

## EFFECT OF LIMESTONE ON THE CEMENT PASTE HYDRATION IN THE PRESENCE OF POLYCARBOXYLATE SUPERPLASTICISER

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### ABSTRACT:

The addition of certain ingredients in conventional concrete is essential for improving rheological properties of this construction material. The effect of limestone and superplasticisers on the hydration kinetics of self-compacting concrete (SCC) was investigated on cement paste scale. These additives interact mostly with cement paste, since aggregates are considered to be inert materials. The understanding of the effect of these mineral and chemical additives on the hydration kinetics of cement paste is the key to design a self-compacting concrete with great properties. Four CEM I 52.5 N Portland Cements, limestone (LS) and one type of superplasticiser (SP) were used in this research. The hydration kinetics were evaluated by monitoring the storage modulus growth and different coefficients of a self-acceleration kinetics equation were used to depict the effect of different concentrations of SP with and without the optimum concentration of limestone (30 %) on the hydration kinetics of cement pastes. It was observed that the rate of hydration increased with the increase in SP concentration depending on the cement used. The addition of limestone in the superplasticised cement paste significantly retarded the hydration kinetics for all four cements. The rheological behaviour of self-compacting cement paste was found to be very sensitive to the chemical and physical properties of the cements used.

### KEY WORDS:

Cement hydration, complex modulus, rheokenetics, admixtures

## 1 INTRODUCTION

Self-compacting concrete (SCC) presents a number of advantages to the concrete industry when compared to traditional concrete [1]. SCC is defined by [2–4] as a concrete that is able to flow under its own weight, fill the formwork while exhibiting great resistance to segregation. This concrete does not require any type of vibration for its placement owing to its high flowability and it is widely used in situations where casting conditions are quite difficult i.e. densely reinforced concrete and/or complex shapes [5]. The use of mineral and chemical additives such as limestone and SP improve the rheological properties of cement paste for a better performance of self-compacting concrete [6]. Limestone improves the viscosity of the latter to transport the aggregate within the concrete as a composite material e.g. resisting segregation [7]. The addition of SP in cement paste decreases the yield stress and therefore improves the concrete flowability [8]. Properties of fresh and hardened self-compacting concrete are affected by the hydration of cement paste [9, 10]. Dur-

ing hydration, the increase in the magnitude of attractive forces between cement particles results in microstructural changes within the paste. This affects the overall rigidification process of cement paste and thus its workability [11]. The rigidification of cement paste has been attributed to the formation of hydrate products such calcium-silicate hydrate (C-S-H) [12]. It is therefore apparent that cement hydration is the backbone upon which the rheological properties of cement paste mostly depend [13].

Various techniques [14, 15] have been used to show the effect of limestone on the hydrate products particularly on the monocarbonate [16] that is responsible for ettringite stability around the most reactive cement compound (C<sub>3</sub>A). According to Klemm and Adams [17], ettringite formation is characterised by faster kinetics. It is therefore clear that limestone affects the early evolution of hydration. However, there are still certain ambiguities over the effect of limestone on the formation of ettringite. In Tsivilis et al. and Kakali et al. [18, 19] it was found that ettringite formation is retarded by the presence of limestone, though the opposite effect was

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C<sub>3</sub>A, and sulphate. Limestone blended cements with high content of C<sub>3</sub>A (C<sub>1</sub> and C<sub>2</sub>) were experiencing a long hydration time while the opposite behaviour was noticed in those with a low content of C<sub>3</sub>A (C<sub>3</sub> and C<sub>4</sub>). The competition between C<sub>3</sub>A and sulphate on the adsorption of SP on cement particles was reported by Vikan et al. [41]. Sulphate is known to prevent the adsorption of SP on C<sub>3</sub>A during early hydration. Therefore, more SP would remain in the suspension, allowing the repulsion effect between cement particles. Consequently, the hydration of cement paste would take long in the presence of gypsum [38, 42]. Celik et al. [16] explained the chemical reaction between C<sub>3</sub>A and limestone by emphasising the effect of their hydrate products on the evolution of hydration. The interaction of these two compounds yields monocarbonate that has been reported to indirectly provide a high stabilisation of ettringite around cement particles [14, 43]. Ettringites are needle-like crystals resulting from the reaction between C<sub>3</sub>A and sulphate that precipitates and deposits around cement compounds and slows down the hydration process.

#### 4 CONCLUSIONS

The following conclusions were drawn based on the observations of this research. The rheokinetic equation of self-acceleration type can be used to characterise the hydration of limestone blended cement paste. The increase of SP concentration significantly affects the rate of hydration by increasing the hydration time of both blended and unblended limestone cement pastes. The addition of limestone in cements with polycarboxylate acid based SP doubled the initial hydration time by drastically decreasing the rate of hydration. Though the cements used were of the same type, they presented different rheokinetic behaviour, due to their variations in physical and chemical compositions. Special attention should then be paid on the cement properties when studying their rheological behaviour. The hydration rate of superplasticised cement pastes was found to be affected by the concentration of C<sub>3</sub>A content and the alkali equivalent available in the cements used. When limestone was however added, the competition between C<sub>3</sub>A and sulphate content on the SP used prevailed and governed the hydration behaviour.

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