THE BRAZILIAN CERAMIC TILE INDUSTRY: QUALITY AND TECHNOLOGICAL EVOLUTION

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ABSTRACT

Ceramic floor and wall tile production in Brazil has evolved tremendously in recent years, with production growth in 2002 of 7.3% and export growth of 56% relative to 2001. Brazil is the world's fourth ceramic tile producer after China, Italy and Spain. Brazil has approximately 130 ceramic companies, though Brazilian production is heavily concentrated in the southeastern and southern regions of the country. Brazil enjoys important raw materials resources for tile production.

53% of tile production quality is certified by the Ceramic Centre of Brazil, CCB. At the moment, 71% of certified tile production is made in the State of São Paulo. In São Paulo, production takes place in three regions: Great São Paulo, Mogi Guaçu and Santa Gertrudes/Cordeirópolis. The largest number of ceramic companies is concentrated in the region of Santa Gertrudes/Cordeirópolis, with a production of approximately 200 million m^2 in 2002 (representing about 40% of national tile production). In 2002, the Santa Gertrudes/Cordeirópolis region consumed 240 thousand tons of ceramic glazes, 400 million m^3 natural gas, 550 million kWh, 3 million pallets and 300 million cardboard packings. Important Universities and development Centres are also found close at hand, and the Ceramic Centre of Brazil inaugurated its Centre for Technological Innovation in Ceramics in Santa Gertrudes in September 2002.

The present paper sets out the development of the ceramic tile industry in Brazil: it provides a breakdown of production capacity, production, and exports, national consumption, number of companies, certified production, characteristics of all the manufacturing regions, energy consumption, main types of product and evolution of quality, principally of products made by the dry milling process. The results are also presented of a study evaluating the level of quality (taking standard NBR 13818/ISO 13006 as a reference) of Brazilian products available on the domestic market.

1. WORLD AND BRAZILIAN CERAMIC TILE MARKET

World ceramic tile production is concentrated in five countries: China, Italy, Spain, Brazil and Turkey, which account for approximately 60% of global production. Figure 1 depicts the evolution of tile production in these five countries.

In 2001, world tile production reached a volume of approximately 5226 million m^2, around 3% above that of 2000. In the same year, consumption reached 4864 million m^2, a percentage increase of 6% in comparison to 2000. As Figure 1 shows, Europe continues to be in a stage of expansion in ceramic floor and wall tile production.

Chinese production data are not official, but according to industrial equipment manufacturers, China had an estimated an annual production of 1700 million m^2 and a domestic consumption of 1600 million m^2 ceramic tile. Its production is mainly destined for the domestic market, as Chinese exports are estimated at 53 million m^2.

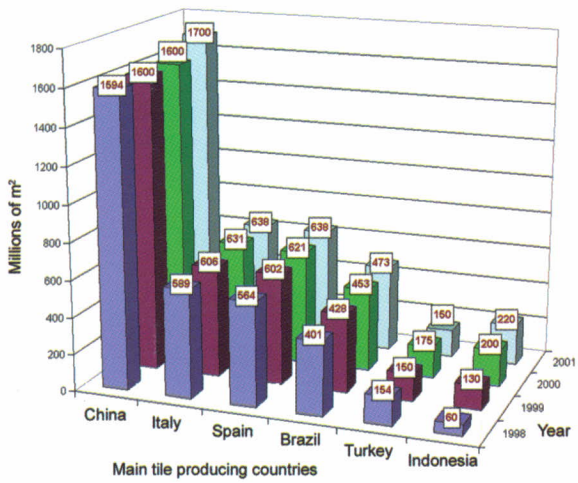


Figure 1. Evolution of tile production in the world's major tile producing countries from 1998 to 2001.[2]

Figures 2 and 3 show the world's main tile exporting and importing countries. In 2001, Italian production displayed a small growth (638 million m^2, 0.9% above 2000), as did exports (441 million of m^2, 1% above 2000). Sales fell from 623 million m^2 in 2000 to 620 million m^2 in 2001. This (3.96%) was mainly due to stagnation in domestic sales. For the first time, total Italian sales fell behind those of Spain, which reached 644.9 million m^2.

Spain displayed a significant production evolution, reaching a volume of 638 million m^2 in 2001 (2.74% above 2000), equalling that of Italy. In 2002 Spanish production reached 651 million m^2, i.e., 2% more than in 2001. As mentioned previously, sales totalled 645 million m^2, of which 306 million went to the domestic market. Exports also increased by 8.6% compared with 2000, reaching 339 million m^2. Exports have continued to rise at an increasing rate; 2002 recorded a rise of 3.6% in relation to 2001.

In 2001, the Brazilian ceramic tile industry witnessed growth in manufacturing and sales volumes. 473.4 million m^2 were produced, around 4.5% above 2000 (figure 4). Sales rose by 4.9% to 462.8 million m^2. Figures 5 and 6 respectively set out the sales in domestic and foreign markets. The turnover was of 2250 reales in the domestic market, and US$ 176.8 million in foreign markets. In 2002, these numbers continued

to grow, with national production reaching 508.4 million m² (an increase of 7.3%) and exports totalling around 72.8 million (rise of 56% relative to 2001). These figures highlight Brazil's position in the global ceramic sector.

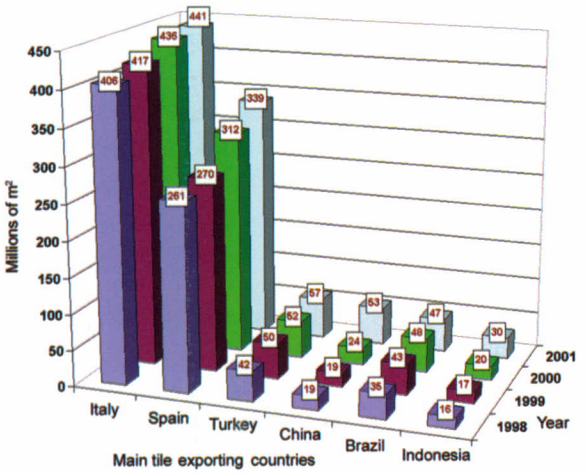


Figure 2. Main tile exporting countries in 2001[2].

