SOLUTIONS TO THE PROBLEM OF GLAZE ACCUMULATION AT TILE EDGES AND ASSOCIATED FAULTS

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INTRODUCTION

During ceramic tile manufacturing, glaze tends to accumulate at the tile sides. This accumulation can already be observed during glazing, but it becomes more obvious in the fired tile and may even reach aesthetically unacceptable limits.

These accumulations at the tile edges give rise to a series of problems:

- In the newly glazed tile:
    - Difficulties in decorating and the appearance of faulty edges
    - Rise in the thickness ratio (glaze layer thickness/body thickness) in this area with regard to the rest of the tile and increased tendency to curl compared to other areas (presence of deformations)
- In the fired tile
    - Lack of surface flatness in the finished tile
    - Difficulties in surface grinding owing to different thicknesses
    - Difficulties in grinding and bevelling owing to differences in thickness and side deformation
    - Visual appearance of "topping" on the sides of the polished tile, joint area between the tiles.
    - Tile side curling owing to the differential increase of the glaze layer in this area.

This defect is more apparent when considerable layers of glaze are applied, as is the case in bell glazing, typically used in single-fire wall tile production.

This effect is more clearly visible when transparent glazes are used as a result of the visual effect of the glossy surface.

At present, the problem has become greater with the appearance of products, especially wall tiles, with considerable coats of glaze for subsequent polishing:

- Thicker glaze layer and larger accumulations at the sides
- Use of larger rectangular sizes exhibiting a greater tendency to curl
- Need for the smoothest possible finish:
    - Homogeneous surface polishing
    - Side bevelling and grinding

Besides the foregoing, a local rise (at the tile edges) of glaze thickness (where the tile body is less thick to compensate compaction) produces a greater tendency to deflection precisely in this area, which will decisively affect:

- Side deformation
- Difficulties in grinding and bevelling

The difficulties should finally be mentioned in decoration with the introduction of screen printing, flexography and rotary printing systems:

- One of the basic features of these systems is keeping a parallel machine turning axis with the tile plane.
- The presence of side irregularities causes this parallelism to vary.
- One of the main challenges of these machines is precisely being able to print to the edge. On the other hand, the edge needs to be bevelled to facilitate ejection from the press die cavity in the pressing operation. To solve this problem, the machines involved have screens, rolls or photopolymers with a certain flexibility. However, roll pressure needs to be increased (rotary screen or photopolymer) precisely in this area, in which, if the surface is raised further by glaze accumulation, decoration faults appear such as smudging or blurring.
- The application of ceramic slips (aqueous suspensions) onto flat tiles is accompanied by the associated phenomena relating to surface tension, in which the following factors play a role:
- Suspension surface tension
- Shape of the surface on which the suspension is deposited.

By surface tension (ST) is meant the force exerted at the liquid surface per unit length:

$$ST = Fl \ / \ L$$

The causes of surface tension lie in the cohesion forces which are particularly intense in liquids. The gravitational forces acting on the attraction of two molecules in a liquid are negligible compared to the Van der Waals forces. For the same distance between the molecules, the intensity of the Newtonian forces varies inversely to the square of the distance, while the other forces vary inversely as the second, third and even eighth power of the distance, and therefore grow very quickly when the molecules approach each other. Intermolecular forces only achieve extraordinary intensities at very small distances. ST can therefore also be defined as the work required to increase the surface area of a liquid on the unit surface:

- A liquid with a high ST tends to "draw together".
- A liquid with a low ST tends to "spread".

Factors affecting surface tension include:

- Liquid temperature:
  - Raising temperature produces a progressive drop of surface tension until reaching a temperature at which ST is zero. This (critical temperature) represents the boundary between the liquid and gaseous state.
  - The drop is a consequence of rise in thermal agitation, which lowers intermolecular forces.
- Presence of impurities in the liquid:
  - When the impurities accumulate at the surface, surface tension decreases.
  - When they accumulate inside the liquid or are distanced from the surface, ST remains invariable (Gibbs' law)
- The influence of impurities on ST is known as surface activity. ST will be affected in one way or another depending on the orienting activity of the hydrophilic or hydrophobic groups (as ceramic slips are aqueous suspensions).

In the case at issue, the purpose is to reduce ST to achieve maximum liquid or suspension spread over the flat tile surface.

Taking into account the relation between ST and hydrophilic or hydrophobic character, suspension drying time will be directly related to the presence of solids at the surface or inside the suspension, and will therefore be an indirect measurement of ST. In any case, bearing in mind that the detrimental phenomenon is glaze accumulation, glaze layer thickness was also measured at different distances from the tile edge to minimise the differences.

The objective of the present study was to reduce or suppress glaze accumulations at the tile edges, and study and assess the factors that influence the appearance of this phenomenon. This was tackled by studying the following features:

- Glaze-body thickness ratio.
- Form of the surface on which the glaze is applied (roughness and/or bevel).
- Temperature of the item to be glazed.
- Glaze conditions that prevent this accumulation (type, rheology and additives).
- Type of ceramic body.

EXPERIMENTAL

Materials and facilities were used under industrial conditions:

- **Materials:**
  - Body, engobe and transparent industrial porosa glaze
  - Additives:
    - Polyphosphate-based dispersant
    - Organic binder with inorganic surface-active agents

- **Test apparatus:**
  - Line pycnometer for controlling slip density
  - Ford cup (No. 4) line viscometer for controlling slip viscosity
  - Line contact thermometer for controlling the temperature of the tile to be glazed
  - Line chronometer for controlling drying time
  - Binocular magnifying glass (400x) for measuring layer thickness
  - Colorimeter

- **Laboratory testing conditions:**
  - Standard engobe (commonly used) with its respective additives:
    - Bentonite
    - Sodium tripolyphosphate
  - Standard crystalline glaze (commonly used) with its respective additives:
    - Adhesive
    - Tripolyphosphate
  - Milling water from the respective industrial plants
  - Preparation of a new engobe slip without the original additives, replaced by the proposed additives
  - Preparation of a new transparent glaze slip without the original additives, replaced by the proposed additives

- **Variable to be measured:**
  - Drying time of the glazed surface:
    - With different slips
    - With tiles at different temperatures
    - With tiles having a different type of surface
  - Thickness of the layer at different distances from the edge for each of the foregoing tiles
  - Tile colour (L, a, b)

- **Data processing:**
  - Different measurements were performed in different parts of the tile and in different tiles for each measurement or control point so as to have a representative value of the population. These data are set out in the tables and graphs.

