EXPERIMENTAL STUDIES ON SELF-COMPACTING CONCRETE MIXED WITH PALM OIL FUEL ASH AND FLY ASH

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THESIS SUBMITTED IN FULFILLMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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2016

DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excerpts, equations, summaries and references, which have been duly acknowledged.

22nd June 2016

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ABSTRACT

Self-compacting concrete (SCC) is an innovative construction material that is competent to flow, filling all areas and corners of the formwork even in the presence of congested reinforcement under its own self-weight. Compared to normally vibrated concrete (NVC), SCC enhances productivity, working conditions and reduces the number of labourers due to the elimination of compaction. SCC has high powder content and thus it is necessary to replace some of the cement by pozzolanic admixtures to achieve an economical and durable concrete. This thesis presents a study on the utilization of agricultural and industrial wastes such as palm oil fuel ash (POFA) and fly ash (FA) as pozzolans in SCC with blended aggregates. The control mixture contained Ordinary Portland Cement (OPC) as the binder at 540 kg/m^3 while the remaining mixtures incorporated binary and ternary blends of OPC, POFA and FA. The wastes replacement was in the range of 0 to 40% by weight of cement and water to binder (w/b) ratio was at 0.35 to 0.44. Super-plasticiser (SP) content was kept at a minimum of around 1%. Workability i.e. passing ability, filling ability and segregation resistance was determined and semi-adiabatic temperature rise during the initial stage of hydration was measured. It was observed that FA mixes required the least amount of SP to obtain a workable SCC; however, POFA mixes needed higher w/b ratio and SP content. The ternary use of POFA and FA in equal portions (TNY) had better workability properties than the POFA mixes and performed the best in terms of segregation resistance. The observed workability such as filling ability passing ability and segregation resistance were about 750 mm in slump diameter, less than 10 mm for step height, and less than 2% segregation ratio; indicating a highly workable SCC. The SCC with POFA mixes had the lowest amount of heat dissipation with peak temperatures of 57.9°C. The TNY mixes had lower heat dissipation compared to FA only mixes at 58.4°C. The hardened SCC was tested for the cube and cylinder compressive strength and splitting tensile strength for up to 90 days. The developed 28 days cylinder compressive strength for 40% POFA, FA and TNY mix were 25.3, 37.4 and 35.2 MPa, respectively, and were identified as medium strength concrete and is suitable for conventional concrete structures. The tensile strength at 28 days was around 3 MPa. The durability properties were determined using water absorption, sorptivity, and chloride penetration (RCPT and salt ponding tests) for up to 90 days. The durability properties; water absorption ≤ 6%, initial sorptivity of ≤ 0.02 mm/s$^{1/2}$, RCPT ≤ 1000 Coulombs and salt concentration of ≤ 0.04% of concrete weight in SCM with 40% replacement indicate significant improvement in durability. Furthermore, the cost analysis shows that the material cost for SCC utilising FA can be comparable to the local NVC and cheaper than conventional SCC using European or Japanese mix design. In conclusion, the experimental studies indicate that SCC with binary and ternary blends of POFA and FA has significant potential as medium strength concrete when considering a sustainable construction material, hence also providing a cleaner production solution for the palm oil and coal power industry.

ABSTRAK

PENGGUNAAN SISA PERTANIAN DAN PERINDUSTRIAN DALAM KONKRIT TANPA PEMADATAN

Konkrit tanpa pemadatan (SCC) merupakan bahan pembinaan inovatif yang berupaya untuk mengalir, mengisi seluruh ruangan dan sudut acuan walaupun dengan kehadiran tetulang yang padat di bawah beratnya sendiri. Berbanding dengan konkrit biasa (NVC), SCC meningkatkan produktiviti dan mengurangkan tenaga buruh melalui penghapusan aktiviti pemadatan. SCC mempunyai kandungan simen yang tinggi dan ini menyebabkan keperluan untuk menggantikan bahan ini dengan bahan pozolan lain untuk menjimatkan kos dan meningkatkan sifat-sifat konkrit. Tesis ini membentangkan kajian mengenai penggunaan sisa pertanian dan perindustrian seperti abu bahan api kelapa sawit (POFA) dan abu industri arang batu (FA) sebagai bahan pozolan dalam SCC dengan agregat sebati. Campuran kawalan mengandungi Simen Portland Biasa (OPC) sebagai pengikat sebanyak 540 kg/m^3 manakala campuran lain digantikan dengan POFA dan FA dalam lingkungan 0-40% mengikut berat simen dan mengikut nisbah air-simen 0.35 hingga 0.44. Kandungan bahan tambahan kimia (SP) adalah kira-kira 1%. Kebolehkerjaan dan kenaikan suhu separuh adiabatik pada peringkat awal penghidratan diukur. Adalah diperhatikan bahawa sp diperlukan dengan kandungan paling sedikit apabila FA menggantikan simen, manakala, POFA memerlukan kandungan air dan SP yang jauh lebih tinggi. Campuran POFA dengan FA dalam nisbah yang sama menghasilkan ciri-ciri kebolehkerjaan yang lebih baik daripada campuran POFA sahaja. Kebolehkerjaan yang diperhatikan adalah keupayaan mengisi, keupayaan laluan dan rintangan pengasingan menggunakan bahan sisa menghasilkan diameter 750 mm dalam ujian kon, 10 mm dalam untuk ketinggian langkah, dan kurang daripada 2% nisbah rintangan pengasingan; menunjukkan SCC dengan kebolehkerjaan yang unggul. SCC dengan campuran POFA mempunyai pelesapan haba yang paling rendah dengan suhu puncak 57.9 °C. manakala campuran POFA dan FA adalah 58.4 °C. SCC telah diuji dari segi kekuatan mampatan kiub dan silinder dan kekuatan tegangan sehingga 90 hari. Kekuatan mampatan silinder untuk 40% campuran pada hari ke-28 adalah 25.31, 37.41 dan 35.2MPa untuk POFA40, FA40 dan TNY40 dan boleh diklassifikasi sebagai konkrit kekuatan sederhana (kekuatan biasa) sesuai untuk digunakan dalam konkrit struktur konvensional. Kekuatan tegangan pada 28 hari adalah sekitar 3MPa. Sifat-sifat ketahanan telah ditentukan dengan menggunakan penyerapan air (penyerapan keseluruhan dan penyerapan satu hala), dan penembusan klorida (RCPT dan ujian garam) sehingga 90 hari. Sifat-sifat ketahanan pada hari ke-90; penyerapan air keseluruhan ≤ 6%, penyerapan air-sehala ≤ 0.02mm/sec$^{1/2}$, RCPT≤1000 Coulomb dan penembusan klorida ≤ 0.04% menunjukkan penambahan yang ketara dalam ketahanan. Tambahan pula, analisis kos menunjukkan bahawa kos bahan untuk SCC menggunakan FA boleh setanding dengan NVC tempatan dan lebih murah daripada SCC konvensional menggunakan rekabentuk campuran Eropah atau Jepun. Kesimpulannya, kajian eksperimen menunjukkan bahawa SCC dengan POFA dan FA mempunyai potensi yang besar sebagai konkrit kekuatan sederhana dengan itu juga menyediakan penyelesaian bagi isu alam sekitar dalam industri minyak sawit dan arang batu.

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