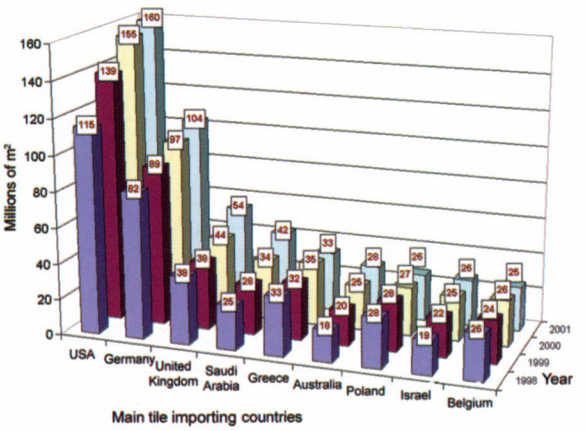


Figure 3. Main tile importing countries in 2001[3].

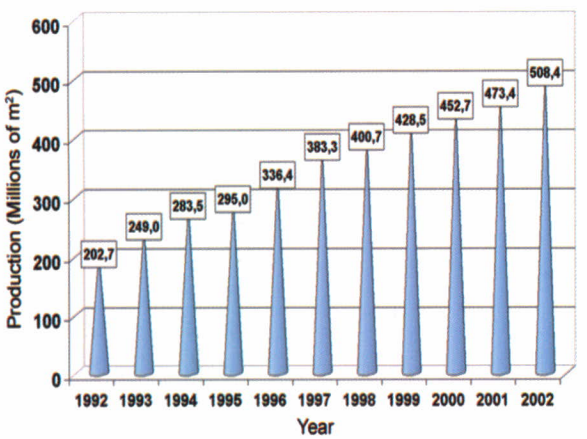


Figure 4. Evolution of Brazilian tile production in the last ten years[2].

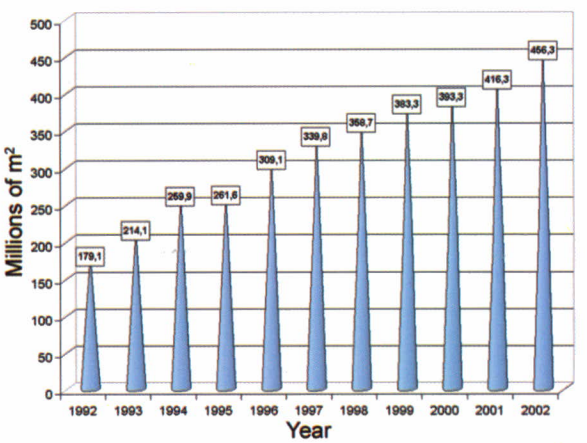


Figure 5. Evolution of tile sales in the Brazilian domestic market in the last ten years[2].

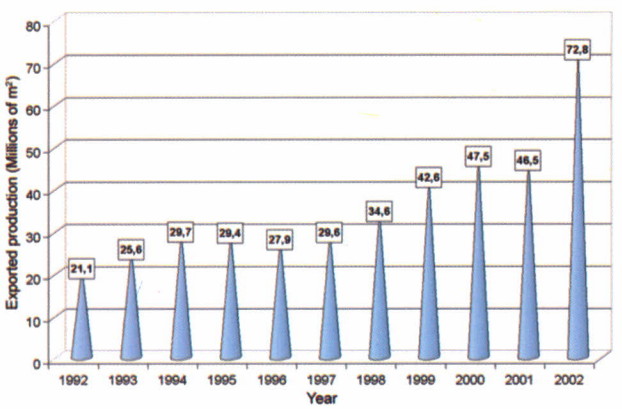


Figure 6. Evolution of Brazilian tile exports[2].

As Figures 1 and 2 show, Brazil is the world's fourth largest producer and exporter of ceramic tiles. However, the average value of the Brazilian product (invoicing/production) is 63% of the Spanish product. Compared with the Italian product, this drops to 52%.

Brazilian export volume is low, i.e., Brazil exports around 10% of its production, while Italy and Spain export around 69 and 50%, respectively.

Figure 7 displays the Brazilian export destinations. North America accounted for 46% of total Brazilian export volume and around 8% of the products went to Europe. Exports to Latin America (without MERCOSUR) accounted for 18%, and for the MERCOSUR market this was 21%.

Although Brazil is one of the world's major producers and consumers of ceramic floor and wall tiles, Brazilian consumption per capita is low (around 2.2 m^2/inhabitant/year) compared, for example, with Spain (around 5.5 m^2/inhabitant/year) and Italy (around 3.1 m^2/inhabitant/year). This indicates that Brazil has a great potential for ceramic production and consumption.[4]

The ceramic tile sector in Brazil is made up of approximately 130 industrial units. The main producing districts are located in the following regions[5]:

- Criciúma Region – State of Santa Catarina;
- Great São Paulo - Capital Region including Diadema, São Caetano do Sul, Suzano and Jundiaí;
- Mogi Guaçu Region - São Paulo;
- Santa Gertrudes/Cordeirópolis Region - São Paulo.

The State of São Paulo has the most extensive tile manufacturing facilities, accounting for around 60% of national production, in which the Ceramic District of Santa Gertrudes/Cordeirópolis stands out; this alone currently contributes approximately 50% of total production, i.e., around 19 million m^2/month, almost exclusively by the dry milling process[6]. The national ceramic tile industry provides 23 thousand direct jobs and 160 thousand indirect jobs.

At present, approximately 53% (Figure 8) of national tile production has quality certified by CCB/INMETRO in accordance with Standard NBR 13818/ISO 13006.

