MOISTURE EXPANSION OF POROUS BISCUIT BODIES - REASON OF GLAZE CRACKING

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This article presents the results of the thermal expansion coefficient (TEC) of the four porous ceramic bodies and their moisture expansion as well as the TEC of glazes and glaze cracking on these bodies. TEC (20-540 °C) of the tested porous ceramic biscuits were relatively low, depending on the kind of the biscuits close to $52 \times 10^{-7}K^{-1}$ and $72 \times 10^{-7}K^{-1}$, respectively. If the TEC of the glaze applied on the biscuits is higher than the TEC of the biscuit by more than about $10 \times 10^{-7} K^{-1}$, the glaze is cracking in the kiln during the cooling of samples. The glaze on the biscuit is under high tensile stress. If the difference between the TEC of the biscuit and of the glaze is in the range of $(-10 \text{ to } 0) \times 10^{-7}K^{-1}$, the glazes can crack on the glazed body as late as several days after firing. The glazes are first under slight tensile stress, which slowly increases due to the moisture expansion of these porous biscuits. The moisture expansions of the tested biscuits are relatively high, from 0.05 up to 0.1% $(100\Delta l/l_o)$ depending on the kind of the biscuits. Such moisture expansion leads to the development of hair-cracks on the glaze early after firing. If the TEC glaze is lower than that of the biscuit the glaze on the ceramic body is under compression stress. The cracks did not appear even after exposure of the glazed samples to vapour (98 °C/12 hours).

INTRODUCTION

The thermal expansion coefficient (*TEC*) is the characteristic material constant. The value of *TEC* of the glazes (the homogenous amorphous solid solution) is considered to be the additive function of glaze composition at the specified temperature range and can be approximately calculated according to the equation (1), suggested by Winkalmann and Schott:

$$3\alpha = \beta = W_1 \beta_1 + W_2 \beta_2 + W_3 \beta_3 + W_4 \beta_4 + \ldots\ldots W_n \beta_n \quad (1)$$

where α - linear thermal expansion coefficient (K^{-1}), β - volume expansion coefficient (K^{-1}), W - amount of compound in the glaze (wt.%), β_x - volume expansion coefficient of the individual compound (K^{-1}) [1,2].

The ceramic itself belongs to the group of polycrystalline, multiphase materials. The thermal expansion coefficient of ceramic body can be calculated on the basis of additive function of the *TEC* of individual solid phases (crystalline and/or amorphous phases) and their volume fraction in material. The effect of porosity on the *TEC* value is very small at temperatures below 700 °C and also the granulometry has almost no influence on the *TEC* value.

The choice of an adequate glaze for biscuit requires knowledge of the basic characteristics of glazes as well as of the biscuit, mainly the firing temperature of the glaze, the dilatation curve of the biscuit and of the glaze below T_g temperature (transformation point of glass). The match of dilatation behaviour between biscuit and glaze is a basic and unavoidable requirement so that tensile and/or compression stress is not originating in the glaze during cooling in the end of firing process. Tensile and higher compression stress in the glaze releases via cracks forming. The number and shape of the cracks in the glaze is dependent on the value of *TEC* difference between biscuit and glaze, also on glaze coat thickness (usual 150 - 250 μm), on nature of glaze-biscuit interface which forms during the firing, on the firing quality of the glaze and on the cooling rate [3,4].

The compression stress $(+\sigma)$ arises in the glaze if $\sigma_{glaze} - \sigma_{body} > 0$, i.e. the *TEC* of the glaze is lower than that of the ceramic body, on the other hand the tensile stress in the glaze $(-\sigma)$ generates if $\sigma_{glaze} - \sigma_{body} < 0$, i.e. the *TEC* of the glaze is higher than that of the body [2]. The equation (2) allows to estimate the values of the stress in the glaze covering the biscuit while the equation (3) the stress in the glazed body, suggested by Salmang a Scholze.

