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Durability of sintered materials modified by alternative silicate filling agents

Tomáš Melichar[1]
[1]Faculty of civil engineering, Institute of Technology of Building Materials and Components, Brno University of Technology, Brno, 602 00, Czech Republic, melichar.t@fce.vutbr.cz

Summary

The issues contained in the study are focused mainly on the durability of glass-based sintered materials for whose production alternative silicate filling agents were used. These sources are waste glass gravel from collected coloured container glass, disassembled TV screens and, last but not least, so-called secondary energy products, i.e. mainly fluid fly-ash and blast-furnace slag. It is generally known that currently fluid fly-ash is not being used as a secondary raw material much. The same applies to the above-mentioned raw glass. I focused mainly on the frost impact on the strength features of sintered materials using both crystalline and amorphous silicate filling agents. I drew up 19 formulas in total. Two sets of test samples consisting of five specimens were made for each formula. The above-mentioned analyses of the samples were carried out and subsequently assessed. I found out that amorphous filling agents had a positive effect on the durability features of the produced materials, whereas secondary products had a negative effect. Therefore, crystalline substances do not seem to be suitable for production of glass-silicates considering their strength features in terms of durability which is stated in this study.

KEYWORDS: durability, bending strength, alternative sources, silicates, glass, waste, recycling, strength

1. INTRODUCTION

Many publications, patents, production technologies, etc. concerning waste production and its subsequent utilization in the form of secondary raw materials based on various researches and experiments have been made. The area of production of building materials and elements is not an exception, on the contrary, with respect to the large volumes of various materials being produced and related waste and consumed energy sources, the effort to utilize secondary raw materials has become one of the primary targets. Because of the current world crisis consumption of secondary raw materials has partially dropped down in some industrial areas and primary sources are being used again. But we can expect that it

ISSN 1582-3024

is just a temporary effect which should not last long. One of the intensively discussed secondary raw materials in terms of its optimum utilization is raw glass from collected coloured bottles. With respect to its features, i.e. significantly variable chemical composition, this raw glass is not being fully utilized which you can see not only in the Czech Republic but also throughout the EU. Another interesting raw material in terms of its utilization is glass from ordinary TV screens and computer monitors. Increased production of waste, or more precisely electro-waste, which includes TV screens and computer monitors, depends on new technologies which are, thanks to their progressiveness, more lucrative for most consumers. They are mainly LCD-based products and plasma screens which currently have a significant share in the market compared to ordinary screens. An important criterion for the effort to utilize old, useless screens is mainly the fact that they contain some toxic substances. Some recycling lines have been solving the problems how to remove these substances but some harmful elements are contained right in glass matrices and, therefore, they cannot be removed effectively or, more precisely, elimination of these substances is possible but with high economic costs which would probably lead to disappearance of these technologies in practice. Therefore, there is an option to use raw glass directly in specific building materials. One of the ways how to effectively use the above-mentioned secondary raw materials is e.g. production of glass-silicate materials. They are already being used in the building industry in different ways. Thanks to their excellent features you can see them in various types of buildings. Glass-silicate materials are designed mainly for surface treatment of walls and floors. Production of these materials consists in a heat treatment of granulated batches of glass, other substances and admixtures and their subsequent mechanical processing to the required form.

2. EXPERIMENTAL PART

2.1. Formulas

At the beginning I drew up a basic material batch according to my practical experience on whose basis I determined the input raw glass – borosilicate glass – and the temperature regime of the production process. In this way I made reference samples whose features were compared with the features of samples which had been modified in a certain way. In that year I modified the composition of the batch in the following three ways:

- correction of the grain size composition,
- correction of the raw material batch composition,

- modification of the temperature regime.

I used four types of secondary raw materials in total. The features of the samples made of them were compared with the reference samples produced on the basis of the practical findings. Three test specimens (whose dimensions were approx. 65 × 25 × 130 mm) were made for each formula within the research. The following symbols were used for marking the test specimens:

- RE – reference raw glass,
- CR – screen raw glass (a mixture of funnel screens)
- CO – recycled coloured container glass,
- SLX – finely ground blast-furnace slag (X – a number representing the share of the secondary raw material from the original batch in percents),
- FAX – fluid fly-ash (X - a number representing the share of the secondary raw material from the original batch in percents).

