,53	4,41	20	1100
	-0,08	4,78	7	1120
	-	5,11	6	1140
	Linear shrinkage (%)	**Loss on Ignition (%)**	**flexural strength (MPa)**	**T(°C)**
Residue 40%	6,98	4,53	23	1100
	4,63	5,59	15	1120
	Linear shrinkage (%)	**Loss on Ignition (%)**	**flexural strength (MPa)**	**T(°C)**
Residue 30%	6,33	5,40	21	1100
	5,59	5,58	19	1120
	Linear shrinkage (%)	**Loss on Ignition (%)**	**flexural strength (MPa)**	**T(°C)**
Residue 20%	6,09	5,27	26	1100
	5,59	6,18	22	1120
	-	5,72	17	1140

In the characterization of thermal comfort will be analyzed the superficial temperature of a commercial white floor, that serves as comparative reference to the ceramic tiles manufactured with the incorporation of residues (20, 30, 40 and 50%). The measure values of thermal effusivity will be evaluated as conductivity and density, as well as specific heat. The contact temperature skin-coating ceramic should be determined considering the skin temperature in contact with the floors exposed to the sunny atmosphere and the superficial temperature presented by the coating.

Taking into account the results obtained so far, surface characteristics and values of flexural strength of the samples, it can see that the application of the material for wall coverings is a good alternative.

The use of alternative materials provides a new type of interaction between the user and the coating, combining the characteristics of the ceramic body with the new paging arrangements through the appreciation of the surface by the differentiation of textures and visuals recourses taken from the effects of light and shadows.

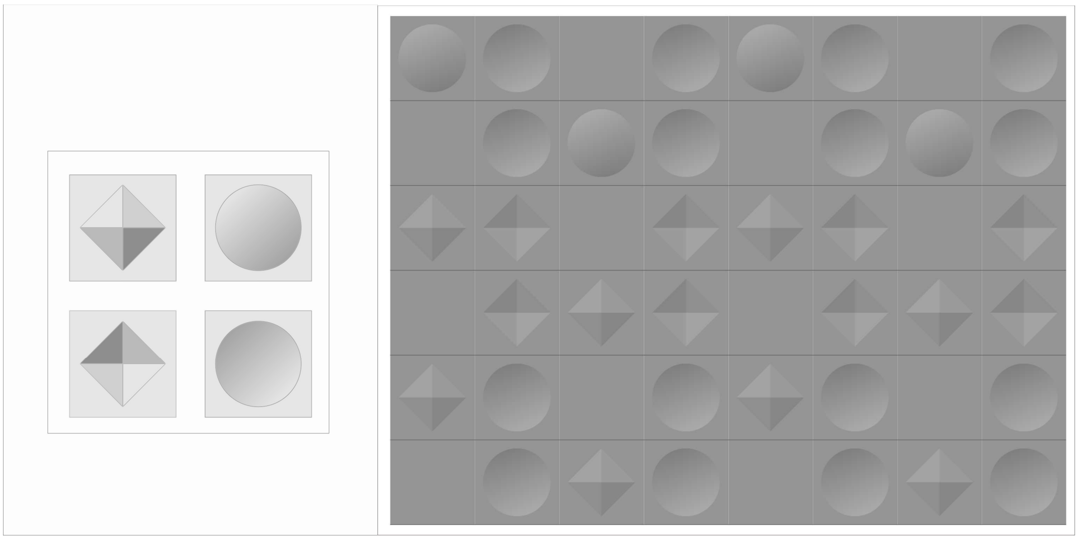

Figure 5 – Drawings of parts with different suggestions for paging.

The results of water absorption, bulk density and bending strength of the fired ceramic bodies formulated with 40, 50 and 60% of waste are presented in tables 2 to 4.

Table 2 - Physical characterization of the composition RES40, processed in industrial conditions.

Essays | Samples	1100 ºC	1120 ºC	1140 ºC	1150 ºC
Water Absorption (%)	16,4	10,2	6,1	5,3
Bulk density (g/cm³)	1,8	2,0	2,0	1,6
flexural strength (MPa)	28,0	38,7	50,4	31,1

Table 3 - Physical characterization of the composition RES50, processed in industrial conditions.

Essays | Samples	1100 ºC	1120 ºC	1140 ºC	1150 ºC
Water Absorption (%)	14,1	7,6	7,4	18,5
Bulk density (g/cm³)	1,8	2,0	1,7	1,2
flexural strength (MPa)	34,7	41,5	36,2	21,8

Table 4 - Physical characterization of the composition RES60, processed in industrial conditions.

Essays | Samples	1100 ºC	1120 ºC	1140 ºC	1150 ºC
Water Absorption (%)	9,9	9,2	20,1	39,3
Bulk density (g/cm³)	2,0	1,8	1,3	0,9
flexural strength (MPa)	44,8	38,2	22,0	11,8

It is observed that the composition RES40 (40% of waste) presents a significant mechanical strength at 1140 °C (50.4 MPa). With the increase in temperature to 1150°C this composition shows a decrease in resistance and water absorption, fitting into the BIIa group (Abs <6%). This behavior, as well as the ratio mass/volume (decrease in density, 1.6 g/cm3 at 1150 °C) can be explained by the closure of the superficial pores of the ceramic body. With the increase of the waste percentage to 50% an interesting relationship between absorption and resistance was obtained at 1140 °C (respectively, 7.4% and 36.2 MPa). Even with a high percentage of waste (60%), the composition RES60 stands out in the temperature of 1120 °C with an absorption of less than 10% and a resistance of 38.2 MPa.

CONSIDERATIONS

Materials with low conductivities and densities can be obtained by the inclusion of pores maintaining the properties and characteristics required for the finished products. Properly combining the raw materials and processing techniques, it is possible to obtain porous ceramic with satisfactory values of mechanical strength, chemical resistance and high refractoriness and structural uniformity of thermal properties favorable to its application.

The introduction of porosity in ceramic tiles implies in a low thermal effusivity that is directly correlated with conductivity and density. The less effusivity, the more comfortable tiled floor. This feature can also give good acoustic properties.

The thermal sensation of cold or heat depends on the local environmental conditions and the material properties including its microstructure and surface roughness. The introduction of porosity and rough surface (contact resistance) to ceramic promotes thermal comfort (walk-coating).

The studied compositions and the ceramic tiles obtained can be classified as semi-stoneware product, BIIa class or semi-porous, BIIb class. The firing temperature used in experimental development demonstrates that there may be a significant reduction of energy consumption in the production of this new product in relation to the temperature usually used (about 1170 °C).

The development of coating with surface formatting ally to material characteristics, such as thermal comfort, lightness, porosity, will create a product line where sophistication is also synonymous of simplicity, essential nature, comfort and integration. Specific searches are necessary to deepen the knowledge about the acoustic properties and light presented in this material.

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