$$\sigma_{glaze} = \frac{(\alpha_{body} - \alpha_{glaze}) \cdot \Delta T}{\dfrac{1 - \mu_{glaze}}{E_{glaze}} + \dfrac{1 - \mu_{body}}{E_{body}} \cdot \dfrac{d_{glaze}}{d_{body}}} \quad (2)$$

$$\sigma_{body} = \frac{(\alpha_{glaze} - \alpha_{body}) \cdot \Delta T}{\dfrac{1 - \mu_{body}}{E_{body}} + \dfrac{1 - \mu_{glaze}}{E_{glaze}} \cdot \dfrac{d_{body}}{d_{glaze}}} \qquad (3)$$

σ - stress (Pa), α - linear thermal expansion coefficient (K^{-1}), d - thickness of body and/or glaze coat, E - elasticity module (E_{glaze}, $E_{body} \cong 60 \times 10^9$ N/m^2), μ - Poisson constant (≈ 0.20; for the body and the glaze) [2,5].

The glaze resists better to compression stress than to the tensile stress. Compression stress load capacity of the glaze is 10-15 times higher than for the tensile stress. In fact, it is recommended that the glaze be under gentle compression stress, about 15-20 MPa, because it has positive influence on the mechanical strength of product. Such glaze stress arises when the *TEC* of the body is by about 5×10^{-7} K^{-1} higher than the *TEC* of the glaze, in the other words no more than 0.04 % = 100 $\Delta_{(body-glaze)}l/l_o$ [1,4]. The excess of the value of compression or tensile strength of the glaze leads to its cracking just during the cooling of the glazed ware, as well as immediately after the firing.

Cracks in the glaze can arise even after a long time since the firing. This phenomenon is usual for the glazed porous bodies, which are exposed to moist and variable thermal changes. If the body interacts with humidity, this results in its moisture expansion. The stress in the glaze gradually changes and tensile stress is rising. In case of the compression stress in the glaze the moisture expansion of the body can lead to the elimination of this stress, it can even cause tensile stress. The long *Haarrisse* cracks are forming if the value of the stress exceeds the value of the tensile strength of the glaze. The first cracks in the glaze can appear even after several years of usage.

The authors [1,5,6] treat in details the glaze defects, which are caused by difference in the dilatation behaviour of the glaze and of the ceramic body. The tests enable to define the reason of the crack formation. The tests evaluate:

- thermal expansion of the glaze and of the body,

- resistance of the glaze cracks at forming the sudden change of temperature (Harkort test of fast cooling of glaze on the ceramic body),

- moisture expansion of ceramic body (autoclave test), autoclave test can be completed by measurement of body dilatation up to the temperatures of 550-600°C.

The aim of the work is to investigate the dilatation and the moisture expansion of four porous ceramic bodies. These ceramic materials are suggested to be used for production of glazed stove tiles (double firing process). Their dilatation behaviour is discussed in relation to the dilatation of selected middle-temperature and low-temperature melting glazes and to formation of glaze stress and cracks.

EXPERIMENTAL

Thermal linear expansion coefficient was measured on the body prepared from:

- plastic coarse-grained body compound from Slovak clays and light chamotte (grain size up to 2 mm, relative humidity about 18.5-19.5 wt.%),

- fine plastic body prepared by grounding of the coarse-grained body (grain size with a maximum ratio of 4 wt.% of sizes above 0.09 mm, relative humidity about 20.5-21.5 wt.%),

- cast slip body compound from the granulate GW/K-10/SK, low-absorbing fire clay and water in weight ratio of 48 : 32 : 20,

- plastic body KMO 4005 SG with chamotte (grain size up to 0.5 mm, relative humidity about 15-15.6 wt %) (table 1).

The specimens, if made from the plastic body, were pressed and if made from the cast slip, were cast into the plaster mould. The green bodies were fired in the gas-heated chamber kiln (VULCANO, Fratelli Ficola, Italy) maintaining the following conditions: temperature 1030 °C, firing time 24 hours, holding time 1.5 hours at maximum temperature of 1030 °C). The biscuits were then cut into blocks size $50 \times 5 \times 8$ mm.

