THE EFFECT OF BORATES ON THE VITRIFICATION BEHAVIOUR OF A PORCELAIN TYPE TILE BODY

Sabrina M. de Paula, Ana Paula F. Albers and João B. Baldo

The Federal University of São Carlos
Materials Engineering Department – São Carlos SP
Brazil – 13565-905 – email contact – baldo@power.ufscar.br

ABSTRACT

In this study aimed at improving liquid phase development at lower temperatures, the effects on the vitrification behaviour of a typical porcelain tile mass, when the fluxing agent (Feldspar) was substituted in relatively large proportions (1,3,5 wt%) by inorganic borate sources such as Borax ($Na_2B_4O_7.10H_2$), Hydroboracite ($CaO.MgO.3B_2O_3.6H_2O$) and Ulexite ($Na_2 2CaO.5B_2O_3.16H_2O$), were investigated comparatively. The borate choices were made considering the combined fluxing effect of alkali and alkaline earth oxides together with the glass former B_2O_3. The amounts involved were chosen so as to highlight the effects of the addition. It was found that the inclusion of borates indeed encouraged liquid phase development at lower temperatures with lower firing shrinkage, especially Hydroboracite. However, in all the borate containing compositions, closed porosity increased considerably.

INTRODUCTION

Porcelain tile bodies are very important floor tile products, characterized by virtually no water absorption high strength and abrasion resistance[1,2]. Among the raw materials mixture, the fluxing compounds such as feldspar and its combination with talc play a decisive role in the high level of mass vitrification. However, the glassy phase developed during the fast firing of typical compositions has a high thermal expansion coefficient, narrow firing range and most of the time under the commonly used firing temperatures does not become fluid enough to rearrange the microstructure, unless the temperature reaches the range from 1250 to 1300°C, which can affect shape stability and dimensional control, while moreover trapped porosity degrades the quality of the finished product.

Considering the strong fluxing action of boron-containing compounds, besides their excellent ability to form glass of good characteristics, in this work the effect of adding boron sources such as Borax ($Na_2B_4O_7.10H_2O$), Hydroboracite ($CaO.MgO.3B_2O_3.6H_2O$) and Ulexite ($Na_2O.CaO.5B_2O_3.16H_2O$) on the vitrification behaviour of a typical single fast fired, white-firing porcelain tile composition was studied. The investigation was conducted by substituting 1, 3 and 5 wt% feldspar by identical amounts of the inorganic borate materials. The amounts were chosen in order to highlight more extensively the resulting effects, vis-à-vis to the work of Moreno[3] who used very small borate additions (under 1 wt%).

Materials and Methods

The compositions studied are presented in Table I.

Raw Material	Compositions									
	STD	H1	H3	H5	B1	B3	B5	U1	U3	U5
Ball Clay	30	30	30	30	30	30	30	30	30	30
Kaolin	15	15	15	15	15	15	15	15	15	15
Quartz	7	7	7	7	7	7	7	7	7	7
Talc	3	3	3	3	3	3	3	3	3	3
(K,Na)Feldspar	45	44	42	40	44	42	40	44	42	40
Hydroboracite	-	1	3	5	-	-	-	-	-	-
Borax	-	-	-	-	1	3	5	-	-	-
Ulexite	-	-	-	-	-	-	-	1	3	5

Table 1 – Compositions studied and their references.

Mass Preparation: The raw materials were wet ball milled in order to achieve 98 wt% throughput in a #325 mesh screen. After milling the mass was dried and granulated with 6 wt% water.

Specimen Preparation: The granulated mass was pressed into cylindrical pellets with ϕ = 2.5 cm, thickness 0.5 cm under adequate pressure to produce 2.00g/cm^3 green density followed by drying at 110°C.

Firing Procedure: Fast single firing in laboratory electrical furnace. Heating rate of 30°C/minute. Soaking time of 5 minutes. Cooling rate 30°C/minute.

Properties Evaluated: Water absorption (WA), Linear firing shrinkage (LS), Closed porosity (CP).

RESULTS

In the vitrification diagrams shown in Figures 1 to 3, the evolution of shrinkage and water absorption makes it clear that the addition of borates enhances sintering (higher shrinkage and lower water absorption) at lower temperatures, compared with the standard composition, especially for temperatures below 1200°C.