RESULTS AND DISCUSSION

A) STARTING DATA:

A.1) Layer thickness at different distances from the fired tile edge (standard in-plant application):

The starting data are experimental data both for redware and whiteware bodies, relating to the layer thickness at different distances from the edge, presented in Table 1

Distance from the tile edge (cm)	0.5 cm	1.5 cm	2 cm	4 cm
BASE	0.199	0.283	0.261	0.261
ENGOBE	0.121	0.182	0.171	0.176
TOTAL	0.320	0.465	0.432	0.437

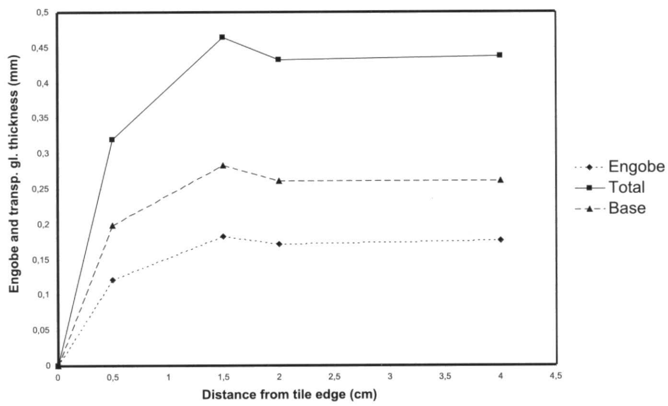

Figure 1. Table 1. *Engobe and transparent glaze layer thickness at different distances (~~µm~~) from the tile edge. Measured on fired tiles.*
cm

To observe the differences in the layer at other distances from the edge and compare the evolution, measurements were performed on other tiles at different cm from the edge.

Distance from the tile edge (cm)	0.5 cm	1.0 cm	2.0 cm	4.0 cm	6.0 cm	10.0 cm
BASE	0.326	0.313	0.314	0.316	0.316	0.320
ENGOBE	0.146	0.139	0.131	0.133	0.126	0.119
TOTAL	0.472	0.452	0.445	0.449	0.442	0.439

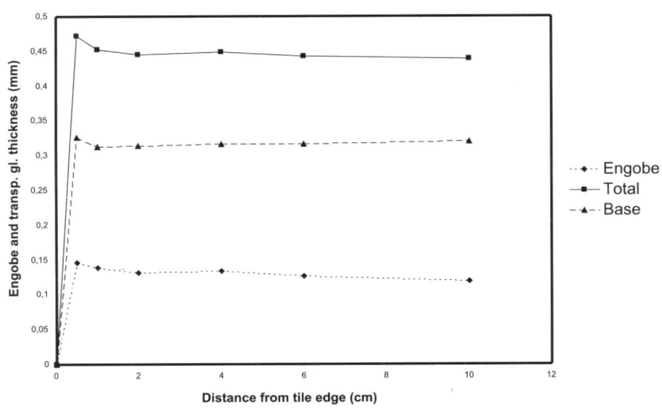

Figure 2. Table 2. *Engobe and transparent glaze layer thickness at different distances (cm) from the tile edge. Measured on fired tiles.*

The absolute values between both populations have no comparative value, as experimental data are involved from different production lines.

A series of tendencies can be observed:

- Tile total glaze accumulation peaks at around 1.5 cm
- Low values are initially found (corresponding to the bevelled area), a maximum is reached at about 1.5/2.0 cm, which gradually decreases to 3/4 cm to rise slightly and keep steady.
- The tiles measured in cm present a maximum at the start, close to the edge, which then gradually decreases, though it exhibits a slight inflection at 2/3 cm.
- The main accumulation therefore occurs within 3 cm of the edge, then remains more or less constant, with an inflection at 2/3 cm coinciding with the area that is visually seen to be "cut off" and which is locally known as the "TV frame".
- In both cases, in agreement with the type of application, the transparent glaze layer is much thicker than the engobe layer.
- The differences in thickness from the edge are smaller in the case of the engobe than the glaze. The value, found as a percentage difference in order to allow comparing it to that of the glaze, reaches 30 % in the transparent glaze and 17 % in the case of the engobe. This indicates better packing of the engobe. Furthermore, the engobe is applied onto the hot tile (reducing engobe tension), whereas the transparent glaze is applied onto a colder engobe (ST decreases less).
- The differences are measured on fired tiles.
- Taking into acount that the difference in total glaze layer thickness between the cold and fired tile is about 0.5 mm, the following differences in height were found:
    - Green surface to be screen printed: Differences of 0.3 mm, which can really be associated with glaze accumulation, if the highest part is considered in respect of the straight stretch.
    - Fired surface to be polished or bevelled: Differences of up to 0.2 mm if the bevelled part is taken, and 0.04 mm from the straight stretch, which can really be associated with glaze accumulation.

These were the starting data on the differences in layer thickness found in industrial production, used for comparison to verify the improvement.

As a CONCLUSION to the first collection of data, the following may be highlighted:

- The glazed surface is not flat.
- There are differences of up to 0.3 mm in the best of cases.
- The difference is a result of glaze accumulation near the tile edge.

A.2) Differences in layer thickness at various distances from the fired tile edge (different application conditions):

To verify the factors influencing the appearance of greater or lesser glaze accumulation at the sides, industrial tiles were prepared under different conditions:

- Different temperature of the tile to be glazed
- Different amount of applied glaze
- Different roughness of the surface to be glazed

Distance from the tile edge	0.5 mm	1,5 mm	2 mm	4 mm	6 mm	10 mm
°C						
120 °C	0.372	0.351	0.365	0.369	0.348	0.372
85 °C	0.418	0.387	0.369	0.359	0.359	0.362

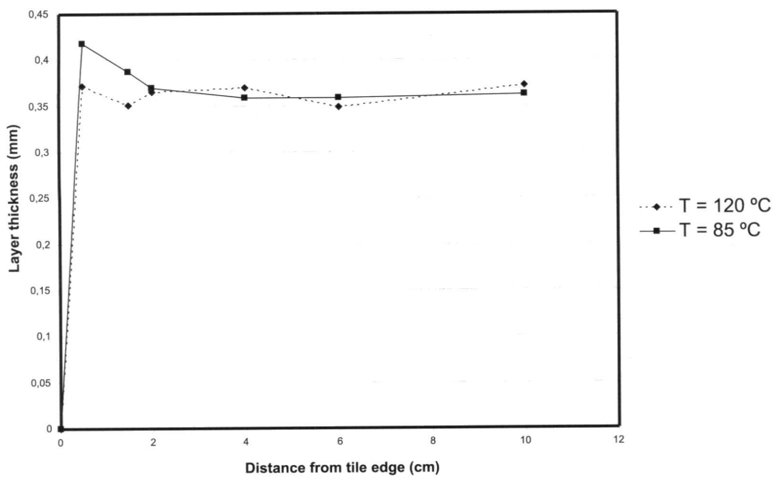

Figure 3. Table 3. Engobe and transparent glaze layer thickness at different distances from the tile edge. Measured on fired tiles ***(different temperatures of the tile to be glazed)***

