INFLUENCE OF PHASE COMPOSITION AND POROSITY ON RESISTANCE TO DEEP ABRASION OF PORCELAIN STONEWARE TILES

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1. INTRODUCTION

Porcelain stoneware tiles are low-porosity products with high technical performances, especially regarding modulus of rupture and resistance to deep abrasion. The distinctive characteristics of the product arise from the compactness of the ceramic structure and, particularly, from the water absorption value, which is, in most commercial tiles, around 0.1% and well below the standard limit (< 0.5% class BI_a of ISO 13006). Among the various technical properties, wear resistance stands out because of its importance in defining product applications and performances. The available studies on wear performance of tiles concern surface abrasion, scratch or pin-on-disk tests. Porosity is certainly linked to resistance to deep abrasion: the greater the body compactness, the lower the porosity and the higher the wear performance, but it would be meaningful to also examine thoroughly the role played by the other compositional and microstructural parameters (e.g. different hardness of components, boundary between grains and amorphous phase or some other textural inhomogeneities).

The present work is designed as an exploratory assessment of the resistance to deep abrasion of porcelain stoneware tiles and its dependence on phase composition and microstructure.

2. MATERIALS AND METHODS

26 samples of porcelain stoneware tiles were considered; most of them were commercial products, the others being laboratory products. Resistance to deep abrasion was measured according to ISO 10545-6. The mineralogical analyses were performed with a Rigaku Miniflex X-ray powder diffractometer with Ni filtered CuKa radiation in the 10 – 50° 2q range and the quantitative interpretation of X-ray patterns was performed with the RIR method, using CaF_2 as internal standard. The relative analytical error is within 5% relative. Water absorption, bulk density and open porosity were measured according to ISO 10545-3. Total and closed porosity were calculated on the basis of bulk density and specific weight (ASTM C-329) of ceramic materials.

3. RESULTS AND DISCUSSION

The resistance to deep abrasion, expressed as the quantity of material removed, exhibits values between 110 and 160 mm^3, always within the standard requirement for porcelain stoneware tiles (maximum 175 mm^3, ISO 13006). The phase composition consists of phases formed during firing (mullite and glass) and residual phases (quartz, zircon, corundum and some plagioclase). The most abundant component is the glassy phase, whose amount is in the 52-66 wt% range. As far as the microstructural characterization is concerned, all products show water absorption £ 0.1%, while open porosity is in the 0.04-0.64 % range. Most porosity is closed and the values are between 2 and 8 % approximately. Bulk density is quite similar (about 2.4 g/cm^3) for all samples.

The results obtained exhibit a complex picture of the possible correlations among phase composition, porosity and resistance to deep abrasion. With a view to clarifying these points, we first focused our attention on the correlation between the porosity of the ceramic body and its resistance to deep abrasion. No clear relationship arose on plotting total porosity against the volume of material removed (Figure 1).