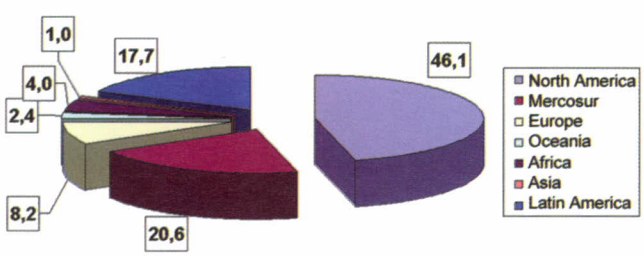


Figure 7. Destination of Brazilian tile exports[2]

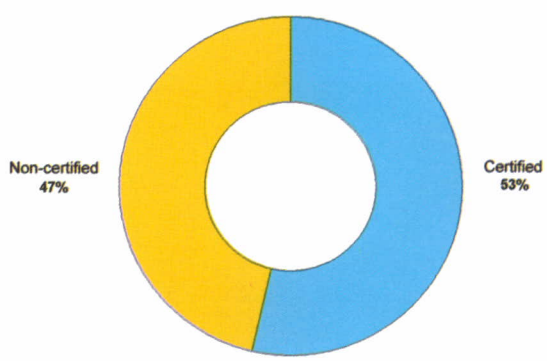


Figure 8. Percentage of products with quality certification by CCB/INMETRO in accordance with Standard NBR 13818/ISO 13006

Figure 9 depicts the evolution of the certification of Brazilian tile production. Until the end of 2001, most of the certified production was from industries located in the southern region of the country, involving industries with a large monthly production (around 3 million m^2/month). However, owing to the international financial situation, many companies from the south have cancelled their product quality certificates. This can be analyzed in Figure 10, which shows the percentage certified Brazilian production as a function of the region where the industries are located. There is a greater concentration in the southeastern region.

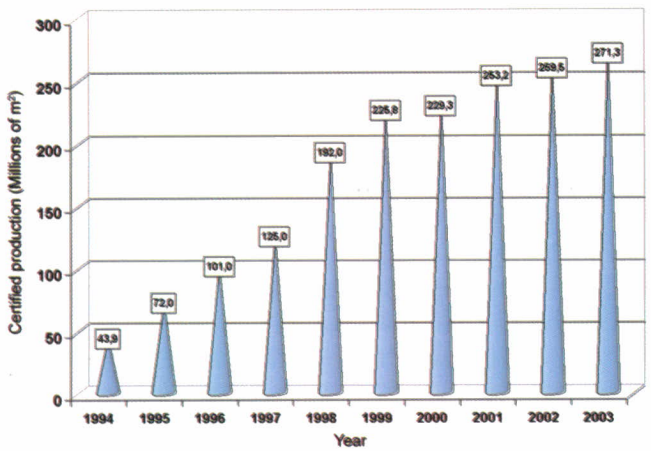


Figure 9 Evolution of certification of Brazilian tile production.[2]

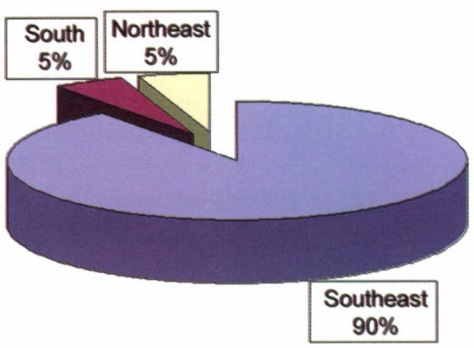
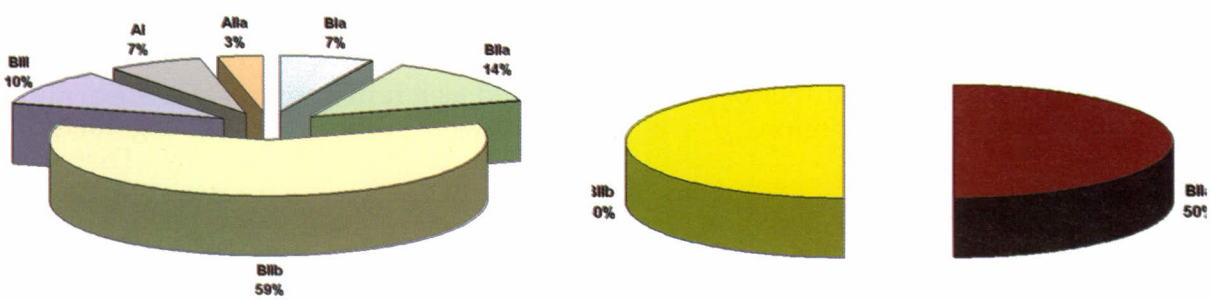


Figure 10 Percentage of production certified by CCB/INMETRO according to the region where the industries are located (September/2003).[7]



(a) Southeast *(b) South*

Figure 11 Percentage of certificates issued according to the water absorption group for the companies located in: (a) southeastern and (b) southern regions.

The type of product certified changes, depending on the region where the companies are located (Figure 11). In the southeastern region, 63% of the certified products belong to water absorption group BIIb (6 to 10%). In the southern region, 50% of the certificates issued are products belonging to water absorption group BIIa (3 to 6%).

In view of the importance of the Brazilian ceramic tile market, as the Ceramic Centre of Brazil is a Certifying organization of the quality of national products, to contribute to raising quality in the sector, a survey has been conducted of the properties of the products currently available in the market, with a view to proposing improvements in the production process. The main results of this survey are set out below.

2. METHODOLOGY USED

A random selection has been made of 46 ceramic tile companies from the southern, northeastern and southeastern regions of Brazil. Products from the five water absorption groups (BIa, BIb, BIIa, BIIb and BIII) were acquired directly in building materials stores. A total of 275 products was analyzed. Table 1 sets out the number of products studied per absorption class.

Absorption group	Number of products studied
BIa	16
BIb	2
BIIa	17
BIIb	226
BIII	14

Table 1. Number of products studied as a function of their water absorption class.

Table 2 lists the number of products and companies studied as a function of the manufacturing region.

Manufacturing region	Number of products studied	Number of different companies studied
Northeast	13	1
South	23	11
Southeast	239	34
TOTAL	**275**	**46**

Table 2. Number of products and companies studied as a function of the manufacturing region.

Table 3 details the number of products studied as a function of water absorption class and manufacturing region.