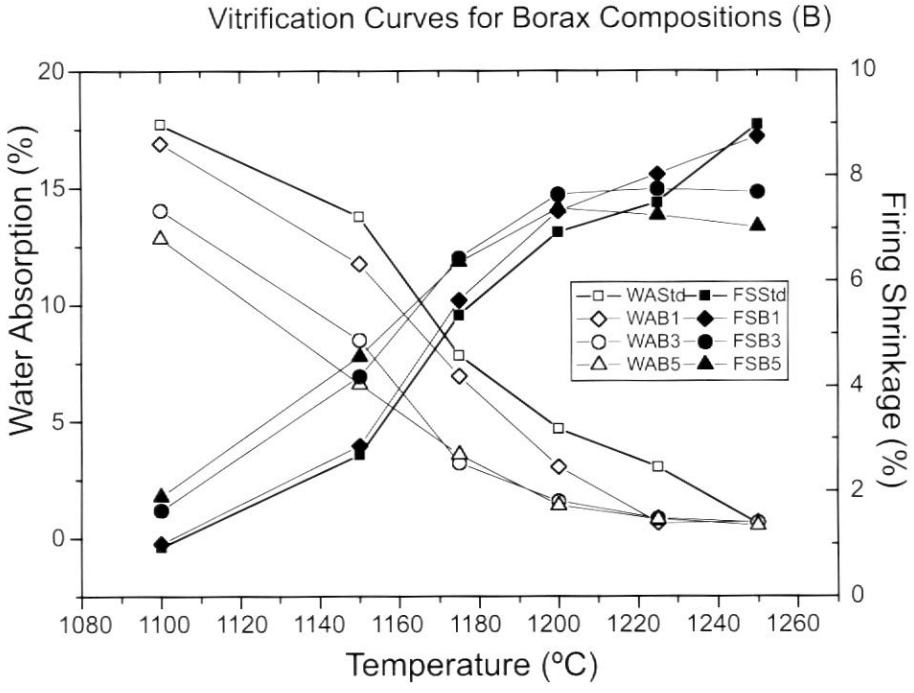

Figure 1 – Vitrification Diagrams for the Borax containing Compositions.

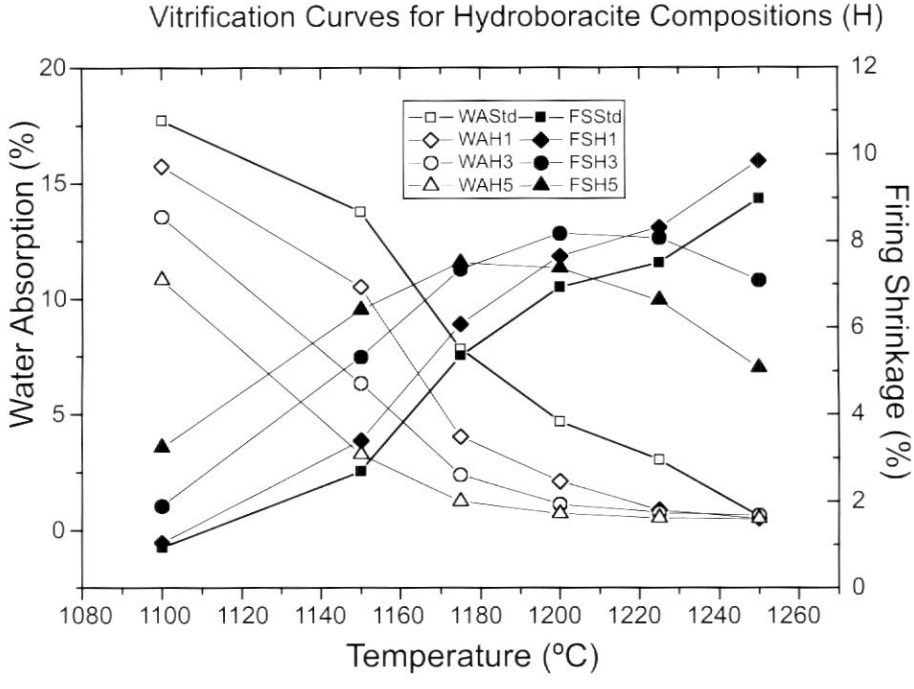

Figure 2 – Vitrification Diagrams for Hydroboracite containing Compositions.