Table 1. Basic characteristics of tested biscuits.

body	producer	firing temperature (°C)	water absorption (%)	labelling of samples
plastic fine grained	ŽIAROMAT a.s. KALINOVO, Slovakia	940 -1060	21-18	plastic J
plastic coarse grained		940 - 1060	21-18	plastic H
plastic	WBB Fuchs Keramische-Massen, Germany [7]	1030 - 1150	12-10	plastic N
cast slip		1000 - 1100	17-13	casting N

Some of the blocks were dried at a temperature of 105 °C before the measurement on the dilatometer E402 (Netzsch, Germany). The thermal expansion of the biscuits was measured at temperatures of up to 1060 °C the heating and cooling rate was 2 °C per minute, simulating thus the cooling schedule of the maturing firing at the factory.

From each kind of body two or three blocks were exposed to water vapour in autoclave at the conditions: $t \cong 110$ °C, $\tau \cong 15$ hours. The dilatation of the biscuits was measured up to the temperature of 575 °C only immediately after the autoclave treatment [1].

The list of testing glaze and the preparation techniques of glaze blocks for the dilatation measurement are given in table 2. The dilatation of glazes was measured at the same conditions as those of the bodies but up only to the deformation temperature of the glazes. The thermal linear expansion coefficients at a determinate temperature range ($TEC_{(20-T)}$) were evaluated for all specimens.

The cracking of the coating glazes on the body (table 2) was evaluated for the cast slip body (N) and fine plastic body (J). The biscuits fired in the chamber kiln (VULCANO, Fratelli Ficola, Italy) were poured by

the glazes. The glaze coated bodies were fired in the laboratory electric furnace LM 212.11 (Germany) in the temperature range of 960 - 1 060 °C according to the kind of glaze. The cooling rate from temperature of 700 to 100 °C was 2 °C per minute. When the specimens got cooled their surfaces were wet painted by ink and the presence of cracks was visually evaluated. The additional evaluations were done after 5 and 72 hours and later on the specimens with the glaze without the cracks were dipped into water for 1 minute.

RESULTS AND DISCUSSION

Linear dilatation of the porous ceramic bodies

The dilatation curves on the heating and cooling of porous bodies (table 1) are shown in figure 1. The cooling curves are recalculated with respect to the sintering shrinkage of the bodies. From the above records it is obvious that the cast body N and plastic body N dilate identically. Their dilatation is higher than the plastic bodies J and H. On the other hand there are small differences in the thermal expansion between the plastic fine (J) and the coarse-grained body (H) even though

Table 2. Basic characteristic of glazes and preparation of the glaze bulks for dilatometry.

internal labelling of glaze /producer	characteristic – colour/ covering ability/ (compound) – firing temperature	preparation of bulk		size of block (mm)
KK 406 / Glazúra - Roudnice nad Labem (Czech)	- olive-green, glossy/ transparent/ (PbO- 49.9%, Cu ,Fe) - 940- 1000°C	glaze was melted in melting-pot at 980 °C/1.5 h	the blocks were pulled from the melt, blocks were reheated on ceramic waffle protected by kaoline to the temperature of 800°C and tempered 5-10 min with subsequent cooling at a rate of 2 °C/min.	∅ 5 × 35
KK 610 / fa Glazúra – Roudnice nad Labem (Czech)	- light brown, glossy/ transparent/ (PbO-52, Fe, Mn, Ni) - 980-1000°C	glaze was melted in melting-pot at 980 °C/ 1.5 h		∅ 5 × 50
KK 001 fa Ferro (Holland)	- cream-white, glossy/semi-covering/ (PbO-15%, SnO,ZnO, 12 % wait fired ton) - 980-1060°C	glaze was melted in melting-pot at 1050 °C/ 1.5h		∅ 6 × 45
KK 002 Reimbold&Strick (Italy)	- white, glossy/ semi-covering/ - 960 – 1060°C	glaze was melted in ceramic tank at 1010 °C/ 1.5 h	tanks with glaze were cooled at a rate 2 °C/min. the blocks were cut from the glazes after cooling (surface of tank was painted with kaoline suspension)	8 × 8 × 50
KK 112 KERMAT s.r.o. Lučenec (Slovakia)	- satin-white, matt / covering - 970-1020 °C	glaze was melted in ceramic tank at 980 °C/ 1.5 h		6 × 6 × 40
KK-102 fa Glazúra - Roudnice nad Labem (Czech)	- white, glossy/ covering (fr5804, without lead +7%kaol. +10%ZrSiO₄) - 960-1060 °C	glaze was melted in ceramic tank at 1010 °C/ 1.5 h		6 × 8 × 50
KK-111 Ferro (Holland)	- white, matt / covering/ (33%fr23045+40%frFc490+20 %Nefel+7kaol.%) - 1000-1060 °C	glaze was melted in ceramic tank at 1050 °C/ 1.5 h		10 × 8 × 45

