THE INFLUENCE OF BODY, ENGOBE AND GLAZE ON THE TRANSIENT CURVATURES OF PORCELAIN TILE COMPOSITIONS DURING FIRING

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INTRODUCTION

Planarity is one of the most important quality characteristics of a ceramic tile. Several factors can have an impact on the manufacturing process[1]. Traditional quality control experiments can easily measure and control well-known factors such as thermal expansion mismatch and firing shrinkage[2]. Pyroplastic deformations are another important factor to keep under control. In this case, the composition should be designed to achieve the desired water absorption while staying within two parameters: firing temperature and the pyroplastic index. Aside from easy-to-detect planarity losses, there is a type of planarity defect that can only be seen against visible light reflectance. This is not a planarity defect itself, but it causes losses in aesthetic properties due to the variation of transitory curvatures in the course of firing. A strong positive curvature was detected between 950 °C and 1150 °C in the authors' previous work[2], which was directly related to this problem. The purpose of this study is to present the results of an investigation into the effect of each layer (body, engobe. and glaze) on the intensity of transitory curvature during the heating of porcelain tile.

MATERIALS AND METHODS

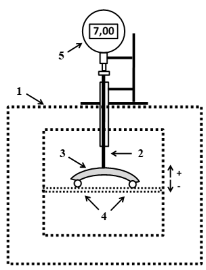
The approach of factorial design of experiments was used. To obtain 2x2x2 experimental runs, two compositions of each layer were combined. The amount of feldspar in the body was increased from 10% to 25%, while the amount of illitic clay was reduced from 50% to 35%. The frit content of the engobe composition was increased from 15% to 35%, while the feldspar content was reduced from 20% to 0%. In the matt glaze composition, the amount of dolomite was reduced from 12% to 0%, which was replaced by all other components in their own proportion. The compositions were prepared on an industrial scale. Laboratorial samples of 100x50x4 mm were prepared with 6% moisture and a pressing pressure of 40 MPa. After drying, the samples were treated with engobe and glaze in the same amount of 1 kg/m^2 via industrial wet application procedures. After drying, the samples were fired in a kiln and the curvature was measured on-line against temperature using a contact dilatometry mechanism. The heating rate was 20 °C/min, and the experiment ended when the negative curvature reached -4.0 mm or 1220 °C.

RESULTS AND CONCLUSIONS

Table 1 shows all the compositions prepared for the body, engobe and glaze. The changes are highlighted. The coefficient of thermal expansion (CTE) is also shown for each raw material as well as for the compositions. The CTE mismatch between layers was kept constant in order not to add more factors in this experimental design. Figure 1 shows the top curvature measured in each run and some selected experimental plots.

α_{325} (x10^{-6} °C^{-1})		**Cly1**	**Cly2**	**Fld1**	**Fld2**	**Tlc**
		71.5	67.8	109.0	69.6	120
S1	74.3	0.25	**0.60**	0.10	**0.00**	0.05
S2	75.0	0.25	**0.20**	0.10	**0.40**	0.05

α_{325} (x10^{-6} °C^{-1})		**Frt 1**	**Zrt**	**Cly 3**	**Kln**	**Qtz**	**Abt**	**Frt2**	**Frt3**	**Znc**	**Alm**	**Dlt**
		63.2	40.0	61.5	40.0	120	70.0	86.2	58.5	70.0	40.0	70.0
E1	70.5	**0.15**	0.11	0.23	0.09	0.19	**0.20**	-	-	-	-	-
E2	69.1	**0.35**	0.11	0.23	0.09	0.19	**0**	-	-	-	-	-
G1	65.3	-	-	-	0.10	0.03	0.23	0.16	0.25	0.01	0.10	**0.12**
G2	64.7	-	-	-	0.11	0.03	0.26	0.18	0.28	0.02	0.11	-



Cly – clay; Fld – feldspar; Tlc – talc; Frt – frit; Zrt – zirconite; Kln – kaolin; Qtz – quartz; Abt – albite; Znc – zinc; Alm – alumina; Dlt – dolomite

***Table 1**. Composition of Bodies (S1 and S2), Engobe (E1 and E3), Glaze (G1 and G2) and experimental apparatus applied to curvature measurements. 1. Kiln. 2. SiO_2 glass. 3. Sample. 4. Refractory support. 5. LVDT sensor.*

Run	S E G	Cvtr (mm)
1	S1	0.03
2	S2	0.04
3	S1E1	4.15
4	S2E1	4.13
5	S1E1G1	7.25
6	S1E1G2	5.05
7	S2E1G1	2.59
8	S2E1G2	2.69
9	S1E2G1	4.23
10	S1E2G2	2.63
11	S2E2G1	1.55
12	S2E2G2	0.08

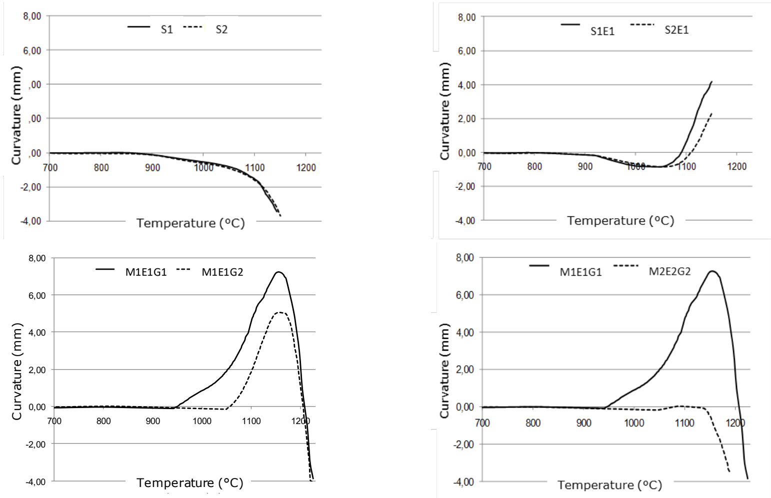


***Figure 1**. Top curvatures (Cvtr) for each experimental run and experimental plots of curvature vs temperature of selected runs.*

The findings revealed that all layers have almost the same magnitude of influence on curvature despite their thickness. At 1150 °C, the worst combination produced the highest curvature value of +7.0 mm, whereas the best combination produced negligible curvatures at the same temperature. Increasing the amount of feldspar in the body and the amount of frit in the engobe and glaze layers reduces transient curvature and appears to solve the problem. To reduce the problem, the softening of the body should be delayed while the softening of the engobe and glaze should be brought forward. The extent of such changes is determined by the constraints that each company faces.

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