Alkali activated foams from slag

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ABSTRACT

The alkali-activated (AA) slag-based lightweight foams are promising alternative for insulation materials products for civil engineering sector and industrial use. In the present study, the electric arc furnace steel slag (Slag A) and the ladle furnace basic slag (Slag R) from different metallurgical industries in Slovenia were selected for alkali activation, and foaming process. To obtain optimal bending (σBS) and compressive strength (σCS) the study in first stage has focused on the influence of the precursor to activator solution mix ratio. The optimal mixture was further used for the development of AA lightweight foams. Different proportions ranging from 1 to 2 % of the selected chemical foaming agent (H_2O_2) were added to the optimal mixture and activated with sodium silicate (activator to slag ratio 0.5) and cured under 70 °C for 3 days. Activation and foaming resulted in densities from 0.59 to 0.85 g/cm^3.

INTRODUCTION

Alkali activated materials (AAM) are inorganic aluminosilicate based materials, mainly produced from fly ashes, metallurgical slags or clays containing Al_2O_3 and SiO_2 with high solubility in alkali media.[1] Steel slag based alkali activated materials have high mechanical strength, good fire and high thermal resistance at elevated temperatures and in case of low density (lightweight foams) also low thermal conductivity.[2] The important factors for the production of AAM foams are: 1) Al_2O_3 and SiO_2 rich source, 2) high ratio of amorphous to crystalline phase, 3) addition of alkali solution, 4) particle size distribution and 5) ageing and curing conditions, and 6) addition of foaming agent. The aim of this study was: identification of suitable slags from Slovenian metallurgical industry for alkali activation, selection of mixtures with optimal mechanical properties based on the ratio of alkali activators to slag, addition of different amounts of foaming agent and study the influence on density and mechanical strength.

METHODS AND MATERIALS

Chemical analysis (XRF-Thermo Scientific ARL Perform X, USA) and the Rietveld quantitative determination of mineral phases (XRD-Malvern PANalytical Empyrean, NL and UK) were determinated for the electric arc furnace steel slag (Slag A) and the ladle furnace basic slag (Slag R). After alkali activation and foaming the mechanical strength (ToniTechnik, GER) measurements and SEM (SEM, JEOL 5500 LV, USA) analysis were performed. Sodium silicate Crystal 0112 with 2:1 of SiO_2/Na_2O was used for alakli activation (Tennanants Distribution Limited, UK).

RESULTS

The quantitative determination of mineral phases (XRD-Rietveld) has confirmed presence of amorphous phase in both slags (Figure 1).

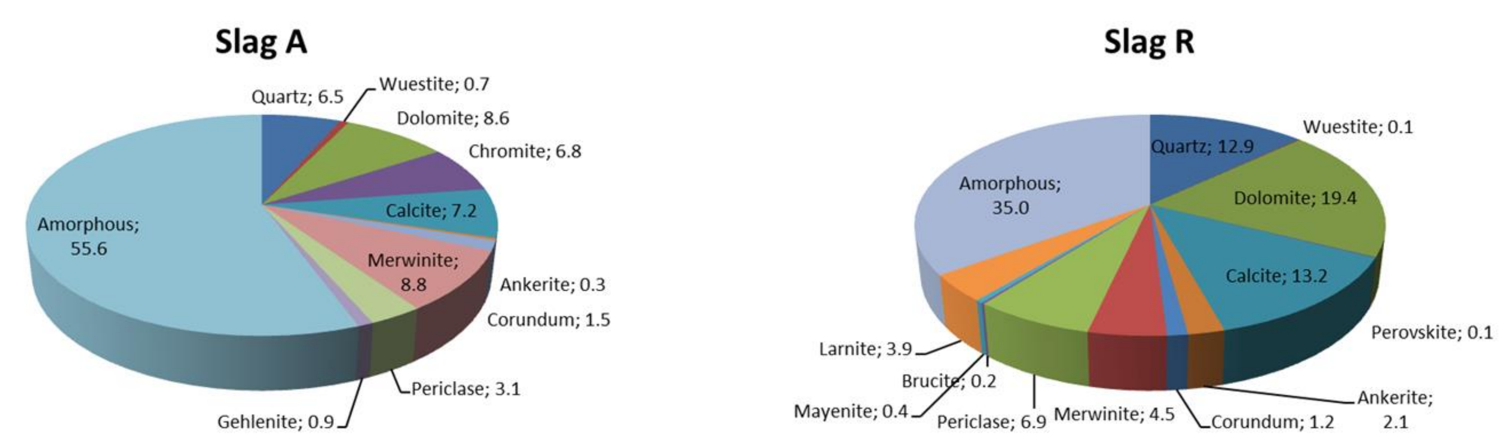

Figure 1: Mineral composition and the quantitative determination.

The A and R slags with various mixture ratios (A/R: 1/0, 0/1, 1/3, 1/1 and 3/1) were activated with sodium silicate with the activator/slag ratio 0.5 and cured in a heat-chamber for 3 days at 70 °C the amount of sodium silicate was 33.3 for all prepared mixtures (Figure 2).