they both are alike in the raw composition. The lower degree of the reaction of the coarser grains in the body H can be the reason of the dilatation differences. Then the phase compositions of the bodies J and H should be a little different after the firing.

The observed small differences between the cooling and heating curves are likely due to the time-exigence of the polymorphic transformations. The modification transformation of β- $\leftrightarrow$ α- quartz (573 °C) and α- quartz $\rightarrow$ α- tridymite (870 °C) are coupled with the volume changes which can clearly be observed on the curves. The solid-phase reactions and sintering continue at high temperature above 900 °C. This means the properties of the body can be a bit varied at the maturing firing of the glazed ware (e.g. water absorption, strength, moisture expansion etc.).

With reference to the thermal behaviour of the glazes the body dilatation is interesting mainly in the temperature range below 600 °C.

Moisture expansion of the porous biscuits

The hydration of the ceramic materials is the reason of the volume expansion of body. The maximum possible moisture expansion of the biscuit (N, J, H) was attained by the autoclave tests ($p_{vapour} \times \tau_{hours} \cong 2000$ (kPa hour) [1]). The dimension growth was determined by the dilatation measured at the temperature of 575 °C. The difference between the initial and the final points on the dilatation record indicates the moisture expansion of the body (figure 2 and table 3). The physically and chemically bound water in the ceramic material has been released during the heating up to temperature of 300 °C. The range of measured weight loss is wide (table 3). Only a part of weight loss represents the release of hygroscopic water and probably the rest represents the vapour, which had condensed into the open pores during the cooling after autoclave test. The amount of condensed water is variable. This explains why the moisture expansion has no direct dependence on the value of the weight loss.

The values of water absorption of the bodies (table 1) need not be related directly to the moisture expansion (table 3). The water absorption is an approximate indicator of the open porosity of ceramic materials.

The moisture increase of the fine (J) and coarse-grained (H) plastic bodies is twice as high as that of bodies N. Consequently, the cracks in the glazes on the porous bodies J and H should develop at a larger extent and earlier after firing than in glazes on the bodies N.
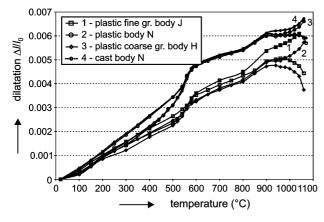

Figure 1. Dilatation curves of the biscuits fine grained J, course grained H, of plastic and cast bodies N. ($\square$,$\diamond$,$\circ$) - heating and ($\blacksquare$,$\blacklozenge$,$\bullet$) - cooling at a rate of 2°C/min.
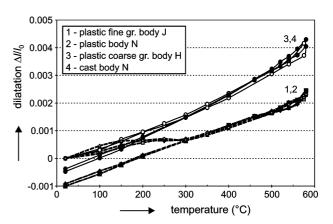

Figure 2. Dilatation curves of the biscuit after autoclave treatment - - - - - fine grained J ($\square$) and course grained H ($\diamond$) bodies, —— plastic and cast bodies N ($\circ$); ($\square$,$\diamond$,$\circ$) - heating and ($\blacksquare$,$\blacklozenge$,$\bullet$) - cooling at a rate of 5 °C/min.