Manufacturing region	Water absorption class	Number of products studied
Northeast	BIa	5
	BIIa	3
	BIIb	5
South	BIa	8
	BIb	2
	BIIa	5
	BIIb	2
	BIII	6
Southeast	BIIa	9
	BIIb	222
	BIII	8

Table 3. Number of products studied as a function of water absorption class and manufacturing region.

Water absorption (NBR 13818 - Annex B) and mechanical strength (NBR 13818 - Annex C) were selected as properties for the initial characterization of the products, because they enable making a degree of quantitative comparison of ceramic tile quality. In addition, the products were also analysed with regard to: chemical resistance (NBR 13818 – Annex), stain resistance (NBR 13818 – Annex), crazing resistance (13818 NBR – Annex), resistance to water staining, resistance to surface abrasion and determination of moisture expansion.

3. RESULTS

Figure 12 plots the mean and maximum individual water absorption values for the 275 studied products. Most of these products were classified class BIIb, followed by classes BIIa, BIII and BIa. Note that only one product declared class BIb was evaluated; however, the test results showed that the material belonged to class BIIa. Figure 12 shows that the BIIb products displayed the greatest variations between the maximum individual and mean water absorption value.

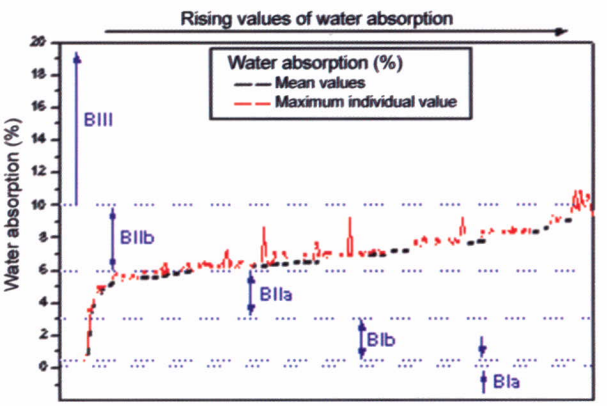


Figure 12. Plot of the mean and individual maximum water absorption values for the 275 studied products.

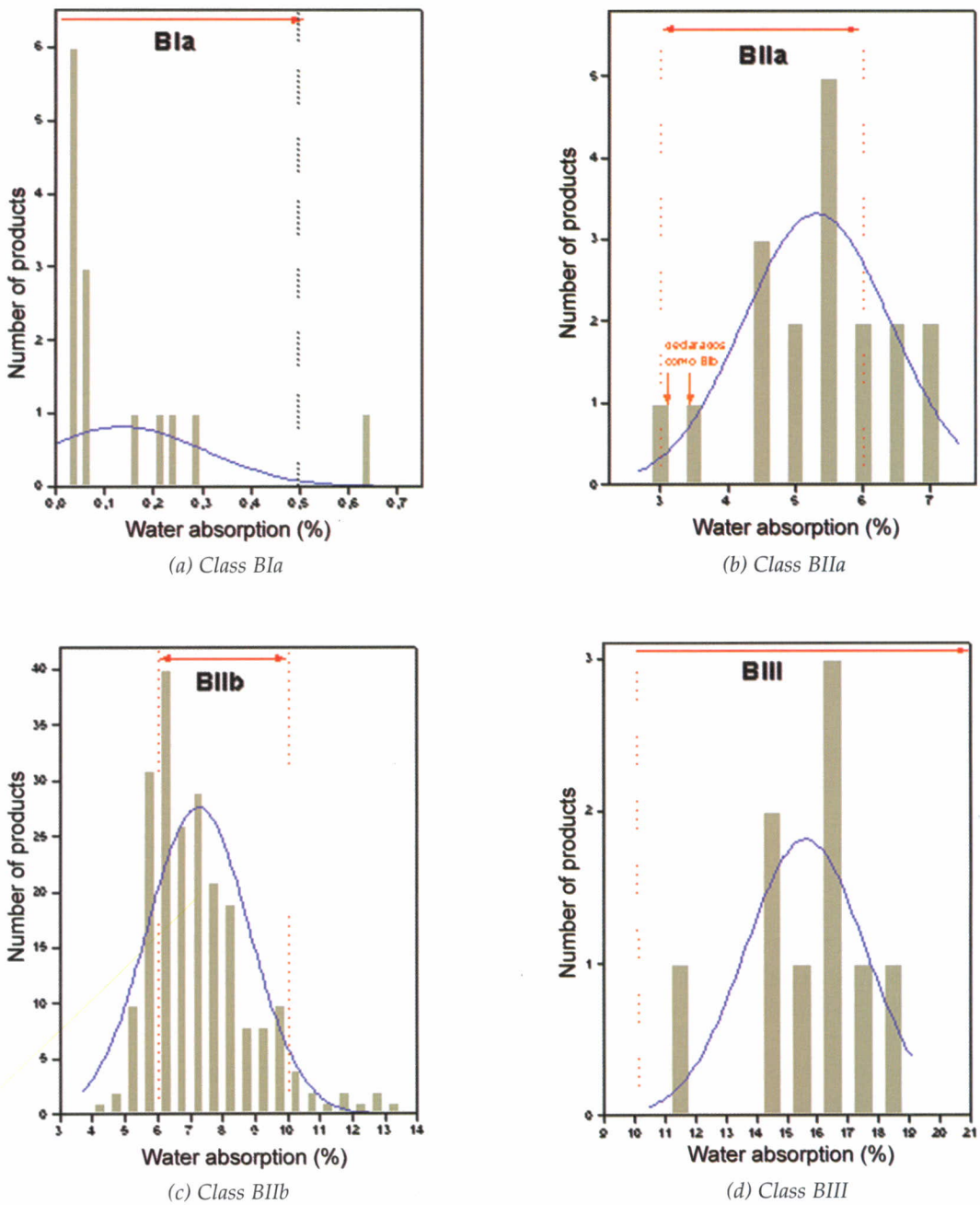
Figure 13 displays the water absorption data distribution for each waterabsorption class.

