Bachelor Thesis in Civil Engineering

Title:

Environmental Aspects of Utilising Silicomanganese Slag as a Cement Substitute

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Introduction

The cement industry is today cited responsible for about 5-7% of all anthropogenic CO_2 emissions. Due to modern development and rapid infrastructural growth, it is expected that the demand for cementing materials will increase. The industry has, therefore, devoted extensive research programs to uncover new and environmentally friendly solutions.

Supplementary cementing materials (SCMs) are estimated to be the most economical and environmentally efficient solution to reduce the environmental impact from the cement and concrete industry. Due to the ever-growing demand for cement, combined with the declining availability of substituting materials, a market for new sources of SCMs is emerging. The main goal of this thesis is to investigate the possibilities for reducing CO_2 emissions from the cement and concrete industry through the utilisation of silicomanganese slag from Eramet.

Theory Background

SiMn-slag produced by Eramet is a by-product from the manufacturing of silicomanganese alloy and can, therefore, be considered carbon neutral. The SiMn-slag exhibits comparable chemical composition close to ground granulated blast furnace slag - a widely used SCM. The characteristics and reactivity of the SiMn-slag vary according to the temperature under which it is formed, and the method and rate of cooling. Studies have predicted granulated slag to be 100% amorphous, while the air cooled slag may exhibit content of crystalline structure. High amorphous phases correspond to high reactivity. The significant amount of CaO imply the slag is equipped with latent hydraulic properties. The high SiO_2 content, in combination with the content of Al_2O_3, suggests the SiMn-slag to exhibit pozzolanic properties.

Research Question

In what way does Eramet's silicomanganese slag as a supplement in the production of cement and concrete, affect the CO_2 emissions?

1. How does energy consumption of grinding silicomanganese slag affect CO_2 emissions when utilised in the manufacturing of cement?
2. How does silicomanganese slag affect CO_2 emissions when used as a raw material in cement clinker production?
3. How does silicomanganese slag affect CO_2 emissions when used as supplementary cementing material for cement clinker?
4. How does silicomanganese slag affect CO_2 emissions when used as a partial replacement for cement in concrete?

Method of Analysis

The thesis method of analysis consists of an empirical study performed at the Civil Engineering laboratory at the University of Agder, collaboration with other students, a literature study, interviews, and an environmental review.

Results

Findings show that utilisation of both air cooled and granulated silicomanganese slag act to reduce carbon dioxide emissions from the cement and concrete industry. The amorphous structure of granulated silicomanganese slag proved enhanced performance due to increased reactivity and grindability when seen in relation to air cooled slag. As for the grinding method, separate grinding is found preferable for silicomanganese slag assumed harder than the clinker.

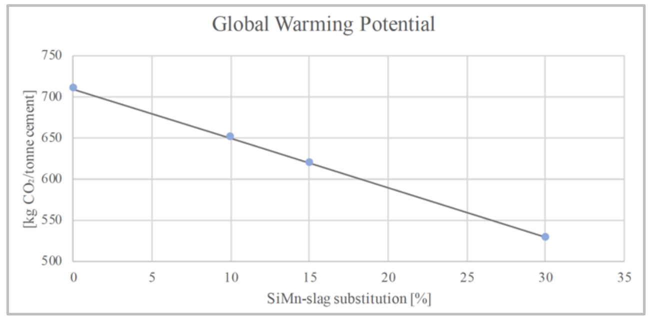

Figure 1: Estimation of total GWP of cement with SiMn-slag as SCM.

Discussion

For use of SiMn-slag as raw material for the cement clinker production, the chemical composition of the slag limits the content of SiMn-slag to no more than 10% of the raw meal mix. From this point, a higher level of SiMn-slag content adversely affects the CO_2 emissions originating from the production process.

The implementation of SiMn-slag as SCM ensures preservation of latent hydraulic and pozzolanic properties. Further, the quality of SCMs are dependent on grinding. The energy consumption due to grinding will, however, have little effect on the environment when compared to the cement production process.

Introducing the slag as a separate product enables application of SiMn-slag for partially replacing the cement in concrete. As this allows for further modification of the cement by concrete producers, substitution levels may increase even further.

Conclusion

Granulated silicomanganese slag that is separately ground yields the largest achievable substitution levels and is, therefore, concluded most beneficial for reducing CO_2 emissions from cement and concrete production. In addition, the heat stored in the water after water quenching of the slag can be utilised for other purposes instead of being lost to the air as done by air cooling today. Implementing all three application methods in combination provides highest application of SiMn-slag and, thus, the greatest potential for reducing total CO_2 emissions from the production of cement and concrete.