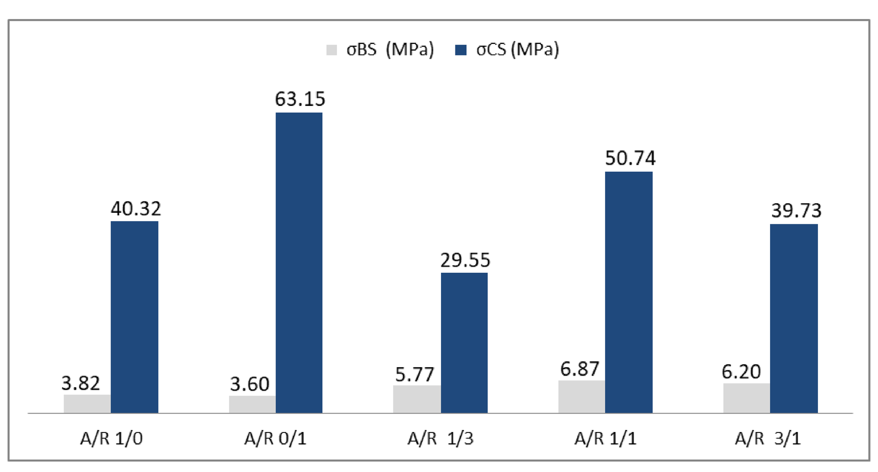

Figure 2: Bending (σBS) and compressive (σCS) strength of slag mixtures.

Different proportions ranging from 1 to 2 % of the selected chemical foaming agent (H_2O_2) were added to the optimal mixture. Densities and mechanical properties of foams are shown in Table 1.

Table 1: Foam content effect on density and mechanical properties

Foam agent content (%)	Density (gcm^{-3})	Bending strength (MPa)	Compressive strength (MPa)
1.0	0.85	3.47	5.00
1.5	0.73	1.86	3.67
2.0	0.59	0.95	1.36

SEM images (Figure 3) show the morphology of AA lightweight foam with different proportions of foaming agent (H_2O_2). Diameter of pores is in the range from app. 400 μm to over 1 mm for 1 % of or 2 % H_2O_2.

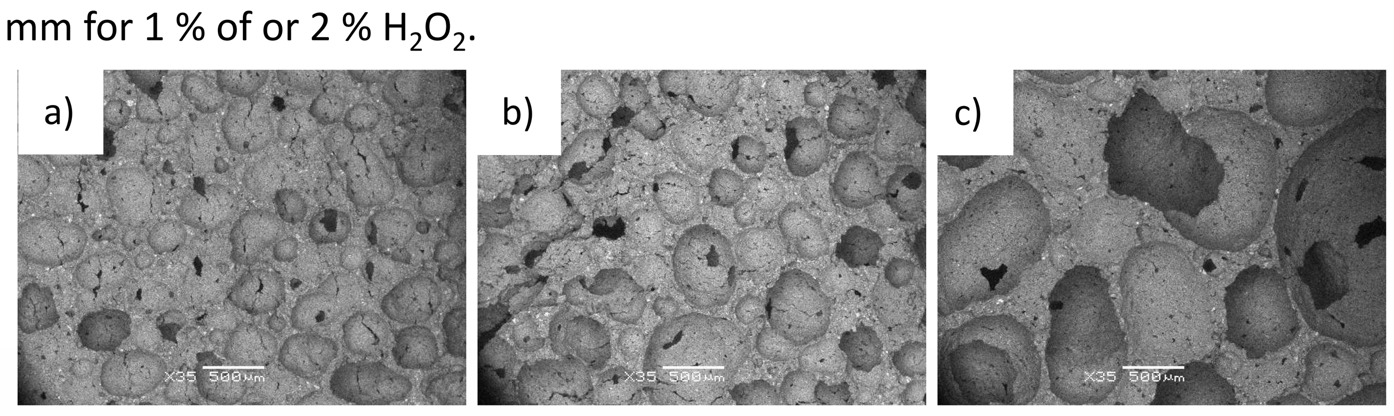

Figure 3: SEM images of AA foam with a) 1 % , b) 1.5 % and c) 2 % H_2O_2

CONCLUSIONS

✓Slags A and R were mixed in ratios 1:0, 0:1, 1:3, 1:1 and 3:1, activated with the activator to slag ratio 0.5 and cured under 70 °C for 3 days. σBS were in range from 3 to 6 MPa, and σCS varied from 29 to 63 MPa.

✓To optimal mixture (1:1) 1 to 2 % of H_2O_2 as foaming agent was added what resulted in densities from 0.59 to 0.85 g/cm3.

✓σBS of foams were from 0.95 to 3.47 MPa, and σCS from 1.36 to 5.0 MPa, respectively what is slightly lower than for aerated concrete[3] but still acceptable for non-load bearing application.

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