The products classified BIa are commercially known as porcelain tile and shall exhibit water absorption below 0.5%. Most products conformed to Standard NBR 13818/ISO 13006, the unglazed products displaying values below 0.1%. The glazed products however displayed water absorption values of about 0.2 to 0.3%. Only one product fell outside the limits set in the Standard, i.e., it exhibited water absorption exceeding 0.5%.

Most of the products classified BIIa displayed values close to the upper limit of the Standard, with 4 products (2 from the State of São Paulo and 2 from Santa Catarina) exceeding this maximum limit. Of the seven products with water absorption values around 6%, six were made in the southeastern and one in the northeastern region of the country. Of the 3 products with water absorption close to 4.4%, two came from the southern region of the country and one from the northeastern region. Of the products with water absorption close to 5%, one was made in the southern region and another in the northeastern region of Brazil. Figure 13(b) shows the products with water absorption of about 3 to 3.5%, which according to the declaration on the product packing were type BIb. However, based on the test results, these products were classified in the BIIa group.

Figure 13 (c) shows the water absorption data distribution of products declared group BIIb, i.e., with water absorption values of 6 to 10%. Analysis of the figure indicates that 44 products (around 16%, of which 42 products came from the southeastern and 2 products from the northeastern region) displayed water absorption below 6%, thus lying outside the specification of the Standard (6 to 10%). Of the total number of evaluated products, around 19 had no quality certification by INMETRO/CCB, while the others were certified.

This non-conformity does not adversely affect the quality of the products, because in general, lower water absorption values mean better mechanical strength. Around 67 products (approximately 24%) displayed water absorption values of 6 to 7%, i.e., close to the required minimum limit of the Standard, which is very positive for the Brazilian industry. However, 16 products (8%, all from the southeastern region), presented water absorption values between 9 and 10%, i.e., close to the upper limit of the Standard. About 11 products did not conform to the Standard, as they fell outside the upper limit of group BIIb. All these products came from the same company, which did not have certified quality.



(a) Class BIa

(b) Class BIIa

(c) Class BIIb

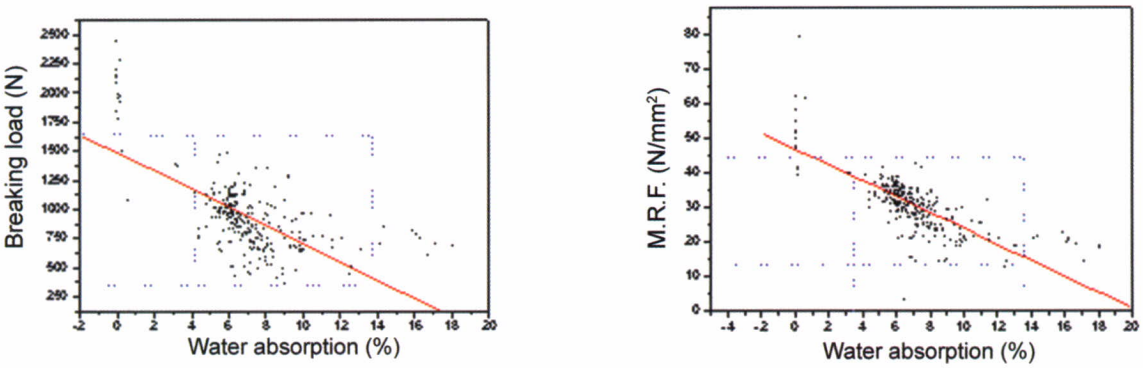
(d) Class BIII

Figure 13. Water absorption data distribution for each water absorption class.

Figure 13(d) displays the water absorption data distribution of products declared BIII (absorption exceeding 10%). Analysis of the figure shows that only one product (produced in the southern region of the country) displayed water absorption close to the lower limit of the Standard. The others (3 products from the southern and 5 from the southeastern region) displayed values above 13%, though not exceeding 20%.

Figure 14(a) plots the mean breaking load values as a function of water absorption of all the studied products. The blue dashed lines delimit the ranges of values in which the products belong. The variation of breaking load for the same water absorption is a consequence of the microstructure and/or difference in thickness of the products.

Figure 14(b) plots the bending strength values (MOR) as a function of water absorption of all the studied products. It shows that products having the same water absorption can display very different bending strength values, as this property is intrinsic to the microstructure and independent of product thickness. Therefore, it is important to consider the value of bending strength and not only water absorption, for quality control and correct product specification.



(a) (b)

Figure 14. (a) Breaking load as a function of water absorption data, (b) Bending strength as a function of water absorption data.

Figure 15 displays the range between the mean and individual minimum breaking load values for the products declared respectively: BIa, BIIa, BIIb and BIII. In Figure 15(a), most of the products declared BIa are observed to display thicknesses exceeding 7.5 mm, and therefore conform to NBR 13818/ISO 13006. Only two products displayed thickness below 7.5 mm, though this complies with the Standard, because the limit, in this case, is below 700 N.

Analysis of Figure 15(b) for products declared BIIa indicates that only three products (all fabricated in the southeastern region) did not conform to Standard NBR 13818/ISO 13006 with regard to the mean breaking load value.

Concerning the products declared BIIb (Figure 15(c)), it can be observed that 11 products (all from the southeastern region) failed to meet the required mean breaking load set in Standard NBR 13818/ISO 13006. This type of product displays a greater discrepancy between the mean and minimum individual breaking load values.

As far as the products declared BIII are concerned, Figure 15(d), all conformed to NBR 13818/ISO 13006.

