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PRODUCTION OF COMPOSITES USING RECYCLED COTTON, POLYESTER SCRAPS AND RESIN: AN ALTERNATIVE FOR ECO-DESIGN

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Abstract

The present manuscript discusses possibilities of art and fashion eco-design added to recycled textiles industry focusing on industrial production sustainability. Starting with a review of textile and fashion waste generation in Brazil and the organizations willing to provide solutions. The feasibility of producing composites employing epoxy resin and cotton and polyester recycled fibers was studied and it´s physical strength characteristics of these composites. The results are products of great visual appeal with possible applications in the hand-crafts, fashion and

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decoration sectors. In addition, the aggregation of creative art with this kind of material could be a real alternative to minimize textile wastes and consequently environmental impacts.

Keywords: textile, recycling, cotton, polyester, fashion, decor, composite, sustainability, handicraft.

1. Introduction

In the textile sector, cotton is among the most important textile fibers in Brazil, representing 70% of industrialized natural fibers (IDEC, 2011). The fashion industry employs 2% of the working population, growing over 5% per year since 2002 in industrial production and representing 4.4% of GDP - "Gross Domestic Product" (APEX-BRASIL, 2010). São Paulo Fashion Week, the greatest fashion event in Latin America, invests 5 million dollars in each edition, with the participation of 64 designers and an estimated public of 1 million people (SPFW, 2012). According to ABIT (Brazilian Association of Textile and Apparel Industry), if GDP would growth between 4% and 5%, the textile consumption in Brazil, from the current 12.8 kg per capita/year, were nearly 20 kg per capita/year in 2014 (ABIT, 2011). In this way, it is necessary to think about the destination of the garments after their disposal, as well as the fabric scraps in clothing process production. It is estimated that 15 tons of textile trimmings per day were collected in Bom Retiro and 10 tones in Brás (LOGA, 2011). These regions are large popular fashion centers located in the city center of São Paulo (Brazil's largest city and fourth largest city in the world). The alternative for textile waste disposal could be recycling, especially of cotton and polyester fiber articles, the most consumed in the country. In order to discuss the sustainability and new recycling products in the textile and fashion industry, it should think about the materials, as the starting point for product development. This plays a significant role when aesthetics aspects are considered together to the creation of new products (MUHAMMAD; MUHAMMAD, 2010). On the

other hand, there is a growing interest in the use of natural fibers reinforcing the thermoset and thermoplastic material composites, especially the biodegradable ones. The employ of composites as alternative material is very attractive and could minimize the problem of the accumulation of textile residues (LINTAO, 2012). In addition, the employ of plastics in fashion products or consumer goods is a large trend in design. Known designers such as Karim Rashid and Zaha Hadid, world-renowned Iranian architect, employ plastic materials in their creations. Among the Brazilian designers and artists, Fernando and Humberto Campana (Campana Brothers), R. Sobral, Silvia Blumberg and Romero Britto must be mentioned. It is also worth of mention Renato Imbroisi, a famous Brazilian designer who develops textile art and creation together poor Brazilian communities (CASA BRASIL, 2012). The development of handmade articles employing composite materials such as resins and fibers or textile trimmings (scraps) is quite feasible for use in the fashion and decor sectors. The cooperatives or communities linked to the textile and fashion industry could promote the collection of textile waste, its separation and reuse. They could also employ simple techniques in order to enhance creativity and dignity of human work, besides generating incomes to them.

2. A brief review of textile and fashion waste generation in Brazil

2.1. Economic Scene

Brazil is one of the largest textile producers, ranking 7th in the production of yarns and woven fabrics and 3rd in the production of knitted fabrics (FINKLER, 2005).

According data from 2005 Brazil is the 4th largest textile producer world - under only to Asian countries like China, India and Indonesia (ECCOTEXTIL, 2012). Textile sector represents an amount equivalent to 4.4% of Brazilian GDP and employs about 2% of the active population, approximately 1.7 million direct

workers according a survey conducted in 2010 (CLOSET ON LINE, 2012).

Moreover, it is the 5th largest cotton producer, which is made 60% of clothing in the country. In 2010 the share of cotton fiber consumption was 57%. Worldwide, the rate was 35.7% (ABIT, 2012).

Currently, Brazilian fashion is in the sights of large consumer of fashion and textiles in general. However against the trend of foreign brands venturing into Brazilian territory is the opposite way, that is, Brazilian brands expanding their business abroad. An example is the brand of designer Alexandre Herchcovitch, which has opened stores outside the country such as Japan and New York. This illustrates the huge potential of Brazilian brands, their positioning in the international market of fashion and talent to create and the business of its designers.

