ACCURACY OF THE PEI METHOD TO DETERMINE THE ABRASIVE WEAR RESISTANCE OF GLAZED CERAMIC TILES

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ABSTRACT

The abrasion of glazed ceramic tiles is perceived as a surface gloss variation. The gloss variation is related to surface properties like roughness and porosity of the glazed layer. The ISO 10545 standards determine the use of the PEI method to evaluate the abrasion effects over glazed tiles. However, the method presents great subjectivity leading to errors in the interpretation of the results. In this work the spectrophotometric techniques are used to interpret and classify the abrasion (ISO 10545) in order to investigate the accuracy of the visual method specified by the ISO standards as the method to determine the degree of abrasion in glazed ceramic tiles. As roughness and porosity affect the light reflection these properties were also studied. The results show the transparent glaze was the most abraded and the matt glaze was the least one. The PEI method does not represent the real conditions of ceramic tile abrasion and leads to misinterpretations of the obtained results.

1. INTRODUCTION

Abrasive wear arises when a hard and rough surface slides against a softer surface ploughing a series of grooves. The material originally in the grooves is normally removed in the form of loose fragments. Abrasive wear also arises when hard particles are introduced between sliding surfaces and abrade material off each. The mechanism of this form of abrasive wear seems to be that an abrasive grain adheres temporarily to one of the sliding surfaces or else is embedded in it and ploughs out a groove in the other. The two types of wear, one involving a hard and rough surface and the other hard and abrasive grains are generally referred to as the two-body and the three-body abrasive wear processes, respectively[1-3].

Three-body abrasive wear does not occur when the particles in the system are small or when they are softer than the sliding materials. It is usually possible that a sliding system is free from abrasive wear. However once the sliding has commenced abrasive wear may become a problem, as wear debris begins to accumulate in the system as a result of other wear processes or when contaminating particles are introduced into the sliding system from the environment. Abrasive wear is very widely used in material-finishing operations as in the polishing of ceramic tile surfaces, but also occurs when a floor tile is abraded during its life in service by pedestrian use[1,3,4].

The abrasive wear rate of a surface, using any particular abrasive medium, is inversely proportional to the hardness of the surface. When the surface hardness is of the same order of magnitude as the abrasive hardness, does not occur an indentation process since deformation occurs in the abrasive and on the surface, and wear can occur in both. When the surface is considerably harder than the abrasive, negligible indentation occurs, hence very little abrasive wear. When abrasive wear is unwanted the sliding surface must be harder than the abrasive. The most common abrasive contaminant is sand (SiO_2) with a hardness of about 750kgf/mm^2, but the standards designated to determine the abrasive resistance of glazed tiles uses fused alumina as abrasive medium[1,5-7].

When the materials and the abrasive remain fixed, but the size of the abrasive is varied, there is a critical abrasive particle size such that the wear rate is independent of abrasive particle size if the latter is above the critical value; there is a strong dependence of wear rate on particle size bellow the critical size. With large abrasive particles, the shape of the abrasive indenters does not depend on the particle size, and consequently the overall wear rate is independent of particle size. The reduction of wear rate when small particles are used occurs due the formation of large particles that prevents the abrasive from contacting the other surface. Such large particles arise from the adhesive wear process, which takes place as the abrasion is occurring. These adhesive wear particles are potentially able to interfere with the abrasive action[1,6-9].

The abrasion of glazed ceramic tiles is perceived as a surface gloss variation. Darker surfaces present a more pronounced gloss variation in relation of clearer surfaces. The gloss variation is related to surface properties like roughness and porosity of the glazed layer. There are three basic types of ceramic glazes: white, matt and transparent, each one with distinguish characteristics regarding abrasive resistance. The ISO 10545 standards determine the use of the PEI method to evaluate the abrasion effects over glazed tiles. However the method presents great subjectivity leading to errors in the interpretation of the results. In this work the spectrophotometric techniques are used to interpret an classify the abrasion (ISO 10545) in order to investigate the accuracy of the visual method specified by the ISO standards as the method to determine the degree of abrasion in glazed ceramic tiles[3-9]. As roughness and porosity affect the light reflection these properties were also studied.

2. MATERIALS AND METHODS

Three glazes were used in this study: white, matt and transparent. The white glaze was composed by 88.1% of white frit and 11.0% of kaolin; the transparent was formed by 89.3% of transparent frit and 10.0% of kaolin; and the matt glaze was composed by 67.5% of matt frit, 7.5% of transparent frit, 10% of kaolin, 14% of zircon and 1% of quartz (all compositions in weight fractions). The glazes were ground in eccentric mill (30min) with the addition of 0.2% of sodium tripolyphosphate, 0.2% of carboxymethylcellulose and 30% of water, forming glaze slurries with controlled density (1.80g/cm^3) and viscosity of (50s flowing time in *Ford cup n° 4*). The glazes were applied in layers of 0.6mm thickness over previously engobed tiles and fired at 1155°C during 33min in an industrial roller kiln ("monoporosa" fast firing heat treatment). The abrasion tests were conducted according the ISO 10545 standard using fused alumina as abrasive agent. The gloss of the glazed samples was determined by spectrophotometry and the roughness (R_a) by means of a roughness meter (4mm of reading profile), and both properties were compared with the visual analyses of the abraded surfaces, according the PEI method (ISO 10545).

