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Incorporation of Metakaolin and waste concrete powder as a partial replacement of silica fume in lime activated GGBFS-cementless UHPC

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ABSTRACT

Metakaolin (MK) and waste concrete powder (WCP) were used as replacement materials for silica fume in lime-activated GGBFS-based cementless ultra-high-performance concrete (UHPC). The reactivity of these replacement materials was evaluated through R^3 analysis, which revealed that MK exhibited significantly higher reactivity compared to WCP, which was found to be less reactive. Despite the lower reactivity of WCP, its replacement of silica fume at a dosage of up to 15% resulted in a compressive strength comparable to that of the reference sample. However, when the replacement dosage of both MK and WCP exceeded this threshold, a substantial decrease in compressive strength was observed. This reduction in strength was further correlated with the findings from thermogravimetric analysis, which provided insights into the phase composition and thermal stability of the hydrated products. The analysis confirmed the presence of calcium silicate hydrate (C-S-H), hydrotalcite, and wollastonite, a more crystalline form of C-S-H, at different decomposition temperatures. These results highlight the significant role of replacement materials in influencing both the mechanical properties and hydration characteristics of cementless UHPC.

1. INTRODUCTION

Ultra-high-performance concrete (UHPC) has emerged as a class of advanced concrete type characterized by superior mechanical strength and durability. The incorporation of highly reactive supplementary materials, such as silica fume, is critical to achieving the desired performance in UHPC mixtures. However, increasing

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environmental concerns and the effort of sustainable construction practices have motivated the exploration of alternative pozzolanic and waste derived materials as partial replacements for silica fume. Among these, metakaolin (MK), a highly reactive aluminosilicate, and waste concrete powder (WCP), a by-product of construction and demolition activities, present promising opportunities to enhance sustainability without compromising performance (Vashistha et al. 2023). This study investigates the effects of substituting silica fume with MK and WCP in a quicklime (CaO) activated ground granulated blast furnace slag (GGBFS) based cementless UHPC system. The research aims to explore the influence of these replacement materials on the reactivity, hydration characteristics, and mechanical properties of the resulting binders, thereby advancing the development of sustainable UHPC formulations.

2. RESULTS

The replacement rate of both WCP and MK was tested up to 50 per cent. In particular, the compressive strength at up to 25 per cent replacement rate was found to be optimum in the case of both MK and WCP. The reference sample showed a compressive strength of 156.9 MPa meanwhile WCP10 had shown an improvement with 163.7 MPa. Moreover, in large amount replacement, MK50 had a superior compressive strength while WCP50 displayed a compressive strength of only 65.7 MPa. These results indicate the feasibility of adopting both MK and WCP, which are cheaper and more abundant in terms of availability as a partial replacement for silica fume in cementless UHPC production(Bernal et al. 2011; Vashistha et al. 2023).

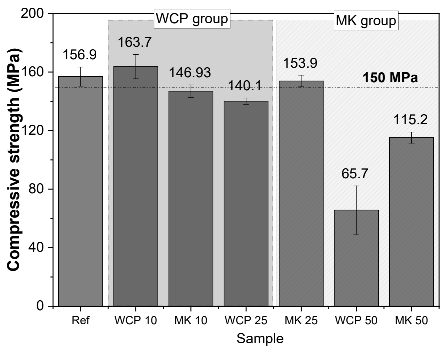

Figure 1. Compressive strength of the sample.

3. CONCLUSIONS

The replacement of WCP and MK can be optimized upto 25 percent based on the developed compressive strength. Meanwhile, 10 percent of WCP improved the overall compressive strength of the cementless UHPC.

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