The other numbers used for marking the samples represent the maximum temperature of isothermal persistence in the course of the production process and the granulated batch fractions (only raw glass; fly-ash and slag were very fine).

2.2. Analysis of the input raw materials

Within the research I carried out several appropriate analyses of the input raw materials first. The chemical composition of the raw materials described in the following table is important in order to find out their features at increased temperatures. There is a significant difference in the content of particular elements of recycled glass and the other raw materials.

Table 1. Chemical analysis of secondary raw materials

Component	Sample			
	CR	CO	FA	SL
SiO_2	66.79	69.79	25.49	30.25
Al_2O_3	4.21	1.80	24.65	5.42
Fe_2O_3	0.28	0.40	7.09	1.12
BaO	10.7	0.30	-	-
CaO	0.28	9.92	22.61	36.95
MgO	0.11	2.17	0.64	6.31
Na_2O	7.57	12.2	0.6	0.37
K_2O	6.91	0.97	0.38	0.56
PbO	0.91	-	-	-
SrO	0.25	-	-	-
TiO_2	0.04	-	5.35	-
LiO_2	0.38	-	-	-

ISSN 1582-3024

MnO	-	0.03	0.043	-
Cr_2O_3	-	0.074	-	-
ZrO_2	-	0.02	-	-
Organic compounds	-	0.50	-	-
SO_3	-	-	15.82	1.75
P_2O_5	-	-	0.32	-

2.3. Durability and strength parameters

In accordance with the normative documents concerning ceramic facing elements and in connection with the previous phases I focused on determination of some basic features by means of which I checked the influence of the substitution of the primary raw materials used for production of glass-silicate materials on their final parameters. Namely it was a study of the influence of cyclic freezing and de-freezing (ČSN EN ISO 10545-12) of these materials on the final strength parameters (ČSN EN ISO 10545-4). The following chart shows a comparison of the average strength values before and after the frost test (100 cycles) with the exception of the test specimens produced using fluid fly-ash. The samples were examined only visually.

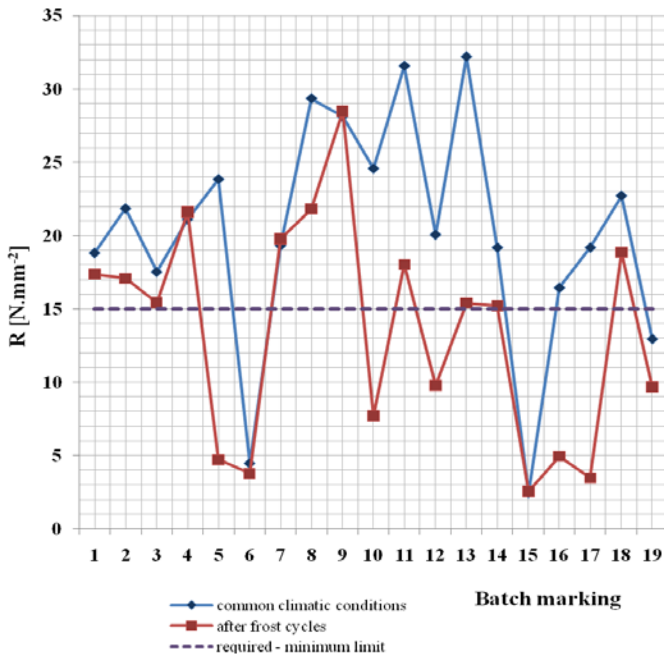

Figure 1. Bending strength comparing before and after frost cycles

Table 2. Explanation of batch marking

1. RE 900 0-6	11. CR 800 1-8
2. RE 960 0-6	12. CR 800 4-8
3. RE 1050 0-6	13. CR 960 0-8
4. CR 700 0-1	14. CO 800 0-4
5. CR 700 0-8	15. CO 800 2-16
6. CR 700 4-8	16. CO 960 2-16
7. CR 750 0-8	17. CO 1050 2-16
8. CR 775 0-8	18. SL2,5
9. CR 800 0-8	19. SL5,0
10. CR 800 1-4	

The graphic assessment of the values shows dependence on the applied secondary raw material as well as on its volume and the related grain size and the maximum temperature of isothermal persistence during the production process. One of the important criteria for assessment of glass-silicate products designed for wall facing and floor paving used for both interiors and exteriors is their appearance. Therefore, I also carried out a visual assessment of their appearance which is documented in the photographs below.