3. RESULTS AND DISCUSSION

All glazes were approved according the visual analysis established by the ISO 10545 standard and were all classified as PEI 5 (resistant to 12000 cycles of abrasive wear). Figure 1 shows the gloss variation of the glazes in function of the PEI abrasion stage. The white and transparent glazes present similar behaviour, with a great gloss variation beginning at the third stage of abrasion. The matt glaze initially presents an increase in gloss due a polishing process that takes place at the initial stages of abrasion. After that presents a less intense gloss variation in comparison with the white and transparent glazes, figure 1.

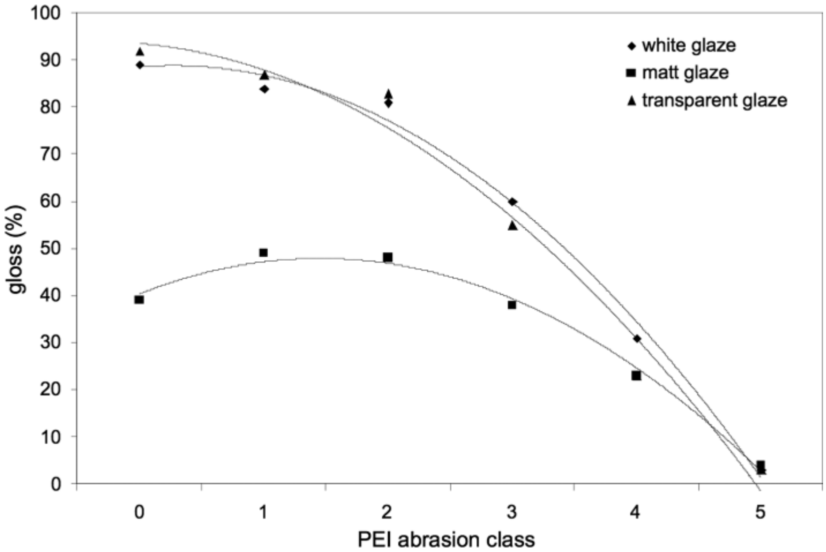

Figure 1. White, matt and transparent glazes gloss variation in function of the PEI abrasion stage

The reflectance curves of the glazes were determined for the PEI V abrasion stage (12000 cycles). Figure 2 shows the reflectance curve for the white glaze. The glaze reflectance shifts toward lower intensity values for all wavelengths, showing the loss of surface gloss after abrasion. The reflectance differences before and after abrasion are bigger for the smallest wavelengths (400nm to 550nm, the violet to green region). These differences are responsible for the great loss in glaze whiteness after abrasion.

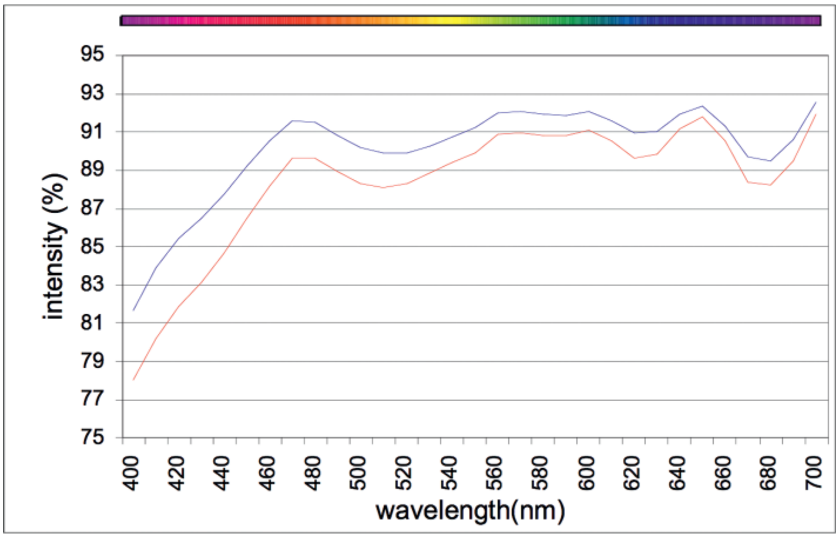

Figure 2. Reflectance for the white glaze before (blue line) and after (red line) abrasion (12000 cycles)

Figure 3 shows the reflectance curve for the matt glaze. Like the white glaze, the reflectance shifts toward lower intensity values for all wavelengths. Also, the reflectance differences before and after abrasion are bigger for the smallest wavelengths. These differences are responsible for the great loss in glaze whiteness after abrasion.