Distance from the tile edge	0.5 mm	1,5 mm	2 mm	4 mm	6 mm	10 mm
Grams						
Std	0.372	0.351	0.365	0.369	0.348	0.372
+ 50 %	0.457	0.401	0.382	0.397	0.365	0.365

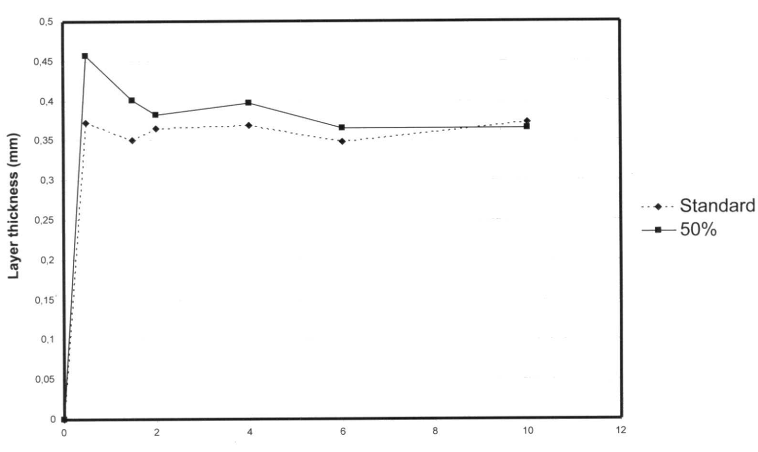

Figure4. Table 4. Engobe and transparent glaze layer thickness at different distances from the tile edge. Measured on fired tiles ***(different amounts of applied glaze)***

Distance from the tile edge	0.5 mm	1,5 mm	2 mm	4 mm	6 mm	10 mm
Smooth	0.372	0.351	0.365	0.369	0.348	0.372
Rough	0.389	0.372	0.380	0.393	0.358	0.362

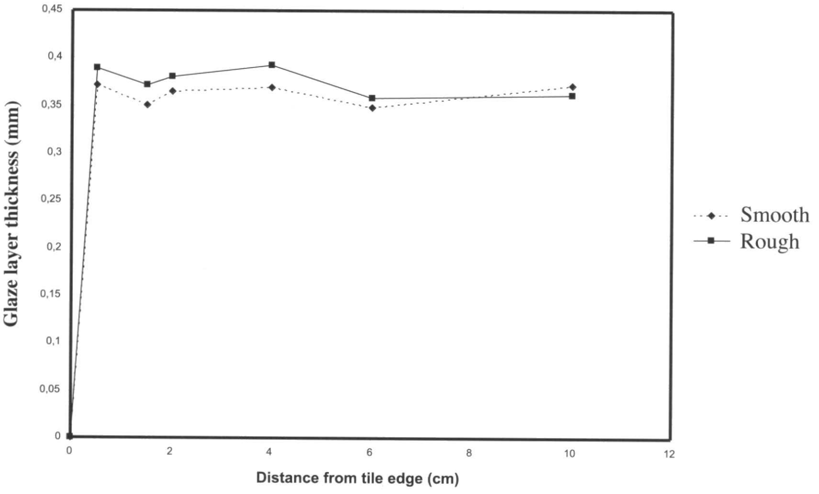

Figure 5.Table 5. *Engobe and transparent glaze layer thickness at different distances from the tile edge. Measured on fired tiles*
(different roughness of the surface to be glazed)

The following may be observed from the data presented in Tables 3, 4 and 5:

- The surface temperature of the tile to be glazed has a pronounced effect on the applied glaze layer. As temperature rises, the thickness of the glaze layer decreases.

- This variation with temperature is as important as the usual variation of the mark of applied glaze (adjustment).

- The variation in glaze thickness associated with variations in the temperature of the surface to be glazed will be a prime factor in the swings in background colour.

- Surface roughness has a marked effect on glaze layer thickness.

- Roughness raises layer thickness.

- Roughness has a similar influence to the variations in quantities of applied glaze of 30% and will have a direct effect on shades.

- Tile models with an irregular edge were most prone to accumulate glaze.

- Surface roughness and temperature have a pronounced influence on the thickness of the deposited layer.

- Taking into account that tile edges are most exposed to temperature swings and roughness, these will be the most variable points in the layer thickness.

A.3) Engobe and/or transparent glaze layer drying rates:

The glaze layer drying times on the tile were also used as starting data. The test was performed with standard glazes (engobe and transparent glaze) used in production, referenced std, as well as with these same glazes, in which the additive charge was replaced by a new charge containing the additives to be studied.

This test was conducted in the laboratory, applying the glaze with a lab applicator onto a previously heated tile body. The applications were performed using the same surface area and temperature, and the time needed to produce a fully dry surface was measured (in seconds).

GLAZE	DENSITY (kg/l)	VISCOSITY Ford 4 mm (SEC)	IMPROVEMENT IN DRYING TIME (SEC.)
STD engobe	1.85	56	-
Transp. gl. 18	1.83	105	-
Transp. gl 42	1.84	86	-
Engobe with "additive"	1.87	45	8
Transp. gl with "additive"	1.84	95	11
Transp. gl "additive"	1.83	69	16

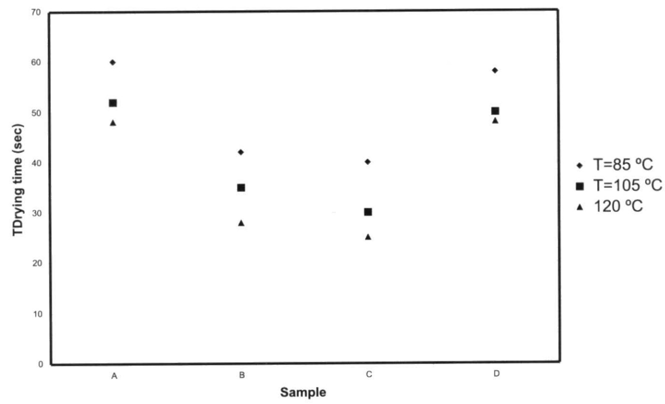

Figure 6. Table 6. *Glaze layer drying rates for the different glazes used (engobes and transparent glazes)*

- A noticeable improvement is found in the drying rate on incorporating the additives.
- Taking into account that for standard industrial application rates (tile temperature of 80/90 ºC and about 20 g engobe and 90 g transparent glaze for a 20x20 to produce false polished products) drying times are about 60 seconds, so that a reduction of 30/40 % would be achieved, bringing drying times down to 45 seconds.

