

**THE EFFECT OF ELEVATED TEMPERATURE
AND HEATING DURATION
ON HIGH STRENGTH CONCRETE WITH
STEEL SLAG AS CEMENT REPLACEMENT**

HO CHIA MIN

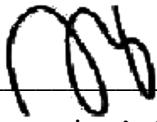
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We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.



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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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**THE EFFECT OF ELEVATED TEMPERATURE AND HEATING DURATION
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REPLACEMENT**

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ABSTRAK

Permintaan konkrit yang signifikan telah menyumbang kepada pengeluaran simen dalam kuantiti yang banyak di mana simen adalah bahan utama dalam pembuatan konkrit. Selain itu, sisa industri seperti sisa keluli (SS) dihasilkan dalam kuantiti yang besar dan kebanyakannya dibuang ke tapak pelupusan, akhirnya menyebabkan impak negatif terhadap alam sekitar. Penggunaan SS sebagai pengganti sebahagian simen dalam pembuatan konkrit akan mengurangkan penggunaan simen dan kuantiti sisa yang dilupuskan. Di samping itu, konkrit berkekuatan tinggi (HSC) adalah komposit heterogen yang mengalami perubahan sifat fizikal, kimia, dan mekanikal yang rumit apabila terdedah kepada suhu tinggi. Penggunaan produk sampingan industri sebagai bahan tambahan dalam HSC telah mempengaruhi sifatnya selepas terdedah kepada suhu tinggi. Oleh itu, penyelidikan ini dilakukan untuk mengkaji kesan suhu tinggi yang berbeza dan tempoh pemanasan terhadap HSC dengan saiz zarah SS yang berbeza sebagai pengganti simen, berdasarkan sifat fizikal, kimia, dan mekanikalnya. Dua saiz zarah SS yang berbeza telah digunakan sebagai pengganti sebahagian simen, iaitu SS halus (FSS-0.075mm) dan SS kasar (CSS-0.15mm). Pada peringkat awal penyelidikan, campuran percubaan telah dijalankan untuk mengenal pasti nisbah air-simen optimum dan nisbah penggantian SS. Satu spesimen kawalan dan SS-HSC telah dibancuh menjadi (100 x 100 x 100) mm kuib, dan (dia. 100 x 300) mm. Selepas 28 hari, spesimen tersebut diletakkan dalam relau elektrik pada suhu 200 °C, 400 °C, 600 °C, dan 800 °C selama 1, 2, dan 3 jam. Sifat fizikokimia SS-HSC telah diperiksa melalui kehilangan jisim, perubahan warna, pengimbasan mikrokop elektron (SEM), difraksi X-Ray (XRD), dan analisis termogravimetrik (TGA). Sifat mekanikal SS-HSC juga telah disiasat melalui ujian kekuatan mampatan dan modulus keanjalan. Keputusan daripada ujian tersebut digunakan dalam pemodelan matematik, menggunakan Response surface methodology (RSM) telah dijalankan untuk membangunkan model matematik dengan pelbagai pembolehubah bebas dan bergantung. Hasil kajian menunjukkan bahawa struktur mikro HSC menjadi lebih padat apabila dipanaskan sehingga 400°C, manakala retakan mikro ditemui apabila terdedah kepada suhu 600°C dan ke atas. Kekuatan mampatan sisa HSC meningkat sehingga 400°C, tetapi berkurangan setelah terdedah kepada suhu 600°C dan ke atas. Selain itu, CSS10 mendapat kekuatan mampatan relatif yang lebih tinggi daripada FSS10 apabila dipanaskan pada suhu yang tinggi. Fenomena yang diperhatikan boleh dikaitkan dengan saiz zarah SS yang lebih kasar yang bertindak sebagai bahan simen tambahan serta agregat dalam HSC. Daripada pemodelan RSM, HSC yang dikenakan suhu yang tinggi selama 2 jam mengekalkan prestasi mekanikal yang baik manakala CSS10 menunjukkan kelakuan selepas kebakaran yang lebih baik berbanding dengan FSS10. Pekali penentuan terlaras (R^2 terlaras) bagi kedua-dua ujian adalah 0.9648 dan 0.9126. Secara keseluruhan, kajian menunjukkan bahawa HSC yang mengandungi CSS berpotensi untuk digunakan sebagai aplikasi struktur dalam rintangan api.

ABSTRACT

A vast demand for concrete contributes to an enormous cement production where cement is the primary constituent in concrete manufacturing. Besides, the industry waste such as steel slag (SS) has produced in a large quantity and a large portion of it is disposed of on landfilling which causing a serious environmental impact. Utilization of the SS as partial cement replacement in producing concrete would reduce the cement consumption and amount of waste disposed. In addition, high strength concrete (HSC) is a heterogeneous composite which undergoes a transformation of physical, chemical, and mechanical behavior in a complicated way when subjected to elevated temperatures. The use of industrial by-products as supplementary cementitious materials in HSC has influenced the performance of itself after exposure to high temperature. Thus, this research was conducted to investigate the effect of different heating temperatures and heating durations on HSC with the different particle sizes of SS as cement replacement based on the physical, chemical, and mechanical properties. Two different SS particle sizes were used as partial cement replacements which are fine SS (0.075mm) and coarse SS (0.15mm). At the early stage of the research, trial mix was conducted to identify the optimum water-cement ratio and SS replacement ratio. A control specimen and SS-HSC was cast into (100 x 100 x 100) mm cube, and (dia. 100 x 300) mm. After 28 days, the specimens were placed in the electrical furnace at temperature of 200°C, 400°C, 600°C and 800°C for 1, 2 and 3 hours. The physicochemical characteristic of the SS-HSC was examined by mass loss, color change, scanning electron microscopy (SEM), X-Ray diffraction (XRD), and thermogravimetric analysis (TGA). While the mechanical properties of SS-HSC were investigated by compressive strength test and modulus of elasticity. Besides, the results from compressive strength test and modulus of elasticity were used in mathematical modelling. In this study, Response surface methodology (RSM) was conducted to develop the mathematical model with various independent and dependent variables. The findings show that microstructure of HSC becomes denser when heated up to 400°C while the microcracks are found when subjected to 600°C and above. The residual compressive strength of SS-HSC is increased up to 400°C and decreased after exposure to 600°C and above. Furthermore, CSS10 obtained slightly higher relative residual compressive strength than FSS10 when heated at elevated temperature. The observed phenomenon could be attributed to the coarser particles size of SS acting as supplementary cementitious materials as well as aggregate in the HSC. From the RSM modelling, HSC subjected to elevated temperatures for 2 hours retains a significantly good performance on the mechanical properties while CSS10 presents a better post-fire behavior as compared to FSS10. The adjusted coefficient of determination (predicted R^2) of the models are 0.9648 and 0.9126, respectively. Finally, the study showed that HSC that containing CSS has the potential to be used as structural application in fire resistance.

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