Table 3. Effect of humidity on the size changes of the biscuits; simulation by autoclave treatment.

sample	weight loss during dilatometry test (max.temperature 575 °C) (wt.%)	sample size difference (before and after dilatometry measurement up to 575 °C) $\Delta l/l_o$ (%)
plastic J	2.3 - 3.45	-0.099 to -0.100
plastic H	1.9 - 3.0	-0.092 to -0.097
plastic N	0.83 -1.48	-0.038 to -0.040
casting N	0.67 - 1.43	-0.048 to -0.055

Linear dilatation of the glazes

The blocks of glazes KK 112, KK 111, KK 102 and KK 002 (table 2) made for the dilatation measurements showed no bubbles or inhomogenity. However, the blocks of glazes KK 406, KK 610 and KK 001 failed to be prepared without small bubbles, even if drawn from the melt. The glaze blocks were without quenching stress after annealing.

The dilatation curves of heating and cooling of the glaze are identical, they overlap up to the temperature of 50 °C below T_g (a change of the dilatation growth of the materials characteristic for the transformation range of glasses). In several cases a 5 °C shift of the T_g towards lower temperature on the cooling curve was observed. The temperature shift of T_g could be caused by a longer exposure of the glaze to temperature around its transformation temperature during the measuring.

The cooling dilatation curves of glazes along with the curves of biscuits J and N are presented in figure 3. The temperature of T_g and $TEC_{(20-T)}$ of the glazes and the biscuits are shown in table 4. The data in the table 3 are evaluated from the cooling curves. The glazes with the $TEC_{(20-560)}$ about 75×10^{-7} K^{-1} are suitable for the bodies N and the glazes with the $TEC_{(20-560)}$ about 55×10^{-7} K^{-1} should be appropriate for the bodies J and H if the moisture expansion of these bodies did not generate increase of the tensile stress in the glaze.

Cracking of glazes on the porous ceramics body

From the dilatation curves of the biscuit and the glazes in figure 3 it is obvious which glazes and on which biscuit will be under tensile or compression stress and without stress immediately after the firing. Differences between the dilatation of body and glaze in the temperature range to 20 - T_g ($\Delta TEC_{body-glaze}$) and the values of the stress in the glazes and bodies (equations 2 and 3) are shown in table 5a-b. The stress in the glaze is significant and essentially greater than in the body. If the $\Delta TEC_{(body-glaze)}$ decreases below - 8×10^{-7} K^{-1}, i.e. 100 $\Delta l_{(body-glaze)}/l_o < - 0.035$ %, the cracks develop in the glazes during the annealing already (tables 5 and 6). Each of the tested glazes on the biscuit made from the plastic
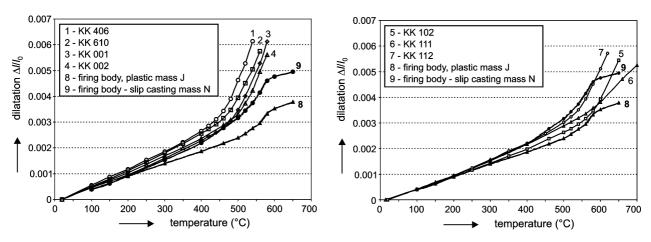

Figure 3. Thermal expansion of the tested glazes in comparison with fired porous bodies from casting mass N and plastic fine ground body J.

Table 4. Coefficient of the linear thermal expansion of ceramic biscuits taken from the cooling curves and glazes.

samples	T_g (°C)	Coefficient of linear thermal expansion 10^{-7} (K^{-1})					
		20 - 400	20 - 460	20 - 500	20 - 540	20 - 560	20 - 600
cast body N	-	57.7	63.0	66	71.8	76.9	82.0
plastic N	-	56	62.0	65.8	73.9	79.7	81.3
plastic H	-	45.7	47.0	47.9	51.3	55.7	56.1
fine plastic body J	-	49.1	49.5	49.9	53.2	54.7	60.9
KK 406	465	69.8	78.0	96.4	118.0	-	-
KK 610	480	67.4	71.7	82.0	97.2	106.6	-
KK 001	510	60.2	67.6	73.2	80.3	99.2	-
KK 002	535	62.2	65.4	69.0	81.4	-	-
KK 112	555	58.1	60.2	63.0	67.5	73.0	88.2
KK 102	580	52.0	53.9	54.5	56.4	58.2	65.3
KK 111	600	57.2	58.8	60.0	61.4	62.3	65.7

body J is under tensile stress. The glazes KK 406, KK 610, KK 001, KK 002 on the biscuit from the body N are under tensile stress, too. However, the glazes KK 112, KK 102 and KK 111 are under moderate compression stress. The cracks in the glaze KK 610 appeared soon after the firing of the glazed bodies N and in the glaze KK 001 and KK 002 in several hours.