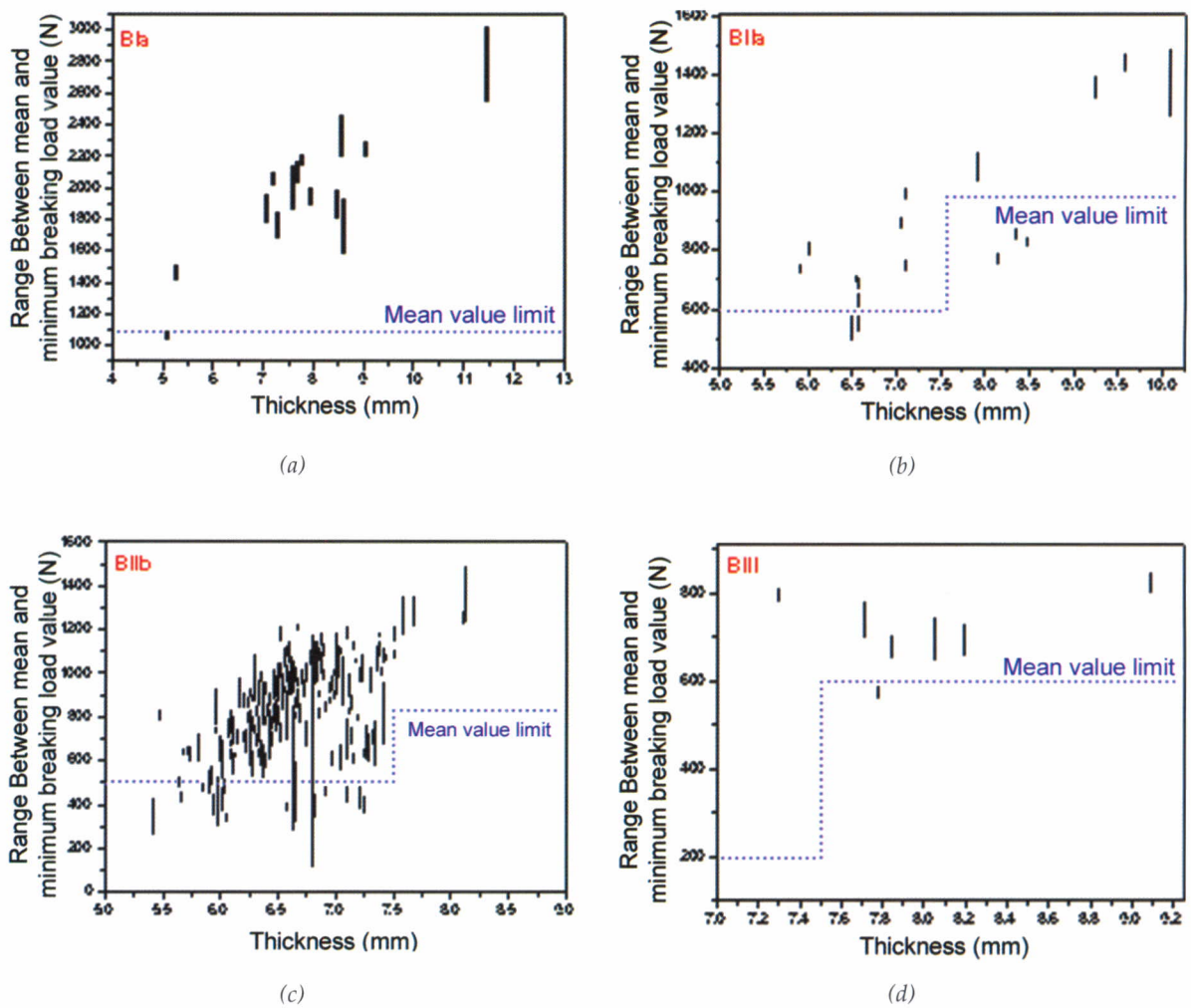


Figure 15. Breaking load values for the studied products as a function of water absorption group.

Figure 16 depicts the range between the mean and individual minimum bending strength values for the products declared respectively: BIa, BIIa, BIIb and BIII. Figure 16 (a) shows that most of the products exhibit mean bending strength values conforming to Standard NBR 13818/ISO 13006. Only one product (made in the southern region of the country) simultaneously displayed non-conformity to the mean and individual minimum values, and another product (from the southern region of the country) only displayed non-conformity to the minimum individual value.

Analysis of Figure 16(b) for products declared BIIa shows that except for a product produced in the southern region of the country, the other products conformed to 13006 NBR 13818/ISO regarding the mean and individual minimum bending strength value.

Regarding the products declared BIIb (Figure 16(c)), it can be observed that 8 products (all from the southeastern region) failed to meet the required mean bending strength value and 15 products (all from the southeastern region) did not meet the minimum individual value set in Standard NBR 13818/ISO 13006. This type of product exhibited a greater discrepancy between the mean and minimum individual bending strength values.

Concerning the products declared BIII (Figure 16 (d)), except for a product made in the southern region of the country, the other products conformed to Standard NBR 13818/ISO 13006.