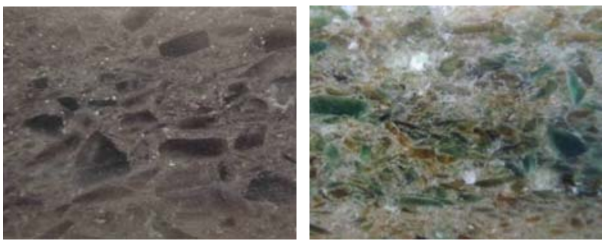

Figure 2, 3. Structure of the samples made of screen raw glass – CR 750 0-8 (left) and coloured container raw glass – CO 800 0-4 (right)

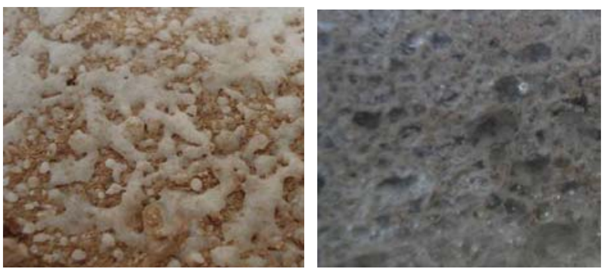

Figure 4, 5. Structure of the sample made of reference raw glass and an admixture of fluid fly-ash – FA5.0 (left) and an admixture of finely ground slag – SL5.0 (right)

ISSN 1582-3024

3. CONCLUSIONS

At the conclusion I can state that I checked the modification option for the composition of the batch of glass-silicate materials using four types of secondary raw materials and one of them was found absolutely unsuitable (i.e. fluid fly-ash – these samples were falling apart when removed from the moulds). Regarding screen raw glass, coloured container raw glass and finely ground blast-furnace slag I reached very good, comparable and in some cases better strength parameters than in the reference samples with appropriately chosen grain size composition, optimum dosing and temperature regime. The visual assessment obviously shows that secondary raw materials do not have any significant effect on the appearance of the structure of the final products but it is necessary to pay attention to purity of these raw materials which plays an important role there. The results also show resistance of glass-silicate materials to frost which is, in terms of their utilization in exteriors under our ordinary climatic conditions, very important. I have also found out that there are no significant negative changes in the strength features, with the exception of the test samples produced using a coloured container recycled material with coarse fraction. Therefore, it is obvious that glass-silicate facing (or paving) materials containing secondary raw materials may be a future solution how to reduce consumption of primary mineral resources and energy which will have a positive effect mainly on the environment. The above-mentioned facts show the need of a further extensive research in order to check the other parameters influencing utilization of sintered glass materials.

Acknowledgements

The text has been drawn up within the MSM 0021630511 research project – “Progressive Building Materials with Utilization of Secondary Raw Materials and their Impact on Structures Durability” and the FT-TA5/147 project – “Sintered products made of by-products for creation of walls and floor surface treatment”.

References

1. FANDERLIK, I.: *Silica glass and its application*, Elsevier Amsterdam, 1991
2. MATOUŠEK, J. *Anorganické nekovové materiály*, VŠCHT v Praze, 1992
3. Lingart, Y. *Imitation of natural material tiling using waste glass*, Glass Technol. 39 (2) (1998) 42–43.
4. N. Menad, Cathode ray tube recycling, Resources Conserv. Recycling 26 (1999) 143–154
5. ČSN EN ISO 10545-4 Ceramic tiles – Part 4: Determination of modulus of rupture and breaking strength
6. ČSN EN ISO 10545-12 Ceramic tiles – Part 12: Determination of frost resistance

ISSN 1582-3024