However, the glazes under compression stress show no cracking neither after 72 hours, nor after dipping of the glazed bodies in water. Exceedingly higher compression stress in the glaze can, however, be troublesome and can cause cracking and peeling of the glaze. The tendency of the cracking of glaze on the porous ceramic body slightly decreases with elapsed time since the firing. The moisture expansion, which is typical for the porous body, decreases the value of compression stress in the glaze.

The values of stress in table 6 predict how the glaze stress, providing of ≈100 % moisture expansion of body, would be. Results in the table 6, compared with table 5, confirmed that tensile stress in the glaze on the porous body increases as a result of moisture expansion and the increase of the stress can result in cracking.

The glazes KK 112, KK 102 on biscuit made from body N and KK 102 on biscuit J, which did not crack after dipping in water, have been exposed later on to water vapour of 98 °C for 12 hours. Only the glaze KK 102 on the body J showed cracking. The glazes KK 102,

KK 111 on the body N have remained under moderate compression stress and this is a guarantee that these glazes on this body could remain without hair-cracks for several years.

CONCLUSION

The thermal expansion coefficients $TEC_{(20\text{-}540\ °C)}$ of the biscuits from the plastic and cast N bodies are about 72×10^{-7} K^{-1} and for the coarse-grained H and fine J bodies about 52×10^{-7} K^{-1} only. The maximum moisture expansions of these bodies are significant, with bodies N achieving the values up to + 0.05 % and with bodies J and H even +0.1 %.

The most significant moisture increase of biscuits occurs during the first days after firing. The moisture expansion of body changes the stress in the glaze and can develop cracking of the glaze after firing.

Because the *TEC*s of bodies are different it is not possible to use the same glazes for their glazing. All tested glazes on the biscuit from fine plastic body (with $TEC_{(20\text{-}500)} = 50 \times 10^{-7}$ K^{-1}) were exposed to tensile stress and therefore they were cracking during and/or shortly after firing. Only a change of the raw composition and/or firing schedule of bodies H and J, with the intention to reduce of the hydration ability, can decrease the moisture expansion and eliminate creation of cracks in the glaze.

Table 5a. Difference of *TEC* of glaze and fired body N expressed by stress value in the glaze and the body (equations 2 and 3), evaluated from crack occurrence in the glaze immediately after glaze firing; C - cracks.

glaze kind	$(TEC_{body}\text{-}TEC_{glaze})_{(20\text{-}Tg)}$ 10^{-7} (K^{-1})	glaze on the body from cast body N			
		$\Delta_{(body\text{-}glaze)}\ l/l_o$ (%)	stress in the glaze σ_g (MPa)	stress in the body σ_b (MPa)	cracks after firing
KK 406	-15	-0.066	-50.6	0.63	tiny C
KK 610	-8.7	-0.038	-29.4	0.37	
KK 001	-7.2	-0.035	-24.8	0.31	without C
KK 002	-3	-0.014	-10.5	0.13	
KK 112	4.3	0.022	17.3	-0.21	
KK 102	18.9	0.100	74.1	-0.92	
KK 111*	14.9	0.079	59.8	-0.74	

* sharp firing glaze

Table 5b. Difference of *TEC* of glaze and fired body J expressed by stress value in the glaze and the body (equations 2 and 3), evaluated from crack occurrence in the glaze immediately after glaze firing; C -cracks.

glaze kind	$(TEC_{body}\text{-}TEC_{glaze})_{(20\text{-}Tg)}$ 10^{-7} (K^{-1})	glaze on the body from plastic fine ground body J			
		$\Delta_{(body\text{-}glaze)}\ l/l_o$ (%)	stress in the glaze σ_g (MPa)	stress in the body σ_b (MPa)	cracks after firing
KK 406	-28.5	-0.120	-98	1.18	rich net of C
KK 610	-22.2	-0.095	-76	0.92	
KK 001	-24.2	-0.110	-81	0.95	sparse net of C
KK 002	-19.2	-0.091	-67	0.84	
KK 112	-14.3	-0.074	-55	0.70	without C
KK 102	-3.5	-0.017	-16	0.14	
KK 111*	-7.6	-0.041	-35	0.38	