B) INDUSTRIAL TEST DATA. TRIAL LINE

B.1) Drying time. Experiment 1.

The drying time of industrially produced slips was controlled.

Standard production slips (std) were used as well as the same std slips in which the additives were replaced by test additives.

The slips were applied to tiles at different temperatures.

Tile temperature in the application (drying time)	D (kg/L)	V (sec)	125 ºC 1	105 ºC 2	85 ºC 3
A: Std engobe std + std transp. gl.	1.88 + 1.84	28 + 105	48	52	60
B: Std engobe + transp. gl. with "additive"	1.88 + 1.86	28 + 95	28	35	42
C: Engobe with "additive" + transp. gl. with "additive"	1.90 + 1.86	35 + 95	25	30	40
D: Engobe with "additive" + std transp. gl	1.90 + 1.86	35 + 100	48	50	58

Table 7. See Figure 6. *Drying time (sec). Tiles at different temperatures.*
Influence of the additive charge
(Application of 20 g engobe and 90 g transp. gl. to 20x20)

- It can be observed that drying time is basically controlled by the transparent glaze, in accordance with the greater applied amount of material.
- Drying times are drastically reduced on incorporating the "additive" in the transparent glaze. The total drying time of 58/60 sec is reduced to 40/42 sec at tile temperature of 85 °C
- The drop is even greater at higher temperatures.

B.2) Layer thickness at different distances from the tile edge for the industrially produced tiles in the foregoing tests.

Distance from the tile edge	0.5 mm		1.0 mm		2 mm		4 mm		5 mm		10 mm	
	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze
A1	0.138	0.670	0.138	0.637	0.127	0.630	0.138	0.617	0.123	0.611	0.131	0.611
A3	0.164	0.676	0.157	0.637	0.157	0.617	0.157	0.611	0.151	0.604	0.151	0.597
B1	0.170	0.740	0.160	0.735	0.170	0.676	0.161	0.668	0.169	0.670	0.167	0.671
B3	0.171	0.742	0.164	0.755	0.157	0.722	0.164	0.719	0.167	0.719	0.164	0.709
C1	0.170	0.683	0.164	0.689	0.170	0.643	0.170	0.644	0.170	0.637	0.169	0.637
C3	0.171	0.683	0.171	0.686	0.170	0.650	0.177	0.647	0.183	0.647	0.180	0.649
D1	0.170	0.706	0.170	0.689	0.183	0.657	0.180	0.653	0.184	0.653	0.183	0.657
D3	0.183	0.657	0.177	0.676	0.164	0.637	0.170	0.627	0.170	0.621	0.171	0.617

Table 8. *Engobe and transparent glaze layer thickness at* ***different distances from the tile edge.*** *Measured on fired tiles (See figures 7, 8, 9, 10, 11 and 12).*
(Additives on glazes)

The following trends can be observed:

- Incorporating additives to glazes and engobes accelerates drying time.
- Incorporating additives increases layer thickness.
- With the same additive proportion, the glaze layer is thicker at lower temperatures, i.e., the glaze layer is thicker with a colder tile.
- This effect is lessened by incorporating additives, in relation to the std tile.
- The differences in layer thickness are lessened by incorporating additives.

B.3) Drying time. Experiment 2.

The drying time of industrially produced slips was controlled.

Standard production slips (std) were used as well as the same std slips in which the additives were replaced by different test additives from those used in Experiment 1.

The slips were applied to tiles at different temperatures.

Tile temperature in the application (drying time)	D (kg/L)	V (sec)	**125 °C 1**	**105 °C 2**	**85 °C 3**
A: Engobe + transp. gl.	1.89 + 1.84	37 + 100	50	55	60
B: Engobe with "additive" + transp. gl.	1.90 + 1.84	36 + 100	40	45	55
C: Engobe with "additive" + transp. gl. with "additive"	1.90 + 1.84	35 + 90	40	45	55

Table 9. See figure 13. *Drying time (sec.). Tiles with different temperatures*
Influence of the additive charge
(Application of 20 g engobe and 90 g transp. gl. on 20x20)

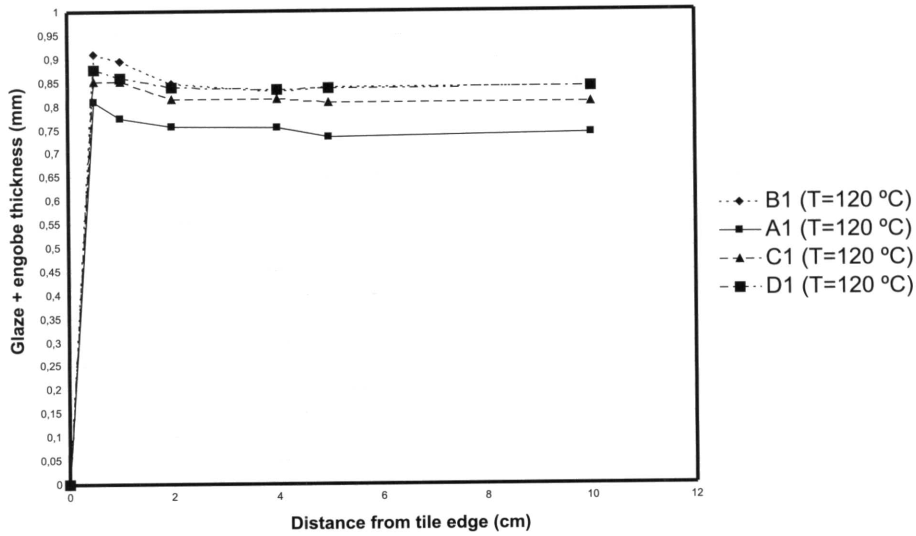

Figure 7. Tiles A1, B1, C1 and D1.