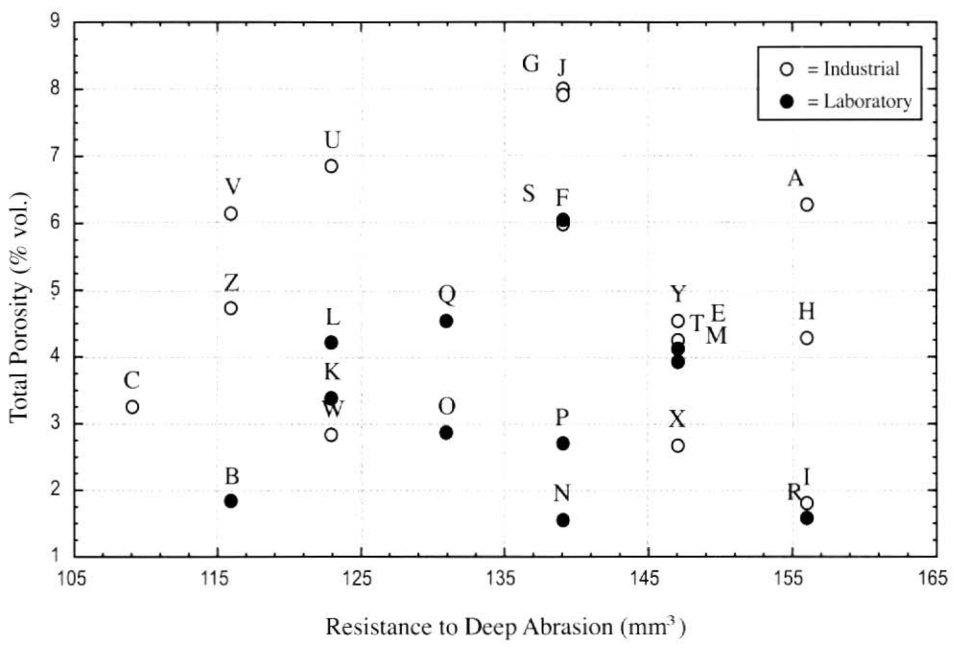
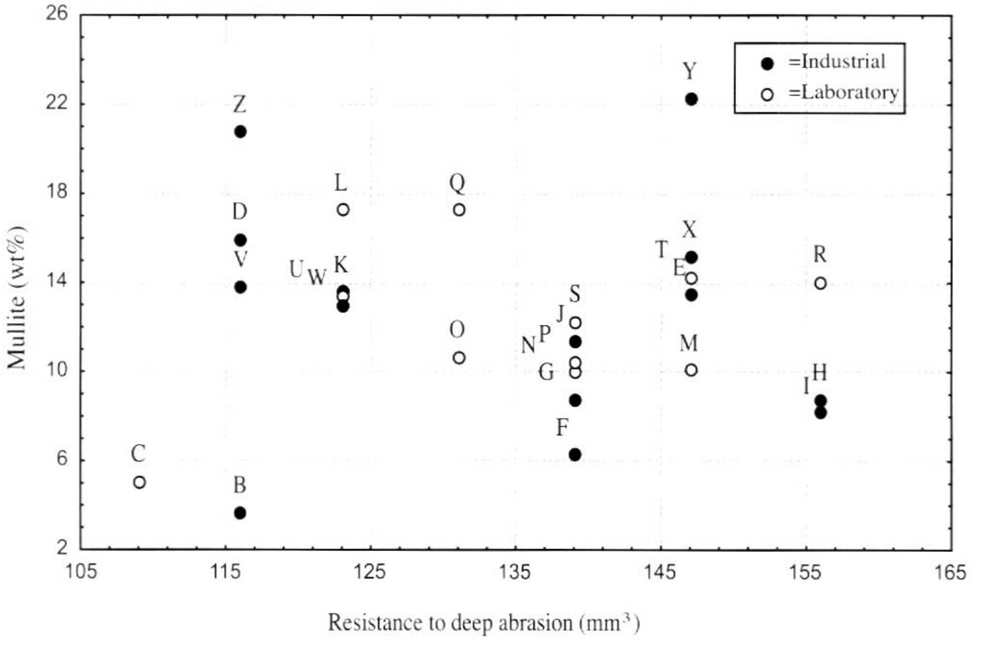