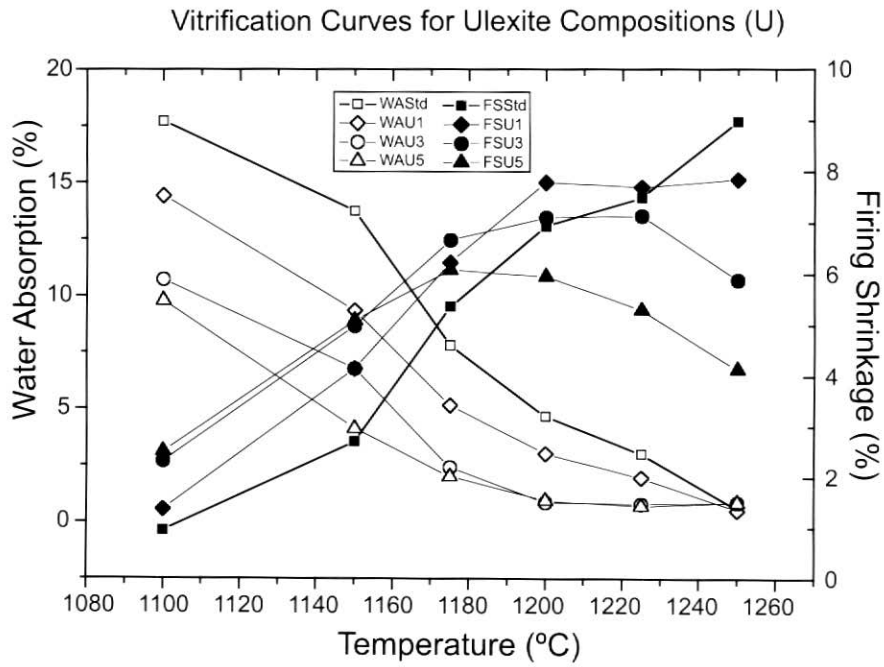

Figure 3 – Vitrification Diagrams of Ulexite Containing Compositions.

However, the borate-containing masses (apparently due to the amounts used) display ready bloating behaviour, revealed by the high closed porosity, which indicates the difficulty of outgassing and/or a greater release of volatiles than the standard composition. It is well known that most inorganic borates display high vapour pressure at high temperatures For comparison, through Figure 4, when one initially only considers the water absorption values, it can be observed that this last property can be misleading for the proper evaluation of the fired characteristics, without taking into account the closed porosity values. Low levels of closed porosity are essential in porcelain tile bodies and have to be kept below 5%. This was only attained by the composition with no borate addition.

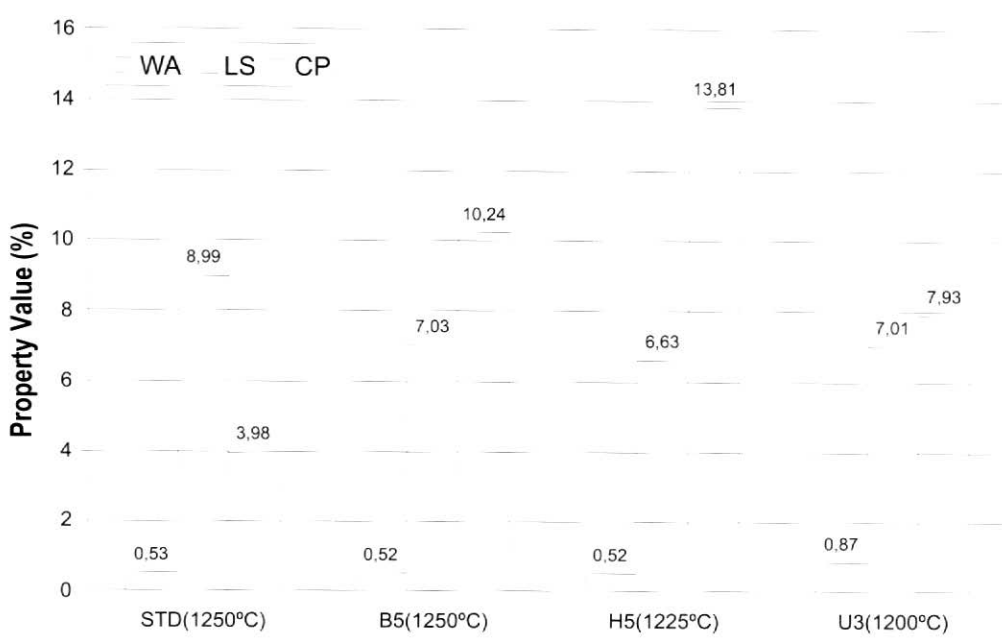

Figure 4 – Comparative behavior between the different compositions and their apparent optimized Water Absorption and Firing shrinkage. It can be seen that when the closed porosity is not taken into account the quality evaluation can be misleading.

Additional experiments belonging to the continuation of the present investigation, not reported here this time, showed that heating rate and dwell time play an important role on the closed porosity development.

CONCLUSIONS

In spite of the increased vitrification rate with a lower level of shrinkage, the use of inorganic borates in porcelain tile masses apparently does not yield good physical properties when used in relatively large amounts (>1 wt%). This is due to the resulting high closed porosity, which is mainly detrimental to stain resistance and overall durability of this class of products.

ACKNOWLEDGEMENTS

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