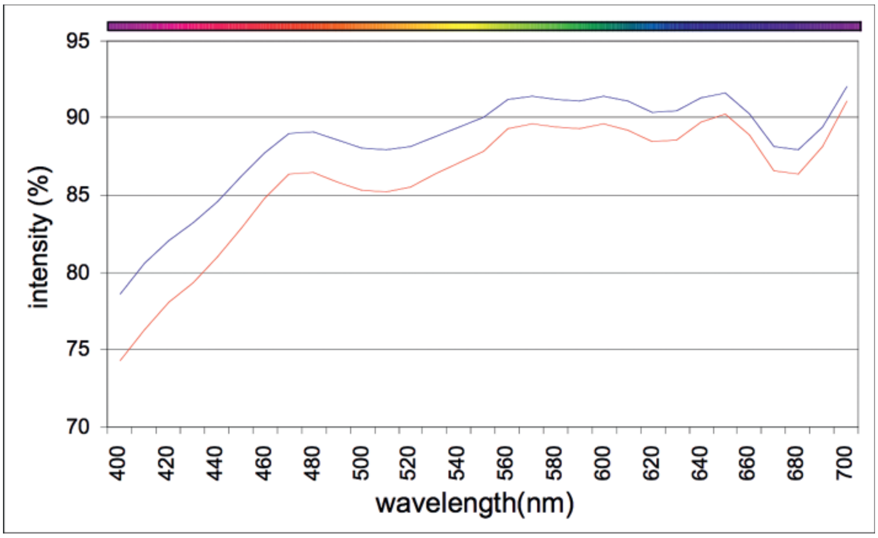

Figure 3. Reflectance for the matt glaze before (blue line) and after (red line) abrasion (12000 cycles)

Figure 4 shows the reflectance curve for the transparent glaze. Like the white and matt glazes, the reflectance also shifts toward lower intensity values for all wavelengths. But the reflectance differences before and after abrasion are bigger for the smallest wavelengths.

As the perception of abrasion is related to the surface aspect, no matter if the abrasion is measured by an instrument or by the human eye, the roughness of the glazes was measured using the R_a scale, the average arithmetic roughness measured along a 4mm line of the glaze surface. All glazes show an increase in the surface roughness after 12000 cycles of abrasive wear (PEI V). If the glaze presents a great initial gloss before abrasion (white and transparent glazes), the gloss variation after abrasion is bigger; so, the roughness is related to the surface gloss. Before abrasion the transparent glaze has the biggest gloss (92%) and smallest roughness (0.04μm). After abrasion, it shows the smallest gloss (3%) and the biggest roughness (1.61μm).

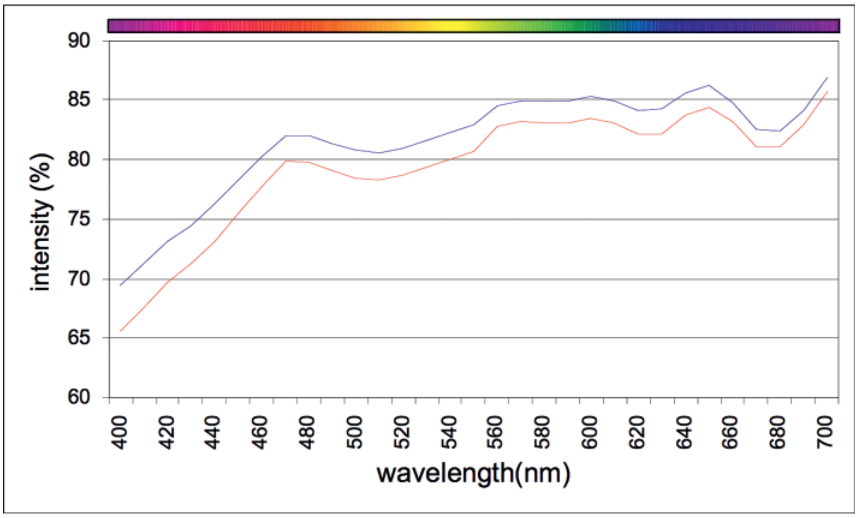

Figure 4. Reflectance for the transparent glaze before (blue line) and after (red line) abrasion (12000 cycles)

The matt glaze shows an interesting behaviour: before abrasion presents the smallest gloss (39%), the gloss rises after the initial stages of abrasion (49%) due a polishing process and finally diminishes after the final stage of abrasion (4%), showing the smallest roughness of all glazes (0.78μm). This behaviour is related to the matt glaze composition, because the glaze contains quartz and zircon (SiO_2.ZrO_2), hard materials that raise the glaze hardness and the glaze resistance to abrasion.

4. CONCLUSION

The transparent glaze is the most affected by abrasion, losing its gloss after the tests. The matt glaze is polished in the initial stages of the abrasion process, raising its gloss, then it is abraded the same way the white and transparent glazes. By the visual inspection used in the PEI method (ISO 10545) all glazes have passed the test, not being considered abraded. But the spetrophotometric and roughness meter tests showed a great variation before and after the abrasion tests, what means all the glazes were in fact visibly abraded after the tests.

The standard abrasion test for glazed tiles uses a visual inspection method to determine if a surface was abraded or not. The method requires human vision to determine the abrasion, with small accuracy and great variation of results depending on several aspects related to human and ambient variables. So, the standard test method for the evaluation of glazed tiles abrasion resistance can fail, resulting in a misinterpretation of the durability of glazed ceramic tiles.

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