However, despite of individual initiatives of Brazilian designers and enterprisers, it is worth of mention the necessity of more intensive Brazilian governmental recognition and support to textile and fashion sectors parallel with respect for natural resources and environment.

2.2. Fast Fashion and Consumer Behavior

The differential symbolic object is associated to competitiveness. Through consumption of these objects, the satisfaction of desires is not reached, going from one to another new object. Added to this production, disposal and sale strategy, there is the planned obsolescence (FINKIELSZTEJN, 2006), in which the life of a product is planned: the object is reset at any given time, resulting in new consumption, which replaces the previous artifact or gadget, then considered obsolete, although the technical conditions for the product to "survive" longer.

Fast Fashion's idea is to reproduce the style of garments or accessories

presented on the major world fashion events and transport them to the shelves so extremely fast. In this way, logistics of great multinational brands could bring to the stores an assortment product varies and which were seen in major fashion weeks in less than one month.

It is important to emphasize that many changes occur in the fashion, presenting an ephemeral quality, which stimulates increased production of textiles. This can affect the environment in several ways, such as depletion of natural resources (for example the use of land for cotton cultivation until its exhaustion or degradation of rivers by dyeing effluent discharges). Furthermore, there is no specific policy established in Brazil for disposal of textiles, although it has been recently approved the National Politic on Solid Waste (Law 12.305 of 02/08/2010) (BRASIL, 2011).

Therefore, although of the huge potential fashion market in Brazil, stimulating the economy in many ways, especially concerning Fast Fashion it is necessary to analyze how minimize environmental impacts of the respective agricultural and industrial processes and discard of textile articles after their consumption and to propose suitable solutions to these questions.

2.3. The District of "Bom Retiro" in Sao Paulo city – Brazil

In 19th century, along with the neighborhoods of Barra Funda, Mooca and Brás, Bom Retiro was a region workers and poor people, focusing, even today, tenements and differing levels of income among its residents.

In the mid-1960s, the neighborhood began to be known for concentrating trades in clothing and textiles, mainly small companies. The Jew, Bolivian and especially the Korean communities are the main in this region. Immigration, multiculturalism, the textile industry and commerce are strong elements in the spatial dynamics and landscape of the site (MARUM; GOMES, 2005).

Nowadays, Bom Retiro is one of the biggest commercial hubs of fashion in São Paulo city, considering retail and wholesale, selling womenswear, menswear and children clothing. This region is also adjacent to trade of jewelry, sewing, knitting and woven fabrics, and machinery for manufacturing, which typically cater to small local companies and clothing manufacturers. In 2000 the district of Bom Retiro had 3.64% of industrial jobs in São Paulo city (EMPLASA, 2012).

The main buyers are merchants who have business in shopping malls, galleries, boutiques, etc in many regions of Brazil. Wholesale stores alongside other ones with popular prices attract a wide range and number of customers.

Currently, Korean and Jew communities have among them the major number of owners of the garment district. Bolivian people is known for their hard work in confection sector and sometimes because questions about illegal workers, slave or undignified conditions of labor.

The fabric scraps of hundreds of producers of this region are disposed in garbage bags for gathering by the municipality. However, before this collection, many poor people, knows as garbage collectors, disrupt the bags for some kind of material with commercial value, leaving the scraps scattered **(Figure 1A** and **1B)** (DIÁRIO DE SP, 2012).

The neighborhood is a major producer of textile waste, approximately 16 tons per day, and usually the scrapes and solid residues end up in landfills. Even with a large number of cooperatives working in the sector, the waste can not be totally eliminated for reasons of logistics and transportation and poor infrastructure of the cooperatives themselves.

A

B

Figure 1. Textile waste spread in the neighborhood of Bom Retiro (DIÁRIO DE SP, 2012).

3. Composites

Composite materials are those having at least two components or two stages, with physical and chemical properties distinctly different in composition. Separately, the constituents of the composite retains their characteristics, but when combined form a compound having properties impossible to obtain with only one of them. Some examples are metals and polymers, metals and ceramics, polymers, ceramics or polymers and textile fibers (ORÉFICE, 2011).

In the present study, the feasibility of producing composites employing epoxy resin and cotton and polyester recycled fibers was analyzed about their physical strength characteristics and possible applications in handicraft, fashion and decor sectors.