* sharp firing glaze

Table 6. Evaluation of cracks appearance in the glaze after 5 and 72 hours from the firing and after dipping in the water for 1 minute (evaluated 72 hours after dipping) and informative values of stress in the glaze on the body after its moisture increase.

| glaze kind | on the body from the casting mass N | | on the body from the plastic mass J | |
| | appearance of cracks (C) | stress in the glaze σ_g (MPa) providing of 100 % moisture increase of body | appearance of cracks (C) | stress in the glaze σ_g (MPa) providing 100 % moisture increase of body |
	5 hours/ 72 hours/ after dipping		5 hours/ 72 hours/ after dipping	
KK 406	few C/ no new C/ a fewC	-80	net C developed/ C developing continues/ number of C increases – rich net of C	-155
KK 610		-60		-135
KK 001	hairy C/ C developing continues/ C developing continues	-55	sparse net of C/ C developing continues / number of C increases – rich net of C	-140
KK 002	a few C/ few C/ sparse net of C	-40		-125
KK 112	without C/ without C/ without C*	-15	hairy C/ C developing continues / sparse net of C	-115
KK 102	without C/ without C/ without C*	35	without C/ without C/ without C**	-75
KK 111		25	--	- 90

*   glaze without cracks after exposure of the samples to vapour at the 98°C/12 hours
** glaze cracked during keeping in vapour at the 98°C/12 hours

The glazes KK 002, KK 406, KK 001 and KK 610 with the $TEC_{(20-Tg)}$ 69 - 78 × 10^{-7} K^{-1} show cracking on body N which continues even after a longer time. Rich crack-net has developed in glazes KK 610, KK 406, KK 001 and KK 002 only later. The glazes KK 102, KK 111 and KK 112 with the $TEC_{(20-Tg)}$ in the range 58 - 68 × × 10^{-7} K^{-1} stick very well on the biscuit from body N. They show no cracking during exposure to vapour, either.

For the more precise evaluation of the resistance of glazes KK 102, KK 112 and KK 111 to cracking on the body N the test of glaze resistance to rapid cooling of glaze on the ceramic body should be made employing a suitable method, i.e. Harkort test. This test is very important for the quality evaluation of the glazed ware (e.g. stove-tiles, wall-tiles).

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VLHKOSTNÝ NÁRAST ČREPU - PRÍČINA TRHLINKOVANIA GLAZÚR

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Práca uvádza výsledky meraní teplotnej dĺžkovej rozťažnosti (KTR) štyroch typov póroviny, z ktorej sa vyrábajú glazované kachlové tvarovky a glazúr, ktoré sa na tieto črepy aplikujú. Testované póroviny vykazujú relatívne nízku strednú hodnotu $KTR_{(20-540\,°C)}$ 52 × 10^{-7} K^{-1} a 72 × 10^{-7} K^{-1}, podľa druhu črepu. Ak je KTR glazúr aplikovaných na keramický črep póroviny vyšší o 10 × 10^{-7} K^{-1} ako KTR črepu, glazúra bude na črepe praskať už počas chladenia výrobku, je na črepe pod relatívne veľkým ťahovým napätím. Ak rozdiel medzi KTR črepu a glazúrou je -10 × 10^{-7} K^{-1} glazúra nemá tendenciu praskať na črepe počas chladenia, po výpale je pod malým ťahovým napätím. Trhliny sa ale v glazúre predsa len po čase objavia. Vlhkostný nárast črepu vyvolá v glazúre vzrast ťahového napätia, ktoré sa uvolní praskaním glazúry pri prekročení jej pevnosti v ťahu. Nameraný vlhkostný nárast testovanej póroviny je od 0,05 až 0,1 %. Táto hodnota je významná. S vlhkostným nárastom črepu rastie pravdepodobnosť skorého vzniku harrissu.