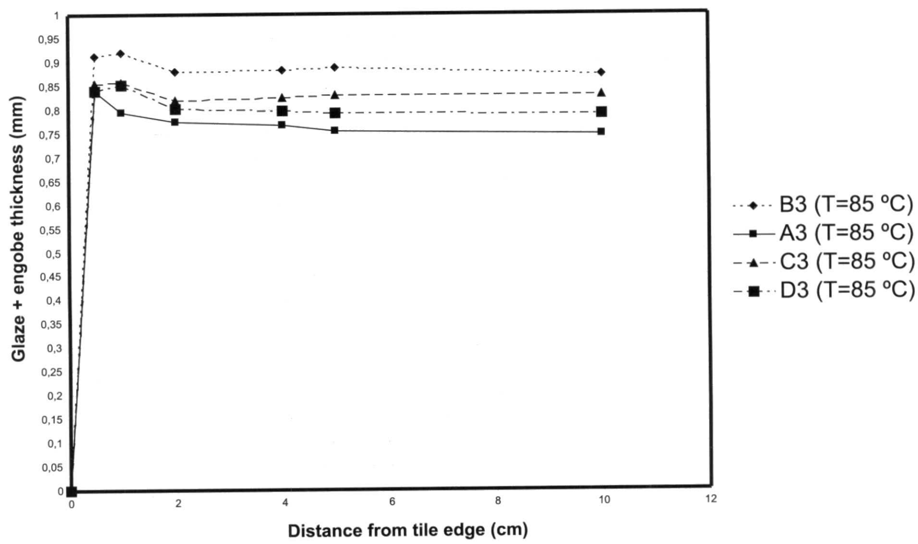

Figure 8. Tiles A3, B3, C3 and D3.