4. Experimental

4.1. Composites of epoxy resin and tests on the tester machine

For material development, BVR Flexible Epoxy Resin 222 (Bonivitta, Brazil), bi-component, cold drying, and hardener BVE 0101 (Bonivitta, Brazil) were employed. BVR 222 is flexible and pliable crystalline, of which 60 mL was used together with the hardener 30 mL BVE 0101.

Fabrics composed by 100% polyester of various colors were employed. Subsequently, part of the samples was shredded by hand and part was cut into pieces with scissors.

In order to obtain the desired thickness of approximately 2 mm, 7 grams of polyester in each beaker were employed, which were weighed on analytical balance (model XB220A, Switzerland) **(Figures 2E** and **2F)**.

The volume was measured with water to see how much resin should be used in order to obtain the desired thickness **(Figure 2G)**. The ideal for the production volume was 90 mL for each composite in an aluminum form of brand Roldan (Brazil) capable of supporting 650 mL. The form used is 21cm long, 9 cm wide and 4 cm.

The resin and hardener were placed in a beaker and mixed with a glass rod; portion of the mixture was placed back in the bottom, and above, the fibers were added, subsequently the remaining resin was poured into the form **(Figure 2H)**.

After hardening of the composite, they were sliced. Each sample had 16 cm height (3 cm in each extremity, called "heads" for jaws pression and 10 cm in center for effective test) and approximately 2 mm of thickness. The tensile testing machine used was Instron, model 5569 (Norwood, USA) **(Figure 3D)**. The dimensions of jaws were 38 x 50 mm and the rate 50 mm/min. In each test were determined tenacity (measured intrinsic mechanical strength of the material) and the extension at break and Young's modulus (which expresses the stiffness and strength of material) (KASWELL, 1963; SAVILLE, 2007).

For each test four samples of composites reinforced with textile trimmings and four samples of composites reinforced with textile yarns were used.

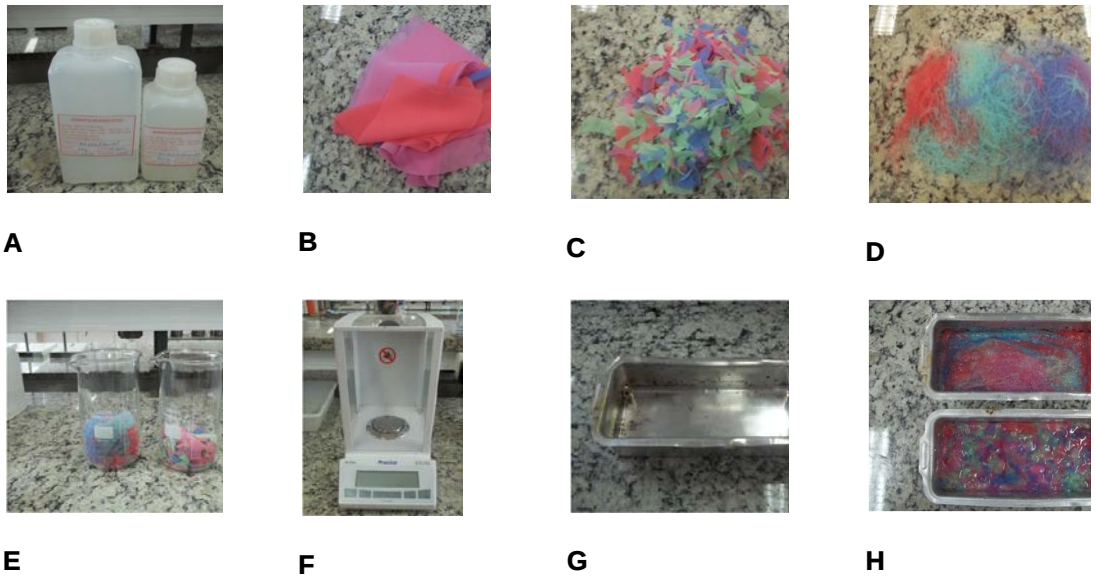
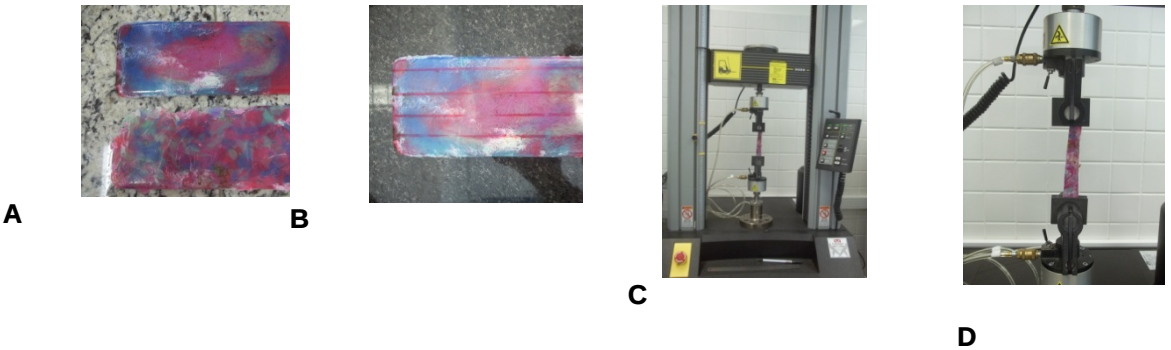


