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PERFORMANCE OF TERNARY BLENDED CEMENT MORTAR CONTAINING PALM OIL FUEL ASH AND METAKAOLIN

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A thesis submitted in fulfilment of the

requirements for the award of the degree of

Doctor of Philosophy (Civil Engineering)

Faculty of Civil Engineering

Universiti Teknologi Malaysia

SEPTEMBER 2015

Dedicated to

my family

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to my main thesis supervisor, Associate Professor Dr. Abdul Rahman Bin Mohd. Sam, for motivations, guidance, critics and full academic support. I am also very appreciative to my co-supervisor, Dr. Yahya Bin Mohammad Yatim, for his diligent advices and encouragements. Without their continued support and interest, this thesis would not have been the same as presented here.

I am greatly indebted to Universiti Teknologi Malaysia (UTM) for given me this golden opportunity to pursue Ph.D., most especially; School of Graduate Studies, Faculty of Civil Engineering, Department of Materials and Structure, Sultanah Zanariah Library and Technicians-Structural and Materials laboratory UTM.

I gratefully acknowledge the support for this research from Ahmadu Bello University Zaria (ABU) Nigeria and TETFUND. Finally, I am grateful to all my family members.

ABSTRACT

The partial substitution of Portland cement with pozzolans in concrete greatly reduces the environmental pollution due to CO_2 emission during cement production. Pozzolans equally enhance mechanical properties and guarantee the production of concrete with minimum costs. These added benefits, result in the increasing use of pozzolans as a significant innovation in the construction industry. Although palm oil fuel ash (POFA) as pozzolan improves strength and durability of concrete, it however delays early strength development due to its low pozzolanicity. Conversely, metakaolin (MK) improves early strength development but equally reduces workability and increases heat of hydration which can be detrimental to the durability of concrete. MK is also deficient in magnesium sulfate environment and at high temperatures. Thus, the scope of application of the binary blends of POFA and MK in the construction industry may be limited. However, the simultaneous use of these materials in the form of ternary blend has the potential to compensate for the deficiencies due to their synergistic interactions. Hence, this study was set out to investigate the effects of the combination of POFA and MK on the properties of cement mortar. Accordingly, a total of 17 different mortar mixtures of binary and ternary blends of POFA and MK at up to 30% replacement levels by weight, and water to binder ratio of 0.55 were used. An optimal ternary blend in terms of strength development and porosity reduction was selected for further detailed investigation. The properties of the optimal ternary assessed at its fresh state include; consistency, setting times, workability and temperature rise. While at its hardened state, compressive strength, sorptivity and microstructures were evaluated. The durability was studied in terms of resistance to sulfuric acid attack, sulfates attack and at high temperatures. The properties of the binders were also examined and their conformity to the relevant standards was confirmed. The results showed that the optimal ternary blend was 10% POFA and 10% MK. The ternary blend significantly improved the workability of mortar with minimal use of superplasticizer compared to MK binary blend. It was also discovered that while the MK binary blend increased the semi-adiabatic temperature by 7% compared to plain OPC, the ternary blend showed a reduction by 4%. Besides, the ternary blend was not only effective in offsetting the low compressive strength of POFA binary at early ages but also enhanced the long-term strength compared to MK, and POFA binary. The TGA and XRD data proved that the early strength improvement of the ternary blend was due to the high pozzolanicity of MK. Furthermore, the ternary blend exhibited superior performance over the MK binary blend and plain OPC in terms of resistance to magnesium sulphate attack and at high temperatures. Generally, the optimal ternary blend of OPC, MK and POFA showed better performance and can be used in construction particularly where the binary blends of either POFA or MK proved deficient. The combined use of POFA and MK would contribute not only to the development of environmental friendly material but also the reduction of CO_2 emission.

ABSTRAK

Penggantian sebahagian simen Portland dengan bahan pozolana dalam konkrit dapat mengurangkan masalah pencemaran alam sekitar disebabkan oleh pembebasan CO_2 semasa pengeluaran simen. Pozolana juga meningkatkan sifat mekanikal dan menjamin pengeluaran konkrit dengan kos yang minima. Kelebihan ini meningkatkan penggunaan pozolana sebagai satu inovasi dalam industri pembinaan. Walaupun abu kelapa sawit (POFA) sebagai bahan pozolana meningkatkan kekuatan dan ketahanlasakan konkrit bagaimanapun perkembangan kekuatan awal adalah kurang disebabkan rendah sifat pozolananya. Sebaliknya Metakolin (MK) meningkatkan perkembangan kekuatan awal tetapi mengurangkan kebolehkerjaan dan meningkatkan haba penghidratan yang boleh menimbulkan masalah ketahanlasakan konkrit. MK juga tidak tahan kepada persekitaran bermagnesium sulfat dan pada suhu yang tinggi. Oleh itu skop penggunaan adunan penduaan POFA dan MK di dalam industri pembinaan adalah terhad. Walau bagaimana pun, penggunaan bersama bahan ini secara sinergi dalam adunan pertigaan mempunyai potensi mengatasi kelemahan-kelemahan tersebut. Oleh yang demikian kajian ini dijalankan untuk mengkaji kesan gabungan POFA dan MK terhadap sifat simen motar. Sebanyak 17 jenis campuran adunan penduaan dan pertigaan POFA dan MK yang berbeza dengan penggantian sehingga 30% mengikut berat dan nisbah air-simen 0.55 telah dibuat. Campuran yang optima adunan pertigaan berpandukan peningkatan kekuatan dan pengurangan keporosan telah dipilih untuk kajian selanjutnya. Sifat campuran optima simen motar semasa basah dikaji dari aspek konsistensi, masa set, kebolehkerjaan dan peningkatan suhu. Sementara dalam keadaan keras, kekuatan mampatan, tahap serapan dan mikrostruktur adunan diuji. Ketahanlasakan diuji terhadap rintangan asid sulfurik, serangan sulfat dan pada suhu tinggi. Ciri-ciri pelekat juga dikaji dan pematuhannya kepada piawaian yang berkaitan dibuktikan. Keputusan menunjukkan campuran pertigaan optima adalah 10% POFA dan 10% MK. Aduan pertigaan didapati meningkatkan kebolehkerjaan mortar dengan penggunaan superpemplastik yang sedikit berbanding adunan penduaan MK. Kajian menunjukkan adunan penduaan MK meningkatkan suhu separuh adiabatik sebanyak 7% berbanding campuran simen (OPC) manakala adunan pertigaan menunjukkan pengurangan sebanyak 4%. Selain daripada itu, adunan pertigaan bukan sahaja mengatasi masalah kekuatan awal yang rendah bagi adunan penduaan POFA tetapi meningkatkan kekuatan jangka panjang berbanding adunan penduaan MK dan POFA. Data TGA dan XRD membuktikan peningkatan kekuatan awal adunan pertigaan disebabkan oleh sifat pozolana MK. Tambahan pula adunan pertigaan memperlihatkan prestasi yang lebih baik berbanding adunan penduaan dan campuran OPC terhadap serangan sulfat dan suhu yang tinggi. Secara keseluruhan adunan pertigaan yang optima OPC, MK dan POFA menunjukkan prestasi yang lebih baik dan boleh digunakan dalam pembinaan terutamanya bagi mengatasi kelemahan adunan penduaan MK dan POFA. Kombinasi POFA dan MK bukan sahaja dapat membangunkan bahan yang mesra alam sekitar tetapi juga dapat mengurangkan kadar pembebasan CO_2.