CRACKING BEHAVIOUR OF COAL ASH CONCRETE BASED ON ACOUSTIC EMISSION TECHNIQUE

ABDUL MUIZ BIN HASIM

MASTER OF SCIENCE

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

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.

(Supervisor's Signature)

Full Name : DR. KHAIRUL ANUAR BIN SHAHID

Position : SENIOR LECTURER

Date : 8/5/2023

(Co-supervisor's Signature)

Full Name : DR. NUR FARHAYU BINTI ARIFFIN

Position : SENIOR LECTURER

Date : 8/5/2023

STUDENT'S DECLARATION

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.

(Student's Signature)

Full Name : ABDUL MUIZ BIN HASIM

ID Number : MAH20008

Date : 8 MAY 2023

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ABSTRAK

Peningkatan berterusan sektor tenaga telah menghasilkan sisa arang batu berlebihan yang dikenali sebagai abu dasar arang batu (CBA) dan abu terbang (FA) yang terhasil daripada proses pembakaran untuk menjana kuasa elektrik. Pelupusan CBA dan FA di tapak yang terbuka telah mengakibatkan banyak kemusnahan alam sekitar. Oleh itu, tindakan perlu diambil untuk mengitar semula sisa-sisa tersebut. Mutakhir ini, campuran CBA di dalam konkrit telah berjaya dikaji dari segi struktur mikro, ketahanan, dan sifat norma yang lain. Walau bagaimanapun, masih terdapat kajian yang kurang mendapat tumpuan iaitu berkaitan prestasi struktur, dan persoalannya adalah bagaimana sifat agregat CBA ini akan memberi kesan terhadap keretakan pada struktur konkrit apabila beban kitaran dikenakan. Pengenalpastian kepada keretakan adalah sangat penting kerana ia menunjukkan tanda-tanda awal kepada masalah kapasiti tanggungan beban dan kelemahan dalam kekuatan elemen struktur. Maka, penyelidikan ini bertujuan untuk mengkaji sifat mekanikal konkrit dan sifat keretakan rasuk konrit bertetulang (RC) dengan penggunaan CBA di dalam pembuatannya. Oleh itu, sampel konkrit dibahagikan kepada empat gabungan penggantian yang berbeza iaitu di antara separuh (50%) dan penuh (100%) kandungan agregat batu dan agregat pasir menggunakan CBA beserta penambahan sebanyak 20% FA kepada keseluruhan jumlah simen. Konkrit basah dilakukan ujian kebolehkerjaan manakala sampel konkrit keras diuji dengan ujian mampatan, ujian tegangan pecah dan ujian lentur untuk mengkaji sifat mekanikal konkrit tersebut. Rasuk RC kemudiannya diuji dengan lenturan 4 titik menggunakan kaedah beban kitaran untuk menilai sifat keretakannya. Penilaian rasuk RC juga dipantau dengan menggunakan teknik emisi akustik (AE) sebagai ujian tanpa musnah (NDT). Keputusan kajian menunjukkan bahawa kekuatan mampatan kesemua penggantian konkrit mencapai kekuatan sasaran iaitu 30 MPa pada hari ke 28. Walau bagaimanapun, kekuatan tegangan dan lenturan berkurang apabila terdapat peningkatkan kandungan CBA di dalam penghasilan konkrit. Selain itu, kriteria beban kitaran oleh sisihan daripada lineariti (DFL) menunjukkan kegagalan rasuk RC mengikut tahap lengkungan dalam setiap kitaran beban. Sifat keretakan rasuk RC adalah dipengaruhi oleh indeks penghancuran dan tahap kekasaran CBA itu sendiri. Semua rasuk RC yang diuji menunjukkan kegagalan retak lentur dan ricih. Dalam analisis parameter AE, korelasi antara kekerapan purata dan nilai RA (kenaikan masa/amplitud) menunjukkan bahawa pembentukan retakan pada kitaran awal sentiasa direkodkan sebagai mod tegangan dengan frekuensi purata yang tinggi. Kemudian, retakan itu bertukar kepada mod ricih yang mengandungi nilai RA tinggi pada kitaran selanjutnya sehingga ke beban akhir. Keputusan teknik AE menunjukkan hasil kajian yang sama seperti pemeriksaan visual kepada keretakan pada permukaan rasuk RC semasa ujikaji dijalankan di dalam makmal. Oleh itu, dapatan yang diperoleh daripada kajian ini menunjukkan bahawa pengenalpastian keretakan daripada penggunaan teknik AE adalah berkesan dalam memantau keadaan struktur, maka ia boleh memberi manfaat dalam memahami sifat CBA terhadap prestasi sesebuah struktur konkrit. Akhir sekali, penggunaan CBA di dalam konkrit secara berlebihan menghasilkan bilangan keretakan yang banyak dan kelebaran retak yang besar, akan tetapi penggunaan CBA sebagai 50% penggantian batu kerikir mempunyai prestasi struktur yang baik terhadap ujian beban kitaran kerana ia setanding dengan rasuk RC kawalan.

ABSTRACT

The continual rise of the power sector has resulted in massive production of coal waste by-products known as coal bottom ash (CBA) and fly ash (FA), which are formed when raw coal is burned to generate electricity. The disposal of CBA and FA contributes significantly to major environmental hazards and thereby extensive efforts are required to utilize these wastes. Recently, CBA in concrete has been successfully investigated in terms of microstructure, durability, and other common properties. However, it is non-trivial to remark that a topic that received less exploration is serviceability of structural performance, and the main concern being whether CBA aggregate affects the cracking of structural concrete due to the cyclic load. The crack identification is critically important because it gives the first sign of serious trouble indicating the load-carrying capacity and deficiencies in strength of structural elements. Therefore, this research aims to investigate the mechanical properties of plain concrete and cracking behaviour of reinforced concrete (RC) beam with inclusion of CBA. Thus, specimens were designed into four distinct combination replacements between half (50%) and full (100%) of coarse aggregate and fine aggregate using CBA with addition of 20% FA to the cement amount. The fresh concrete was tested by workability test while plain concrete specimens were made for compressive test, splitting tensile test and flexural tests to investigate the mechanical properties of concrete. Then RC beam specimens were cast for a 4-point bending test subjected to a cyclic load method to evaluate cracking behaviour. The assessment of the RC beam also used the acoustic emission (AE) technique that worked purposely for non-destructive testing (NDT). The experimental result shows that compressive strength of concrete for all replacements achieves targeted strength of 30 MPa at 28 days. However, splitting tensile and flexural strength decreased slightly when increasing the volume of CBA in the design mixture. Furthermore, the cyclic load criteria with respect to deviation from linearity (DFL) is promising to correlate to RC beam failure according to deflection in each specific load cycle. Nonetheless, the cracking behaviour of RC beams was mainly influenced by porous and high crushing index of coarse CBA and all tested RC beams failed to the flexural and shear crack failure. In AE parameter-based analysis, the correlation between average frequency and RA (rise time/amplitude) value shows that nucleation of cracks in early cycles are always recorded as a tensile mode with a high average frequency. Then, the crack switches to shear mode containing a high RA value at a subsequent cycle until ultimate load. The AE findings are well matched and consistent with the real visual inspection of crack damage that appeared on the RC beam surface during the experimental work in a laboratory. Thus, the obtained finding in this study indicates that the crack identification from AE technique is effective for structural monitoring, so it could benefit understanding the properties of CBA on the performance of concrete structures. Finally, the excessive usage of CBA in concrete contribute to large numbers of crack while producing wide crack width, but the utilization of CBA as a 50% gravel replacement has good structural performance under cyclic load test as they are comparable to the control RC beam.

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