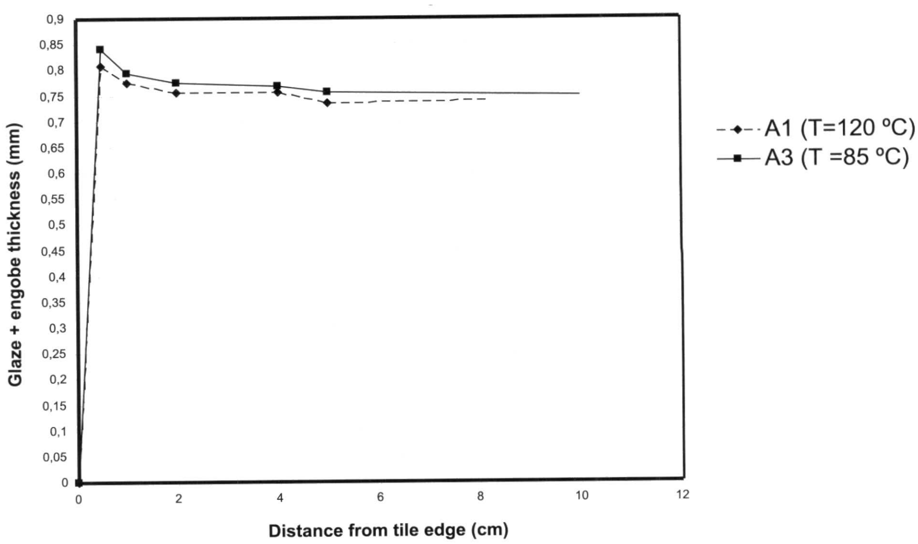

Figure 9. Tiles A1 and A3

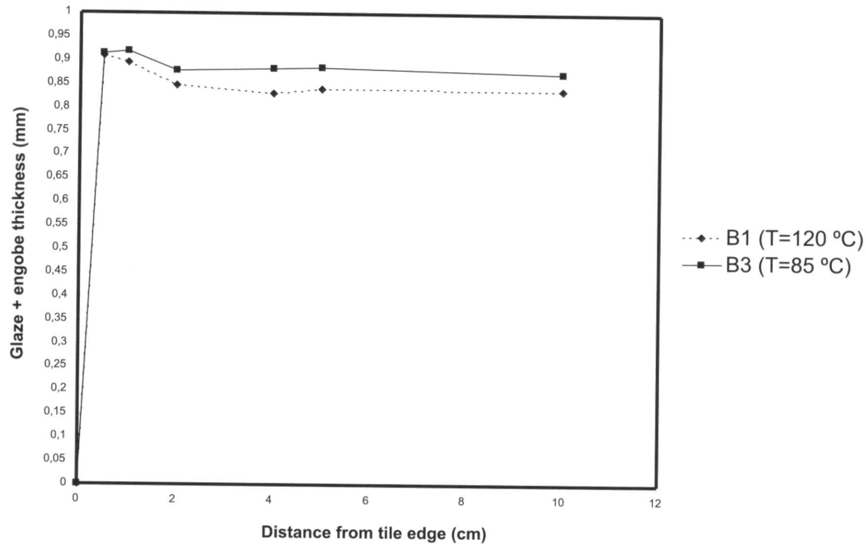

Figure 10. *Tiles B1 and B3.*

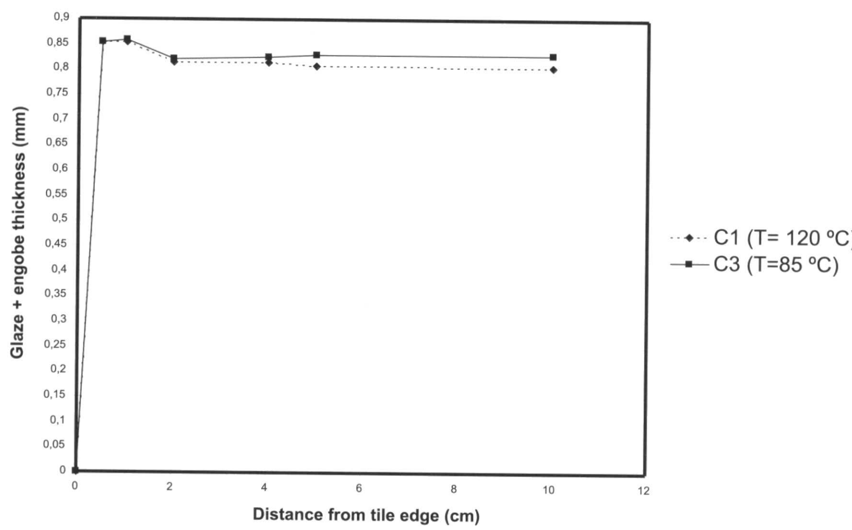

Figure 11. *Tiles C1 and C3.*

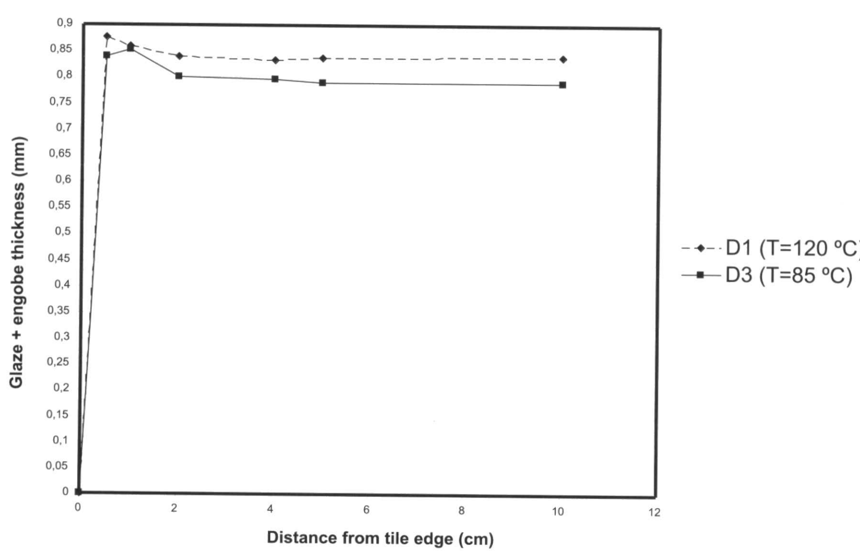

Figure 12. *Tiles D1 and D3.*

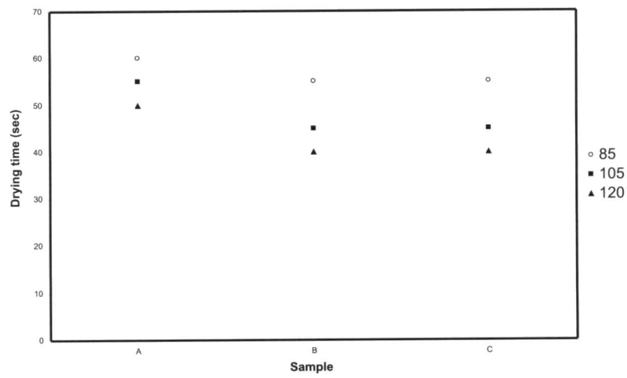

Figure 13. *Drying time (sec.). Tiles with different temperatures.*

B.4) Layer thickness at different distances from the tile edge for the industrially produced tiles in the foregoing tests

Distance from the tile edge	0.5 mm		1,0 mm		2 mm		4 mm		5 mm		10 mm	
	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze
A1	0.134	0.660	0.132	0.620	0.120	0.622	0.132	0.608	0.120	0.609	0.130	0.609
A3	0.160	0.666	0.150	0.627	0.150	0.605	0.150	0.608	0.149	0.602	0.149	0.592
B1	0.164	0.730	0.158	0.715	0.165	0.666	0.149	0.653	0.160	0.640	0.152	0.601
B3	0.164	0.740	0.161	0.742	0.152	0.701	0.162	0.700	0.157	0.701	0.140	0.666
C1	0.172	0.677	0.164	0.682	0.165	0.639	0.170	0.614	0.168	0.608	0.160	0.607
C3	0.177	0.680	0.177	0.694	0.168	0.650	0.174	0.625	0.180	0.631	0.165	0.611

Table 10. *Engobe and transparent glaze layer thickness at* ***different distances from the tile edge.*** *Measured on fired tiles (Additives on glazes).(See figures:14, 15, 16, 17 and 18).*

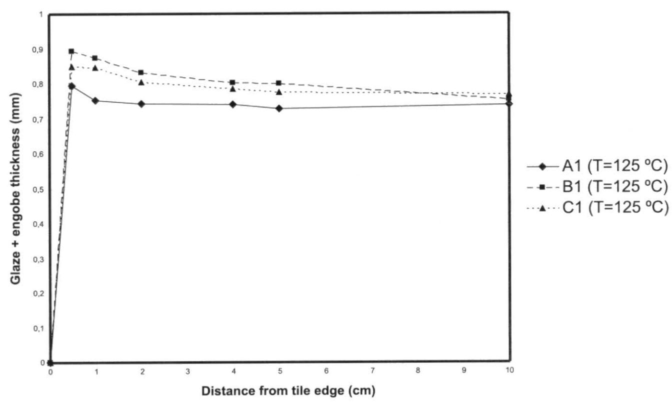

Figure 14. *Tiles A1 (additive in engobe) and C1 (addit. in engobe and transp. gl.).*

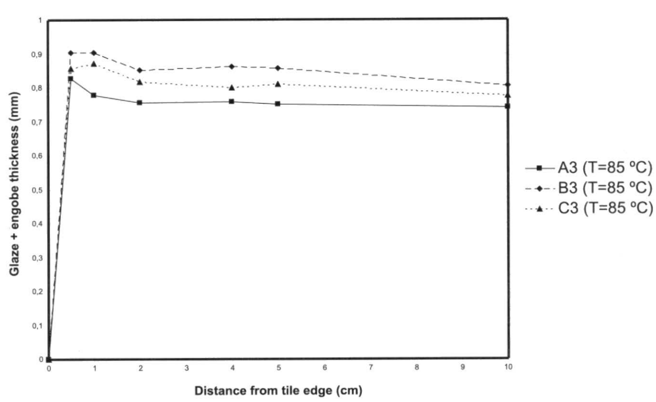

Figure 15. *Tiles A3 (additive in engobe) and C3 (addit. in engobe and transp. gl).*