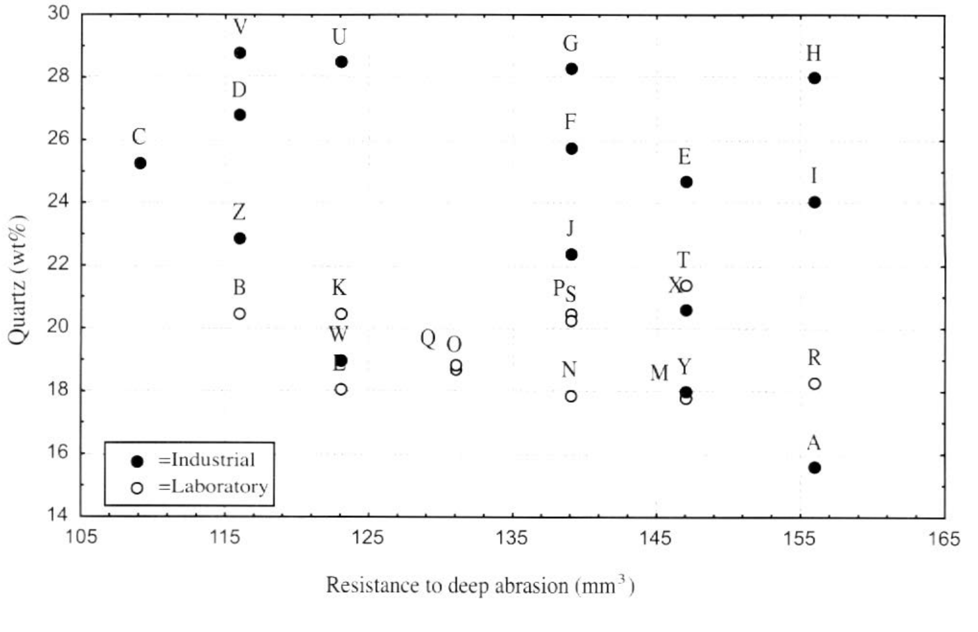
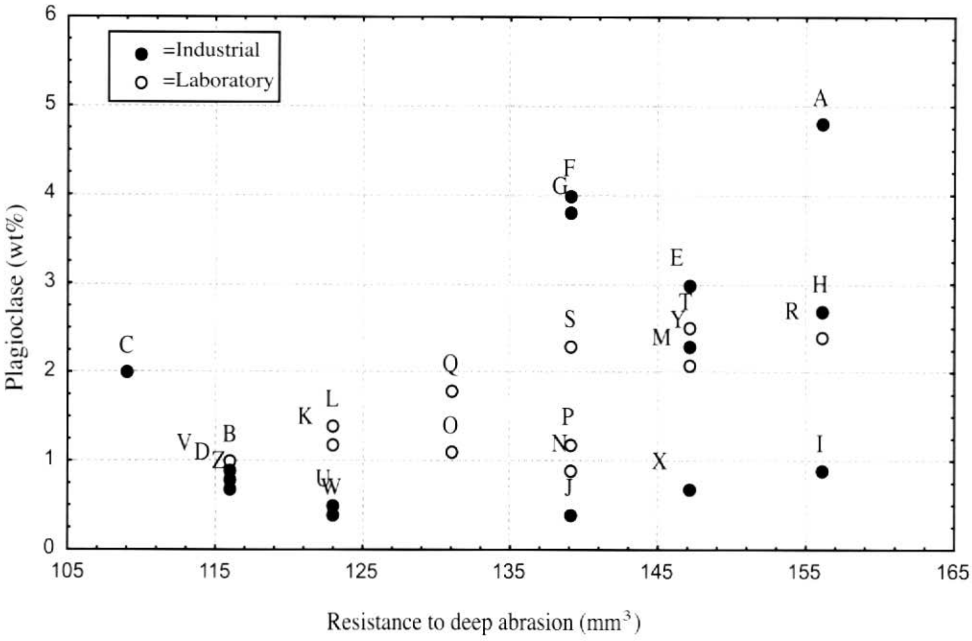