Figure 2. Methodology development of a composite textile: (a) resin hardener BVR 222 BVE 0101, both brand Bonivitta (Brazil), (b) flaps 100% polyester fabric, (c) flaps cut in shears, (d) manually shredded fabric, (e) samples of shreds and shredded separate beakers, (f) analytical balance of Precisa brand (XB model 220 A, Switzerland), (g) aluminum form of Roldan brand (Brazil) used as standard of 4 cm height, 21 cm in length and 9 cm in depth, (h) final result of mixing between the fibers and epoxy resin (Photos by first author, 02/20/2012)



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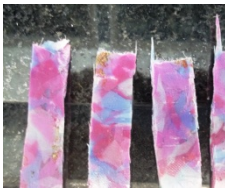

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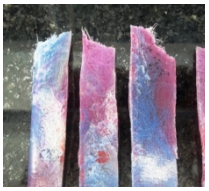

H

Figure 3. Method for tensile testing: (a) composites made from scraps of fabrics, threads and epoxy resin, (b) composite boards were measured and sliced, and 2 cm wide and approximately 2mm of thickness, (c) the tester machine Instron, (model 5569, Norwood, United States), (d) composite sample being pulled on the tester machine, (e) disruption of the composite sample after a specified tensile strength, (f) sample composite after its rupture, (g) samples composites made of wire and epoxy resin, (h) samples of composites made of epoxy resin and flaps (Photos by first author, 02/20/2012)

Results were expressed as mean and standard deviation, as follows:

i) Tenacity of 0.4 ± 0.2 MPa, modulus of 0.7 ± 0.2 MPa and extension of 22 ± 5 mm for composites reinforced with scraps;

ii) Tenacity of 0.7 ± 0.2 MPa, modulus of 1.0 ± 0.2 MPa and extension of 24 ± 5 mm for composites reinforced with yarns.

In order to perform a comparison, the **Table 1** shows approximate values of tenacity and Young's modulus for some materials:

Table 1. Approximate values of tenacity (σp) and the Young's modulus (E) for some materials (RESMAT, 2012):

Material	Acrylic	Average Steel	**Rubber**	Copper	Duralumium
σp (MPa)	14	310	**2**	28	124
E (MPa)	3,400	206,000	**1**	118,000	72,000

From the comparison of the values obtained in this study for the produced composites and the other ones shown in **Table 1**, it is evident that the produced composites have low tenacity and modulus values, which are similar to rubber. This is consistent to the fact that the employed epoxy resin generates flexible and thermoset material after its polymerization. In this way, knowing the properties of this material, it is possible to think about better about eco-design, aesthetical and functionality.

4.2. Composites of epoxy resin and cotton scraps

For material development, BVR Flexible Epoxy Resin 222 (Bonivitta, Brazil), bi-component, cold drying, and hardener BVE 0101 (Bonivitta, Brazil) in the ratio 2:1 were employed.

Figure 4. Methodology development of textile composites (Photos by first author, 02/20/2012)

Employing a scissors, a basic 100% cotton shirt (Hering, Brazil) **(Figure 4A)** was completely shredded and perforated. The result was a pile of waste textiles of various sizes **(Figure 4B)**. After testing the relation to the container and his volume, employing scraps of dry fabric, it was found that 20 grams were ideal for the volume of the aluminum container chosen as standard for this experiment (4x21x9 cm, total volume 650 mL). The cotton trimmings or scraps **(Figure 4C)** were weighed (balance XB 220A, Precisa, Switzerland), mixed in 150 mL flexible epoxy resin with 75 mL of hardener **(Figure 4D)**. The fabric scrapes were placed in shape and homogeneously embedded with a mixture of resin and hardener. After 12 hours, the hardened resin and the composites produced were removed from the containers **(Figures 4E** and **4F)**

The creation eco-design was inspired in ancient mosaics and the modern employ of recycling textiles in fashion and decor **(Figure 4F)**.