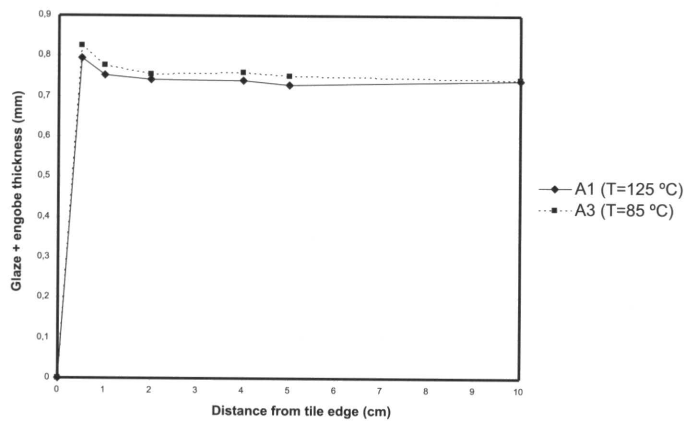

Figure 16. *Tiles A1 and A3 (std)*

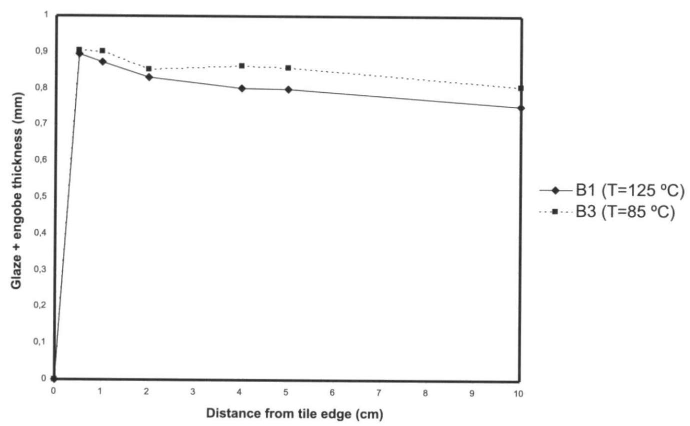

Figure 17. *Tiles B1 and B3 (std).*

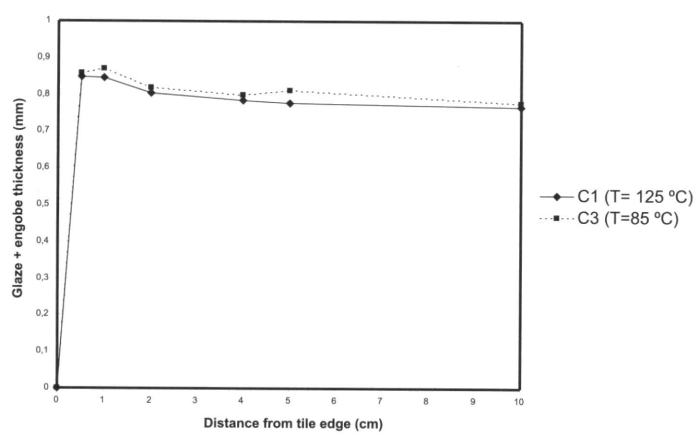

Figure 18. *Tiles C1 and C3 (additive in engobe and tansp. gl.).*

The following trends can be observed:

- Incorporating additives to glazes and engobes accelerates drying time, though less than in the case of the foregoing additives.
- Incorporating additives increases layer thickness.
- With the same additive proportion, the glaze layer is thicker at lower temperatures, i.e., the glaze layer is thicker with a colder tile.
- This effect is lessened by incorporating additives, in relation to the std tile.
- The differences in layer thickness are lessened by incorporating additives.

B.5) Influence tile colour.

In view of the results, tile colour was measured (L,a,b) to determine the possible differences in colour owing to changes in tile temperature.

This measure was justified by the fact that different layer thicknesses were found at the same std application on varying tile temperature.

Temperature (ºC)	Thickness Layer (mm)	L	a	b	dE
85	0.806	87.6	2.76	7.34	-
100	0.758	88.1	2.59	7.14	0.56
120	0.714	87.8	2.60	7.08	0.60

Table 11. Variation of colour (L,a,b) *with temperature variation of the tile to be glazed (constant application). (layer thickness measured at the colour measurement point 10 mm from the edge)*

- The colder tile exhibited a greater layer thickness.
- The hotter tiles, which dried faster, exhibited a thinner layer and a less yellow colour.
- The tiles that are slower to dry yellow more. This had already been observed in practice and was now confirmed experimentally.
- The variations are not very significant as important temperature changes are required (layer thickness) to produce shades.

B.6) Influence of the side bevel

To observe the influence of the shape of the side bevel on glaze accumulation in this area, industrial tiles were produced with a normal bevel on one side and a straight bevel on the parallel side (cut on the green tile).

Distance from the tile edge	1 mm		3 mm		5 mm		10 mm		30 mm		100 mm	
	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze	Engobe	Glaze
R1	0.2	0.30	0.15	0.37	0.16	0.39	0.16	0.4	0.14	0.37	0.14	0.36
R2	0.14	0.29	0.15	0.31	0.18	0.34	0.17	0.37	0.14	0.38	0.13	0.37
B1	0.16	0.25	0.16	0.34	0.13	0.41	0.14	0.37	0.14	0.35	0.13	0.38
B2	0.2	0.32	0.18	0.32	0.17	0.36	0.16	0.32	0.13	0.38	0.13	0.39
INDUS	0.12	0.32	0.16	0.36	0.13	0.35	0.16	0.33	0.14	0.33	0.12	0.34
TRIAL	0.15	0.26	0.16	0.29	0.17	0.34	0.16	0.33	0.16	0.34	0.13	0.34

R: Redware body; B: Whiteware body; 1: Straight bevel; 2:Normal bevel; Indust: Std industrial production; Trial: Industrial production with additives.

Table 12. Variation of layer thickness. Fired tile. *With bevel shape. Different distances from the tile edge (constant application). (See figures 19-24; next page).*

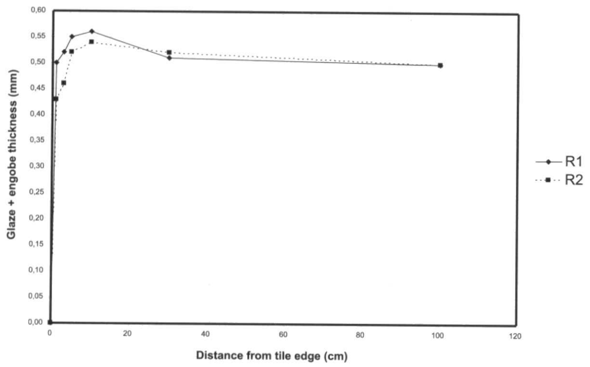

Figure 19. Variation of layer thickness with bevel shape.