Figure 1- Influence of total porosity on resistance to deep abrasion.

The relationships between the resistance to deep abrasion on the one hand, and the content of mullite, quartz, plagioclase and amorphous phase on the other, are reported in Figure 2. The increase of mullite, as well of quartz, appears to involve an improvement of wear resistance, while the amorphous phase seems to work in the opposite way. Perhaps a more significant positive correlation exists between the plagioclase content and the amount of material removed.







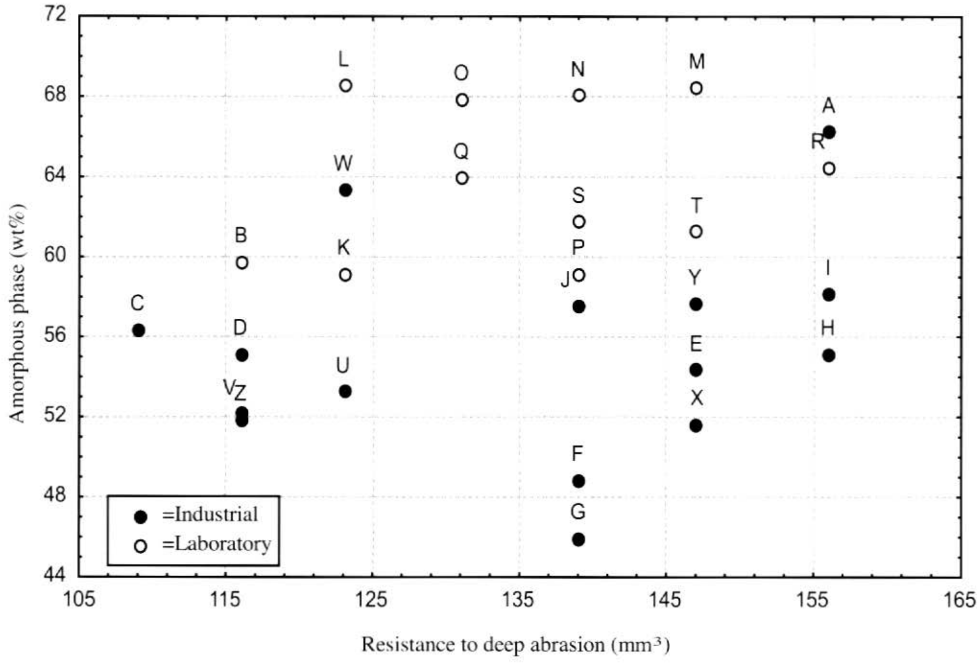


Figure 2-Influence of mullite, quartz, plagioclase and amorphous phase on resistance to deep abrasion.

A statistical analysis of the main components made it possible to collect the variables (resistance to deep abrasion, open and total porosity, bulk density and mineralogical components) into two factors summing about 60% of the total variance. These results confirm the qualitative observations on binary correlations; in particular, mullite is located on the opposite side with respect to resistance to deep abrasion, which means that it improves wear performance. In contrast, total porosity and amorphous phase, plagioclase and cristobalite are more o less close to the resistance to deep abrasion and therefore tend to decrease product durability (Figure 3).

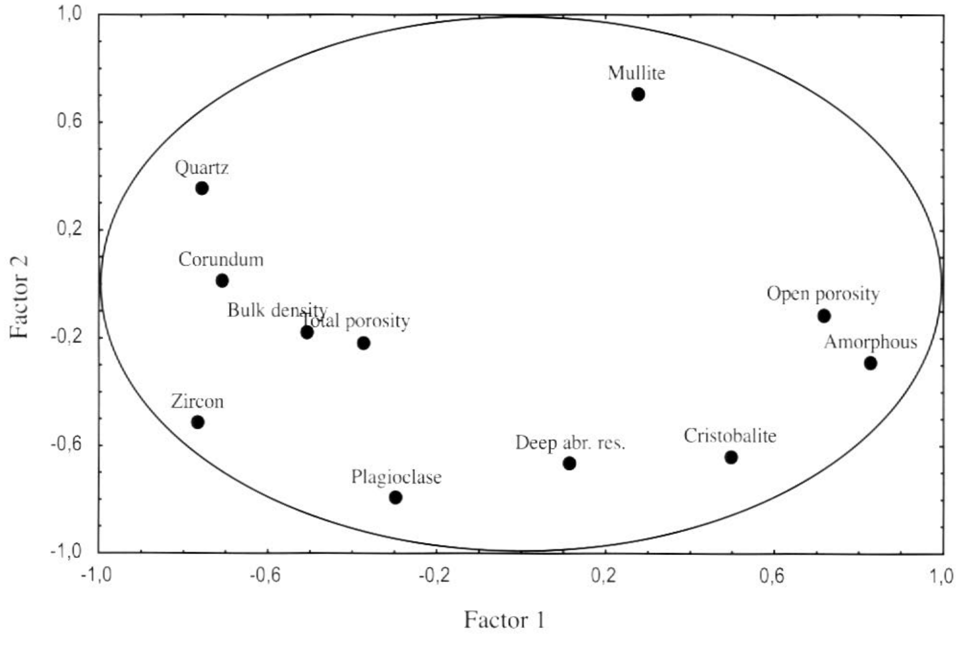


Figure 3- Weight plot of factor 1 and factor 2 obtained by extraction of the main components

4. CONCLUSION

The data on resistance to deep abrasion of 26 samples of tiles showed that lower porosity does not necessarily bring about a better wear performance. In reality, there are other relevant factors, such as phase composition, which affect the wear resistance of tiles. However, the results obtained with a preliminary statistical approach indicate just some trends and no reliable prediction of tile behaviour under service conditions has been developed yet. Therefore a more detailed study on the microstructure of porcelain stoneware tiles is required, in order to assess the role, for example, of pore size and shape, as well as structural defects and grain boundary.