MECHANICAL PROPERTIES OF EXPANDED POLYSTYRENE BEADS -PALM OIL FUEL ASH CONCRETE AND ITS REINFORCED CONCRETE BEAM PERFORMANCE

MOHAMAD HAIRI BIN OSMAN

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To my beloved mother and father

Mr. Osman & Mdm. Fabilah

For being the backbone of my life by supporting me from the very beginning

To my supervisor and mentors,

Assoc. Prof. Ts. Dr. Suraya Hani bt Adnan Assoc. Prof. Ir. Dr. Shahrul Niza bin Mokhatar For their consistent encouragement, guidance and support throughout the research journey

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ABSTRACT

Normal-weight concrete is the common material for constructing reinforced concrete (RC) beams. However, there is also a need for lighter, more efficient, and more environmentally-friendly RC beams to meet the current industrial demand. This study was conducted to develop RC beam using Palm Oil Fuel Ash (POFA) and Expanded Polystyrene (EPS) as substitutes for cement and sand respectively. This study explored the potential of incorporating EPS and POFA into the RC beams as a novel approach. POFA and EPS offer various benefits as sustainable materials, including affordability, renewability, and recyclability. POFA's pozzolanic properties make it suitable for inclusion in concrete, while EPS can potentially reduce concrete density as a structural element. EPS and POFA in concrete are limited from 10% to 30% replacement. Experiments and numerical simulation using finite element analysis (FEA) was conducted for the EPS-POFA RC beam. This study also investigated the mechanical properties of EPS-POFA concrete and its RC beam performance subjected to a threepoint bending test. Experiments followed established standards and recommended methods, while numerical simulations utilized ABAQUS software for FEA analysis. The experiments measured parameters such as density, compressive strength, splitting tensile strength, modulus of elasticity, and ultimate load capacity in the EPS-POFA RC beam. Some of these parameters served as inputs for the ABAQUS software. Results show that the presence of POFA in concrete improved the properties such as compressive strength, splitting tensile strength, and ultimate load capacity of RC Beam. The performance of concrete containing 10% POFA and 10% EPS was comparable to that of normal concrete with a lower density and decreased crack width. Based on the finding and contribution, it is found that the new development of RC Beam has certain advantages that are lighter in mass, higher in strength and capacity, and also could reduce the crack width. To summarise, the RC beam consists of 10% POFA, and EPS is recommended due to the reduction structure self-weight with comparable performance.



ABSTRAK

Konkrit normal ialah bahan untuk membina rasuk konkrit bertetulang (RC). Walau bagaimanapun, ada juga keperluan untuk rasuk RC yang lebih ringan, cekap dan lebih mesra alam untuk memenuhi permintaan industri semasa. Kajian ini dijalankan untuk membangunkan rasuk RC menggunakan Abu Terbang Sawit (POFA) dan Expanded Polystyrene (EPS) bagi pengganti simen dan pasir. Kajian ini meneroka potensi gabungan EPS dan POFA dalam rasuk RC sebagai kaedah baru. POFA dan EPS menawarkan pelbagai faedah sebagai bahan mampan, kebolehperbaharuan dan kebolehkitar semula. Sifat pozzolanik POFA menjadikannya sesuai untuk dimasukkan ke dalam konkrit, manakala EPS berpotensi mengurangkan ketumpatan konkrit. EPS dan POFA dalam konkrit dihadkan kepada 10% hingga 30%. Eksperimen dan simulasi menggunakan analisis unsur terhingga (FEA) telah dijalankan untuk rasuk RC EPS-POFA. Kajian ini juga menyiasat sifat mekanikal konkrit EPS-POFA dan prestasi rasuk RCnya tertakluk kepada ujian lenturan. Eksperimen mengikut piawaian yang ditetapkan manakala simulasi menggunakan perisian ABAQUS untuk analisis FEA. Eksperimen mengukur parameter seperti ketumpatan, kekuatan mampatan, kekuatan tegangan, modulus keanjalan, dan kapasiti beban muktamad dalam rasuk RC EPS-POFA. Beberapa parameter ini berfungsi sebagai input untuk perisian ABAQUS. Keputusan menunjukkan bahawa kehadiran POFA dalam konkrit meningkatkan sifat seperti kekuatan mampatan, kekuatan tegangan, dan kapasiti beban muktamad RC Beam. Prestasi konkrit yang mengandungi 10% POFA dan 10% EPS adalah setanding dengan konkrit biasa dengan ketumpatan yang lebih rendah dan mengurangkan retak. Berdasarkan penemuan dan sumbangan, didapati pembangunan baharu RC Beam mempunyai kelebihan tertentu iaitu jisim yang lebih ringan, kekuatan dan kapasiti yang lebih tinggi, dan juga boleh mengurangkan retakan. Untuk meringkaskan, rasuk RC terdiri daripada 10% POFA, dan EPS disyorkan kerana struktur pengurangan berat sendiri dengan prestasi yang setanding.