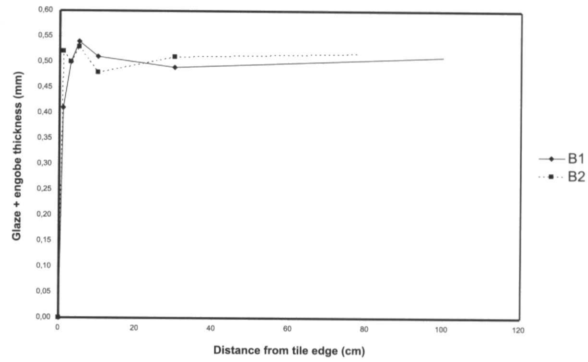

Figure 20. Variation of layer thickness with bevel shape.

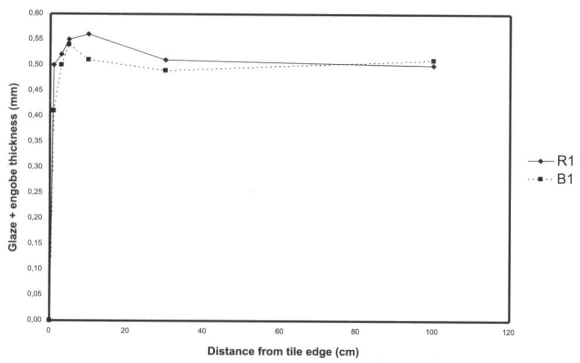

Figure 21. Variation of layer thickness with bevel shape.

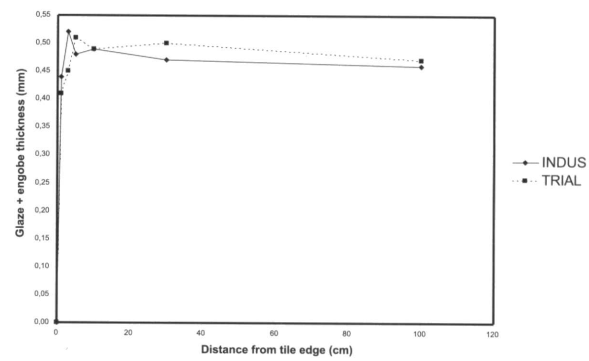

Figure 22. Variation of layer thickness with bevel shape.

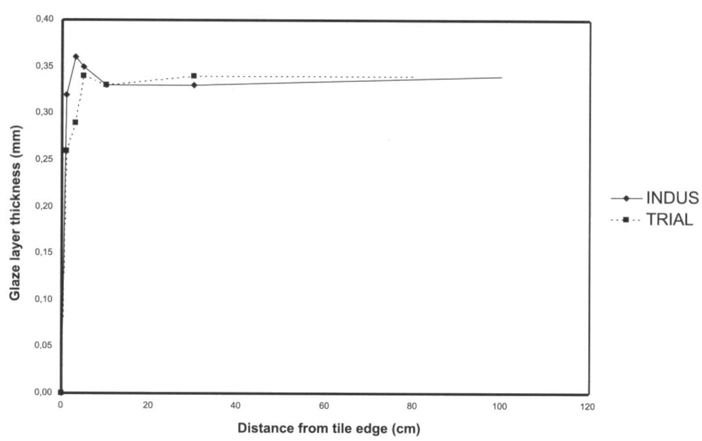

Figure 23. Variation of layer thickness with the redware body.

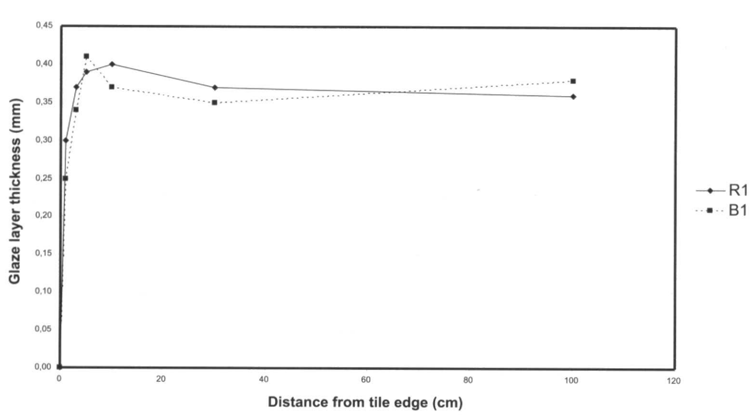

Figure 24. Variation of layer thickness with bevel shape.

The following may be observed with regard to the line data during the industrial tests:

- 15-20 % reduction in drying time with the incorporation of the studied additive.

The following trends were found:

- There is a greater accumulation in the area near the edge with the straight bevel than in the same area for the standard bevel.
- A thinner layer was found with the whiteware body (successively glazed bodies)
- The incorporation of the additives gave rise to the effects already found:
- Slight increase in layer thickness
- Greater drying rate
- Less difference between edge and centre layer thickness.

CONCLUSIONS

The influence of certain factors on the presence of a thicker layer of glaze at ceramic tile edges was studied:

- **Quantity of glaze:**
  - **A minimum is found at the side and a maximum at about 1,5/2,0 mm from the edge. There is a depression at about 2/3 mm followed by a rise, and then a steady thickness.**
  - **The differences in the layer were smaller in the case of the engobe than with the transparent glaze, owing to better packing.**
  - **The engobe is applied to a hotter surface and this lowers surface tension.**
- **Surface roughness:**
  - **The greater the surface roughness, the thicker the layer.**
- **Bevel shape**
  - **Greater glaze accumulation with the straight bevel than with the traditional curved bevel.**
- **Body type**
  - **Greater accumulation, greater height and greater extension of the glaze accumulation with the redware body than with the whiteware body.**
- **Tile temperature during glazing.**
  - **The greater the tile temperature, the thinner the glaze layer.**

The foregoing evidences the fact that there are measurable differences in glaze layer thickness across the tile, which can produce the problems mentioned during firing or subsequent surface treatment of the fired tile, besides the variation in the thickness ratio (glaze/body), which will produce a greater tendency for the tile to curl. The glaze/body thickness ratio exceeds 30% if the cut at 5cm from the edge is compared to that at 1cm from the edge.

Some of the forgoing factors are variable, so that swings in layer thickness will be found. These factors are especially sensitive at the tile edges, so that this will be the most affected region.

The incorporation of additives of a surface-active dispersant type has a pronounced effect on the following factors:

- **Drying rate. Additives raise drying rate.**
- **Consistent glaze layer thickness at different temperatures and roughnesses. Additives lessen layer thickness variations caused by tile temperature differences.**

Additives of a surface-active dispersant type affect slip surface tension and are a convenient way of stabilising glaze suspensions with regard to the studied phenomenon, while providing faster drying and hence the absence of related problems.

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