PROPERTIES OF CONCRETE INCORPORATING EGGSHELL AS PARTIAL CEMENT REPLACEMENT WITH TIRE CRUMB AS SAND REPLACEMENT

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We hereby declare that We have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Pembandaran yang pesat telah menyebabkan peningkatan yang mendadak dalam pembinaan maka selari dengan penggunaan simen sebagai bahan yang banyak menyumbang kepada pelepasan gas rumah hijau kerana penggunaan tenaga yang tinggi. Industri simen adalah antara penyumbang terbesar gas rumah hijau. Kira-kira 7% pelepasan karbon dioxide (CO_2) global berasal dari industry simen, dengan 900 kg CO_2 dilepaskan ke atmosfera untuk menghasilkan satu tan simen. Pengurusan sisa pepejal adalah salah satu masalah utama di Malaysia. Pembangunan pesat dan pertumbuhan penduduk mendorong penyelidikan untuk meningkatkan kitar semula dan penggunaan semula bahan buangan untuk pembangunan lestari. Kulit telur ayam dibuang di Malaysia sebagai sampah perbandaran, sementara tayar terpakai adalah sampah yang sukar dikendalikan dan sering berakhir di tapak pelupusan sampah. Makalah, kajian ini mengemukakan sifat konkrit berprestasi tinggi dengan serbuk kulit telur dan serbuk getah tayar sebagai penggantian separa simen dan pasir. Kulit telur dihancurkan sehingga melepasi jaringan 150µm sementara getah tayar sisa bersaiz 30mesh atau 600µm digunakan untuk kajian ini. Konkrit berprestasi tinggi Gred 55 dihasilkan daripada gentian sehingga 15% kulit telur sebagai pengganti simen dan sehingga 15% serbuk getah tayar sebagai pengganti pasir pada selang 5% untuk kedua-dua bahan. Sifat fizikal spesimen konkrit dinilai melalui ujian kericihan dan ujian keliangan. Ujian tanpa musnah, iaitu tukul pantulan dan kelajuan denyut ultrasonik turut dilakukan pada spesimen. Selain itu, ujian mekanikal juga dinilai bagi menentukan kekuatan mampatan, kekuatan lenturan dan modulus keanjalan spesimen konkrit. Reka bentuk eksperimen digunakan untuk menganalisis semua data yang dikumpulkan dan menentukan peratusan penggantian optimum. Metodologi *Mixed Regression* dan *Response Surface* digunakan untuk menghasilkan model matematik kebolehkerjaan konkrit dan kekuatan mampatan. Keputusan menunjukkan bahawa kulit telur dan tayar getah mengurangkan kebolehkerjaan konkrit. Walau bagaimanapun, spesimen optimum dengan penggantian 5% kulit telur dan tayar getah mengekalkan kebolehkerjaan sederhana. Keliangan konkrit menurun dengan penggantian kulit telur dan spesimen optima mempunyai keliangan serendah 2.71%. Berdasarkan kepada ujian tanpa musnah, nombor pantulan spesimen optima ialah 29.50 dan menunjukkan kekerasan yang munasabah. Kedua-dua spesimen kawalan dan optima mencapai status kualiti tinggi dengan nilai UPV melebihi 4km/s. Untuk ujian mekanikal, spesimen optima memerhatikan peningkatan kekuatan mampatan 13.463% untuk mencapai kekuatan mampatan 28 hari sebanyak 55.37 MPa. Kekuatan lentur spesimen optima mencatat 11.245MPa dengan peningkatan 11.969% daripada spesimen kawalan. Tambahan pula, kekuatan tegangan pecahan spesimen optima meningkat sebanyak 8.528% kepada 35.78MPa. Analisis struktur mikro konkrit menunjukkan bahawa penggantian simen dengan kulit telur menyebabkan kadar penghidratan yang lebih besar, kepadatan dalaman yang lebih tinggi dan kekosongan dalaman yang lebih sedikit. Pemodelan matematik menggunakan ujian tanpa musnah dan perkadaran penggantian menunjukkan bahawa penggantian serbuk kulit telur mempunyai kaitan lengkung dengan prestasi mekanikal konkrit. Model-model mempunyai pekali penentuan di atas 0.90 sementara nilai yang diramalkan dari model mempunyai penyimpangan dalam ±10% dari nilai eksperimen. Kedua-dua model regresi dan RSM mampu meramalkan tingkah laku konkrit, tetapi model *Response Surface* mempunyai penyimpangan yang lebih rendah dan ketepatan yang lebih baik. Oleh itu, konkrit dengan kulit telur dan getah tayar adalah pilihan yang boleh dilaksanakan dalam pengeluaran konkrit demi pemuliharaan sumber asli dan bahan mentah.

ABSTRACT

Rapid urbanization has led to a sharp increase of construction and hence cement usage, a material which contributes greatly to greenhouse gas emission due to high energy consumption. The cement industry is among the largest contributors of greenhouse gas. About 7% of global CO_2 emission comes from the industry, with 900 kg CO_2 emitted to the atmosphere for producing one ton of cement. Solid waste management is one the leading problems in Malaysia. Rapid development and population growth have prompted researches to improve the recycling and reusing of waste material for sustainable development. Chicken eggshell is discarded in Malaysia as municipal waste, while waste tire is a waste that is difficult to handle and often ends up in the landfill. This paper presents the properties of high performance concrete with eggshell powder and tire rubber crumb as partial replacement of cement and sand. The eggshell was grinded to size passing 150µm sieve while waste tire rubber of 30mesh or 600µm was purchased for the study. Grade 55 high-performance concrete was prepared with up to 15% eggshell as cement replacement and up to 15% tire rubber crumb as sand replacement at an interval of 5% for both materials. The physical properties of concrete specimens were evaluated with various tests such as slump cone test and porosity test. Non-destructive tests, namely rebound hammer and ultrasonic pulse velocity are then conducted on the specimens. Mechanical tests are then conducted to determine the compressive strength, flexural strength and modulus of elasticity of concrete specimens. Design of experiment was used to analyse all collected data and determine the optimum percentage of replacement. Mixed regression and Response Surface Methodology were employed to produce mathematical models of concrete workability and compressive strength. The result shows that both eggshell and tire rubber reduces workability of concrete. However, the optimum specimen with 5% eggshell and tire rubber retained medium workability. Porosity of concrete decreases with eggshell replacement and the optimum specimen has a porosity of 2.71%. Based on non-destructive tests, the rebound number of optimum specimen is 29.50 which indicates satisfactory surface hardness. Meanwhile, both control and optimum concrete specimens achieve high-quality status with UPV value above 4km/s. For mechanical properties, optimum concrete specimen observes a 13.46% increase in compressive strength to achieve 28-days compressive strength of 55.37 MPa. Flexural strength of the optimum specimen recorded 11.245 MPa which is 11.969% higher than the control. In addition, split tensile strength of optimum specimen increases by 8.528% to 35.78MPa. Microstructure analysis of concrete reveals that replacement of cement with eggshell causes a greater hydration rate, denser internal packing, and less internal voids. Mathematical modelling using non-destructive test and replacement proportion shows that eggshell powder replacement has a curvilinear relation with concrete mechanical performance. The models have coefficient of determination above 0.90 while the predicted value from the model has deviation within ±10% from the experimental value. Both regression and RSM model could predict the behaviour of concrete, but Response Surface Methodology model has lower deviation and better accuracy. Hence, eggshell powder and tire rubber concrete is concluded as a feasible option in concrete production for the conservation of natural resources and raw materials.

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