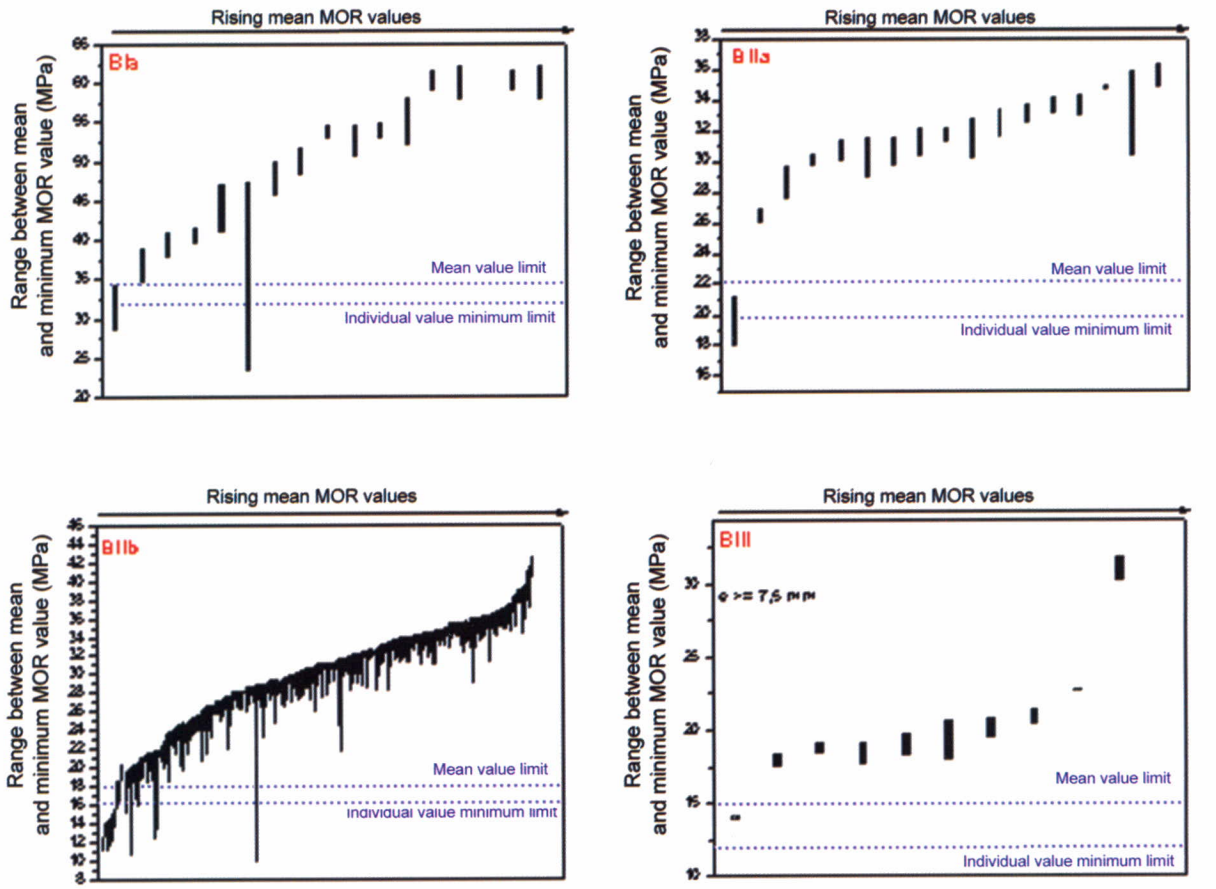


Figure 16. Bending strength values for the studied products declared BIa.

Figure 17 displays the moisture expansion values (EPU) determined for the studied products. Most products are observed to exhibit moisture expansion below 0.6 mm/m. About six products (all from the southeastern region with water absorption BIIb) displayed EPU values above 0.6 mm/m. Moisture expansion is a critical characteristic, since it can cause loss of bonding between the tile and the background in service, as well as glaze crazing, characterized as a hidden defect. Of the six products mentioned, three also displayed crazing (those with moisture expansion close to 1 mm/m). These non-conforming products represent 2% of all the studied products (Figure 18).

Figure 19 depicts the percentage (2%) of tested samples with crazing. All these non-conforming products were classified in absorption group BIIb and were produced in the southeastern region. Note that not all the studied samples were tested for moisture expansion.

Figure 20 shows the percentage of products with chemical resistance classes A, B and C. 60% of the studied products exhibited class A resistance to all low concentration chemical agents. Around 22% (76% from the southeastern, 16% from the southern and 8% from the northeastern region) of the products suffered attack by

at least one chemical agent in Standard NBR 13818/ISO 13006; however they still conformed to the Standards mentioned, which only require the product to have class B for household detergents and swimming pool water treatment products. With regard to low concentration acids and alkalis, NBR 13818/ISO 13006 only requires the manufacturer to declare the respective resistance classes on the packing. Most studied product packings did not state the acid and alkali resistance class, so that product non-conformity could not be established. Around 18% of the studied products (of which 81% was from the southeastern and 19% from the southern region of the country) displayed class C resistance to at least one chemical agent in Standard NBR 13818/ISO 13006. The low resistance to chemical attack should be declared on the product packing.

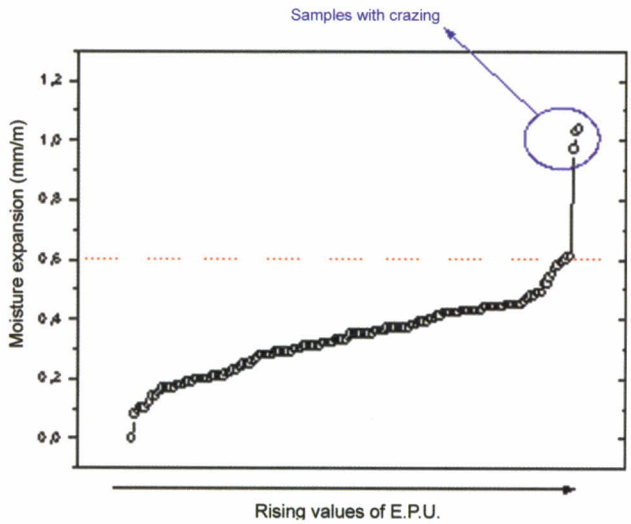


Figure 17. Moisture expansion values of the studied products.

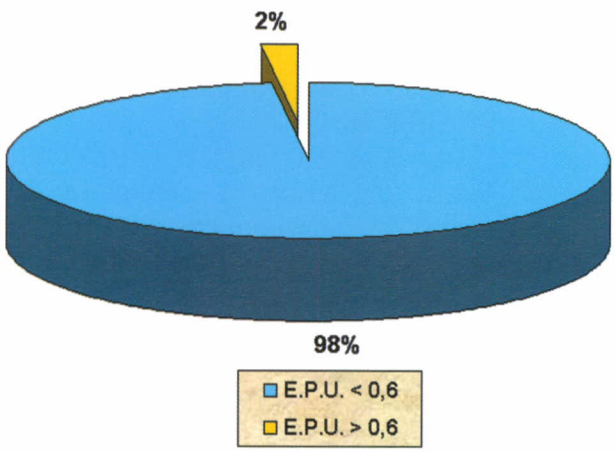


Figure 18. Moisture expansion percentage of the tested products

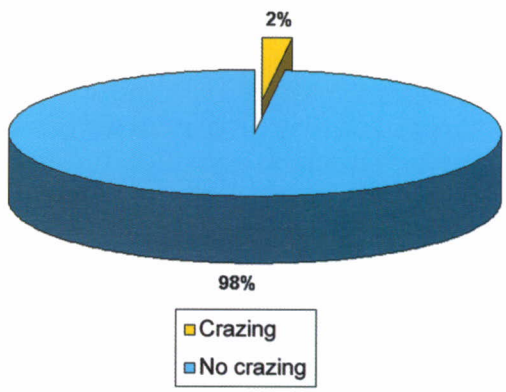


Figure 19. Percentage of the products that displayed crazing

Figure 21 depicts the percentage distribution of chemical agents that attacked the products classified B and C (only for low concentration acids and alkalis). The hydrochloric and citric acids were found to be the most critical.