5. Results and Discussion

As a suggestion for the destination of the waste textiles, the transformation of this raw material in composites would be a viable solution. In addition, it would bring major economic benefits to the environment as well as aesthetic value aggregated to the final product. Through laboratory tests, there was evidenced the potential of waste textiles constitute reinforcement, together with thermorigid resins as matrix in composites. These materials could generate new products and possibilities in fashion and design sectors.

The material sourced from recycled cotton and flexible epoxy resin proved to be very promising as textile composite as well as in decor and fashion sectors. This material is very flexible, their bright and crisp also contributed to the aesthetic item, because the trimmings stayed highly visible and created eye-catching visual effects **(Figure 5A)**. The mosaic effect is a trend in fashion, such as Julie Richey creations (TRENDLAND, 2012) **(Figure 5B)**. Taking in account the obtained effect, this composite could be destined mainly to the field of fashion, decor or jewelry, such as the fashion accessories designer Carlos Alberto Sobral (SOBRAL, 2012) **(Figure 5C)**. In addition, the employ of recycling textiles and resin is largely employed in decor by new designers as Campana Brothers (IRMÃOS CAMPANA, 2012) **(Figure 5D)** and Tom Price (DESIGN KLUB, 2012) **(Figure 5E)**.

A

B

C

D

E

Figure 5. (a) Textile composites produced by hand; (b) Mosaic shirt - Julie Richey (TRENDLAND, 2012); (c) Pendant of rigid resin and sticks of brand R. Sobral (SOBRAL, 2012); (d) Easy chair "Sushi" - Campana Brothers (IRMÃOS CAMPANA, 2012); (e) Easy chair "Fleece Grey Grid" - Tom Price (DESIGN KLUB, 2012)

After tests conducted in composites, some suggested uses are identified below. The final aspect of the composite and its characteristics will depend on the type of resin employed, which could be more rigid or more flexible, glossy or opaque, more or less resilient, etc.

With the type of effect obtained, the composite would be intended for example for composing fashion jewelry or bijou **(Figure 6)**. Thinking about the flexibility of the composite, it could be possible to create bracelets, rings and earrings.

Figure 6. Illustrations of jewelry made of stainless steel or silver and textile composites (Illustrations of the first author, 02/20/2012)

Therefore, they are able to meet specific needs of the consumer market, eager for news, and the demand for studies of new materials in the textile and fashion sectors. In these ones there is a lack of specific bibliography joining aesthetic and technical analysis covering all the production phases, namely: materials, processes, design and creation.

6. Conclusion

Taking in account the ephemeral quality of fashion, textile articles, even those in good condition, are indiscriminately discarded by consumers, eager for news and new products launched. These articles, as well as industrial waste, are configured in a major environmental problem, suggesting that the recycling and reuse of them is a solution to reducing waste in landfills.

In Brazil, Recycling and Reuse of textiles is little practiced and encouraged, even after the Law 12.305 of 02/08/2010 establishing the National Politic of Solid Waste (BRASIL, 2010). Despite being a very profitable activity, since the raw material (scrap and waste textiles of various kinds) is abundant, many tons of textiles are still dumped in landfills in Brazil. Only in the neighborhood of Bom Retiro in Sao Paulo, approximately 16 tons of textile waste are removed per day and approximately 10 tons in the neighborhood of Brás, both large clothing producers (LOGA, 2011). It is observed that a significant number of new products could be developed with the reuse and recycling of this raw material.

In the present study a simple technique was developed in order to recycle textiles through the perforation or shredding, even manually, of discarded clothing. The employ of them in cohesive and well-structured composites could contribute to the decline of textile waste in landfills. The created composite of crystalline resin and textile scrapes resulted in a final product of great visual appeal. In addition, many combinations of colors may be generated depending on the fiber or trimming type employed. Handmade cooperatives or communities linked to textile and

fashion industry could apply this kind of simple composite technique, enhancing creativity and dignity of human work, besides generating incomes to them.

Biodegradable resins were not used in the tests performed in the present study, mainly because the lack of availability of small quantities that could be purchased in the market. However the obtained results could be useful for comparison in future studies where such material could become more accessible. Thus it is expected that the textile composites could be produced hereafter in large scale employing environmental friendly materials and processes that respect environmental standards.

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