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LIST OF SYMBOLS AND ABBREVIATIONS

b	-	Overall width of the cross section
В	-	Length
c/c	-	centre to centre
С	-	Concrete Cover
D	-	Damage parameter
e	-	Eccentricity
Ε	-	Young' Modulus
h	-	Overall depth of the cross section
σ	-	Stress
З	-	Strain
ρ	-	Density
v	-	Poisson Ratio
μ	-	Viscosity parameter
K	-19	Ratio of the stress invariants
ASTM	<u>P</u> .0.	American Standard Test Method
BS	-	British Standard
C3D8R	-	three-dimensional 8-node linear brick element
EC2	-	Eurocode 2
EPS	-	Expanded Polystyrene Beads
FE	-	Finite element
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
LVDT	-	Linear Voltage Displacement Transducers
POFA	-	Palm Oil Fuel Ash
RC	-	Reinforced Concrete
UTHM	-	Universiti Tun Hussein Onn Malaysia
W/B	-	Water-Binder

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CHAPTER 1

INTRODUCTION

1.1 Research background

The adoption of sustainable construction and green building has become the focal point of the construction sector in Malaysia. The Twelfth Malaysia Plan, 2021-2025 (Ministry of Economy, 2019), represents a transformational initiative to create a Prosperous, Inclusive, and Sustainable Malaysia for future generations. Using sustainable materials in civil engineering is mainly associated with Theme 3, which focuses on advancing sustainability to achieve resilience. Consequently, there is an emphasis on shared responsibility towards transitioning to a low-carbon nation and promoting equitable distribution of benefits from utilising natural resources. The national development priorities outlined in the Twelfth Plan align with the Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development (2030 Agenda).



This study also aligns with United Nations' 17 sustainable development goals (SDGs) (United Nations, 2015), prioritising sustainability as a central value. The topic which is the use of sustainable materials in civil engineering is particularly connected to SDG 9 (building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation) and SDG 11 (making cities and human settlements inclusive, safe, resilient, and sustainable). The use of sustainable materials like POFA and EPS which can be recycled, perhaps it is essential to achieving these goals out of all practical alternatives.

Concrete materials made from recycled materials have gained increasing popularity in recent years for sustainable construction and development.

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- Osman, M. H., Adnan, S. H., Jusoh, W. A. W., & Mazlin, N. I. (2020). The Properties of Concrete Containing Palm Oil Fuel Ash and Expanded Polystyrene Beads. *International Journal of Integrated Engineering*, 12(9), 78-86.

Coming Soon:

- Manuscript, entitled: The Deformation Pattern of Reinforced Concrete Beams
 by Using EPS And POFA As Replacement Materials accepted for publication
 in Archives of Metallurgy and Materials journal
- Manuscript, entitled: Behaviour Of Reinforced Concrete Beam Containing EPS And POFA Subjected To Three Point Bending Using Concrete Damage Plasticity (CDP) Model was selected to be published in MCRJ (Scopus indexed)

CONFERENCE PAPERS

 Osman, M. H. B., Kai, O. S., Adnan, S. H., Salim, S., Rahman, M., Jaafar, A., ... & Yahya, N. F. (2021, July). Mechanical properties of concrete containing expanded polystyrene (EPS) and palm oil fuel ash (POFA). In *AIP Conference Proceedings* (Vol. 2347, No. 1, p. 020093). AIP Publishing LLC.

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BOOK CHAPTER

 Mohamad Hairi Osman ,Daing Muhammad Irfan Ambok Lalak , Wan Amizah WanJusoh , Noor Khazanah A Rahman , Suraya Hani Adnan , Mohd Luthfi Mohd Jeni , Mohd Hafizal Hanipah, Nur Faezah Yahya, Hannifah Tami , Salman Salim , Ahmad Hakimi Mat Nor (2020) A Simulation Model Of Reinforced Concrete Beamcontaining Expanded Polystyrene Beads (Eps) And Palm Oil Fueled Ash (Pofa) Using Finite Element Method, *Construction Materials And Technology Series 3*, UTHM , 60, ISBN:9789672389637

LIST OF COMPETITION PARTICIPATED AND AWARD

- Gold Medal Award- International Invention, Innovation & Technology Exhibition, Malaysia (ITEX 2020)- Product Name: EPS-POFA REINFORCED CONCRETE BEAM (EPOFA RC BEAM)
- Gold Medal Award- National Innovation and Invention competition Through Exhibition 2020 (iCompEx'20)- POLIMAS. The Performance of RC Beam Containing potential of using Palm Oil Fuel Ash (POFA) and Expended Polystyrene (EPS) In Term of Flexural Behaviour.
- Gold Medal Award- National Innovation and Invention competition Through Exhibition 2019 (iCompEx'19)- POLIMAS. Title: The potential of using Palm Oil Fuel Ash (POFA) and Expended Polystyrene (EPS) as a Concrete Substance
- 4. Gold Medal Award International Research & Innovation Symposium and Exposition 2019 (RISE 2019) – UTHM. Title : The Performance of RC Beam Containing potential of using Palm Oil Fuel Ash (POFA) and Expended Polystyrene (EPS) In Term of Flexural Behaviour.
- 5. Gold Medal Award Research & Innovative Technology 2019 (RITEC 2019)
 UTHM

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: Literary

VITA



The author was born on August 5_{th}, 1983, in Semabok, Melaka. He went to Sekolah Rendah Kebangsaan (SRK) Semabok, Melaka and Sekolah Menengah Kebangsaan (SMK) Durian Daun, Melaka for his primary and secondary schools respectively. He first obtained his Bachelor's Degree in Civil Engineering in 2006, at the Kolej Universiti Tun Hussein Onn Malaysia (KUiTTHO) located in Batu Pahat, Johor. He further pursued his Master's degree at the same university which is Universiti Tun Hussein Onn Malaysia (UTHM), Batu Pahat, Johor, and graduated

with the M.Eng in Civil Engineering in 2012. During, he pursues his Doctoral Degree in Engineering Technology under Faculty of Engineering Technology (FTK), UTHM as part-time student Mohamad Hairi bin Osman serve as Industrial Fellow in the Department of Civil Engineering Technology at Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia (UTHM) with 11 years of teaching experiences. He also was involved in the construction industry for around 4 years. He has been awarded as a Professional Engineer (Ir) by Board of Engineer Malaysia (BEM) since 2015. In 2017, he awarded Professional Technologist (Ts) by Malaysian Board of Technology (MBOT).