VISCOUS FLOW SINTERING OF PORCELAIN TILE: BEHAVIOUR PREDICTED BY THE FLUEGEL MODEL

F. Contartesi1, F. G. Melchiades[2], C. Zanelli[3], S. Conte[3],

M. Dondi[3], A. O. Boschi[1]

[1]Universidade Federal de São Carlos, Programa de Pós-Graduação em Ciência e Engenharia de Materiais, São Carlos, SP, Brazil.

[2]Centro de Revestimentos Cerâmicos – CRC, São Carlos, SP, Brazil

[3]CNR-ISTEC, Istituto di Scienza e Tecnologia dei Materiali Ceramici, Faenza, Italia

1. INTRODUCTION

The use of vigorous fluxes encourages sintering, promoting lower firing temperatures and, hence, lower economic and environmental impacts. However, the addition of these raw materials is generally performed empirically.

Previous studies point to viscosity of the liquid phase that develops at high temperatures as being the key factor in the development of porcelain tile sintering [1,2]. Thus, in order to try to predict the effects of the addition of vigorous fluxes to porcelain tile formulations on tile behaviour during firing, the Fluegel model was used [3].

2. EXPERIMENTAL APPROACH

Using an industrial tile body (STD), the effects of adding selected fluxes were estimated using the Fluegel model and the predictions were experimentally verified.

The detailed methodology is schematically shown in Figure 1.

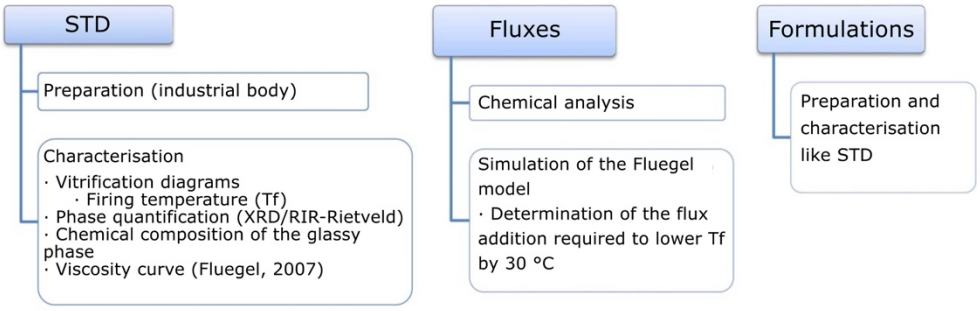

Figure 1. Detailed methodology.

To this end, two hypotheses were considered: (1) the added raw material fuses completely and mixes with the liquid phase of the body, without interfering in its formation; (2) melt viscosity is a sufficient condition for determining firing temperature.

The chemical composition of the glassy phases was estimated in accordance with the method proposed by Conte et al. [2].

3. RESULTS AND DISCUSSION

The initial goal of 30 °C reduction was attained by all fluxes used and was exceeded by some (Table 1). However, all formulations densified without achieving such a low viscosity as STD. These results suggest that the second assumption, presented above, was not valid.

	Addition (%)	Formulation	Tf (°C)	Viscosity (Log_{10} Pa.s)
STD			1215	4,37
Wollastonite	6.5	W6.5	1185	4.44
Ulexite	4.0	U4.0	1140	4.67
Colemanite	4.5	C4.5	1125	4.78
Diopside	12	D12	1185	4.53
Phonolite	14	F14	1170	4.53
Spodumene	20	E20	1170	4.60

Table 1. *Summary of the characteristics of each formulation.*

Table 2 presents a comparison of the estimated and of the experimentally measured chemical composition of the melt. The elements of interest for the fluxing action are detailed, highlighting the main elements in each formulation. The differences between these elements clearly demonstrate that the first hypothesis was also not valid. This indicates that new initial considerations are needed for a better application of the model.

	Estimated melt composition						**Experimentally measured melt composition**					
	W6.5	**U4.0**	**C4.5**	**D12**	**F14**	**E20**	**W6.5**	**U4.0**	**C4.5**	**D12**	**F14**	**E20**
SiO_2	64.95	64.17	63.64	64.82	64.32	65.94	63.23	61.24	61.48	60.28	61.46	63.69
B_2O_3	0.00	1.11	2.63	0.00	0.00	0.00	0.00	1.81	4.08	0.00	0.00	0.00
Al_2O_3	18.38	19.12	18.85	17.65	20.01	21.41	20.02	20.01	19.08	21.21	22.83	22.17
Na_2O	0.00	0.48	0.17	0.07	1.56	0.04	0.00	0.78	0.27	0.10	1.97	0.07
K_2O	4.85	5.04	4.97	4.68	5.10	4.18	4.44	5.10	4.89	4.66	4.95	4.73
MgO	3.48	3.67	3.52	5.33	3.31	3.02	3.47	3.91	3.63	6.01	3.10	3.48
CaO	3.26	1.10	1.04	2.60	0.32	0.09	3.81	1.51	1.23	2.64	0.46	0.25
Li_2O	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	0.47

Table 2. *Comparative analysis of melt chemical composition, highlighting the elements of greatest interest.*

The variations in firing temperature seem to be related to the type of element present. For the raw materials that contributed alkaline earth oxide modifiers, the prediction was exact, whereas for the alkalis, it was approximate. However, for the borates, the results moved quite far from what was predicted by the model.

4. CONCLUSIONS

In spite of all the differences between the experimental data on which the Fluegel model is based and the porcelain tile system, the model could be applied quite accurately to predict the reduction in firing temperature of a porcelain tile for fluxes like wollastonite and diopside, bearers of alkaline earth oxide modifiers. For fluxes that contained alkali oxide modifiers, the model's prediction was not as accurate, but it serves as a good guide for an initial theoretical approach. However, for the borates, the model's predictions were of little value.

5. ACKNOWLEDGEMENTS

This study was performed with the support of the Coordination for Improvement of Higher Education Personnel – Brazil (CAPES) – Funding code 001.

6. REFERENCES

[1] ZANELLI, C. et al. **Revisión de la sinterización por flujo viscoso en el gres porcelánico**. Qualicer 2018 - World Congress on Ceramic Tile Quality. **Proceedings**...Castellón: 2018

[2] CONTE, S. et al. **Viscosidad a alta temperatura de pastas de gres porcelánico**. Qualicer 2018 - World Congress on Ceramic Tile Quality. **Proceedings**...Castellón: 2018

[3] FLUEGEL, A. Glass viscosity calculation based on a global statistical modelling approach. **Glass Technology**, v. 48, n. 1, p. 13–30, 2007.