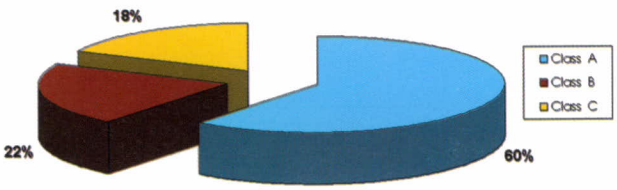


Figure 20. Percentage of the classes of resistance to chemical attack of the studied products.

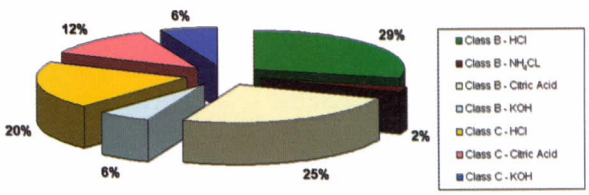


Figure 21. Percentage distribution of the chemical agents that attacked the products classified B and C (only for low concentration acids and alkalis).

Figure 22 depicts the percentage distribution of the cleaning classes of the studied products. The figure shows that 88.2% of the studied products displayed class 5 cleaning, i.e. maximum cleanability. Around 7.2% of the products displayed cleaning class 4, i.e., cleaning with a neutral detergent. The products that exhibited cleaning class 2 and 3 were classified in the BIa group, and were generally unglazed and polished products.

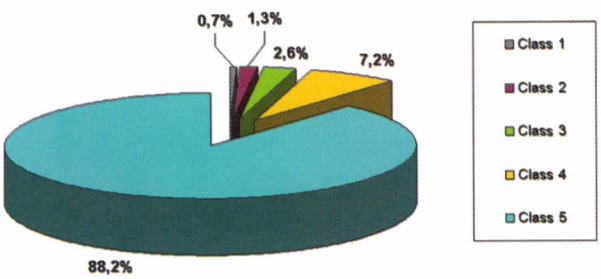


Figure 22. Percentage distribution of the cleaning classes of the studied products.

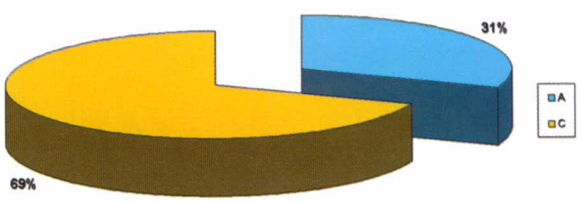


Figure 23. Stain resistance results of 26 studied products.

A study was also made of the stain resistance of 26 products, of which 14 were from the southern and 12 from the southeastern region of the country. Figure 23 displays the results obtained, where A refers to no water stain formation in a time of 60 minutes and C refers to the product that exhibited water staining in a time of 5 to 30 minutes.

Figure 23 shows that 69% of the products displayed water staining, of which 44% was from the southern and 56% from the southeastern region. 31% of the products displayed high water staining resistance, of which 75% was from the southern and 25% from the southeastern region.

With regard to resistance to surface abrasion, 68 products were studied (Figure 24). Of these 19% displayed non-conformity, i.e., they exhibited lower abrasion resistance than the value declared on the packing. Of these non-conforming products, 77% was from the southeastern, 8% from the northeastern and 15% from the southern region of the country.

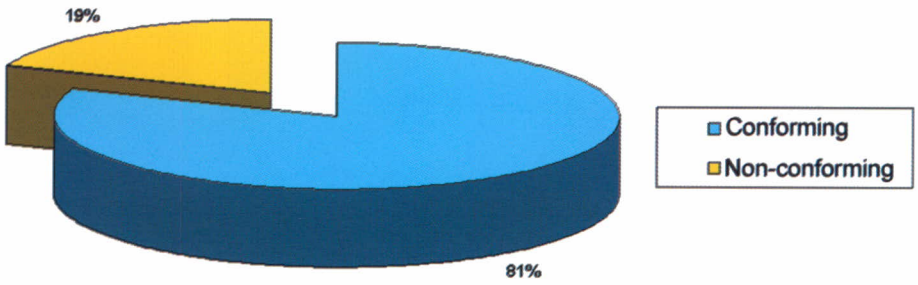


Figure 24. Results of the resistance to surface abrasion of the 68 studied products.

4. FINAL CONSIDERATIONS

In general, the quality of the Brazilian ceramic tiles was very good, as most of the studied products conformed to Standards NBR 13818/ISO 13006.

The characteristics that enabled effective evaluation of the quality of the studied products were water absorption, mechanical strength and moisture expansion, which are directly related to the raw materials and process conditions used.

The products classified BIa displayed optimum results for water absorption and mechanical strength. Of the 14 studied products, only one exhibited non-conformity to the water absorption requirement.

The products classified BIIa displayed values very close to the upper limit (6%) of Standard NBR 13818/ISO 13006. With regard to the products classified BIIb, a product distribution as a function of the absorption limits was determined. There was a large product concentration with water absorption close to the minimum limit of the Standard (6%) for the BIIb group, which is very positive for the national ceramic industry. The number of non-conforming products was small compared with the total number of studied products.

The products classified group BIII displayed conformity to the Standards as regards the water absorption requirement. Only one product displayed non-conformity to the mean bending strength value.

With regard to moisture expansion, 98% of the products conformed to the current Standards. Most of the products exhibited high crazing and stain resistance. Regarding water stain resistance, 69% of the products displayed a tendency to change colour when moisture came into contact with the tile body. The water stain characteristic could lead to many claims after tile installation, mainly when moisture is present, if a time of three days is not respected for executing the installation and the grouting is not fully impermeable.

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