FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE BEAM INCORPORATING COAL WASTE

SAFAA ABBAS SADEJ ALSAHN

UNIVERSITI TEKNOLOGI MALAYSIA

FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE BEAM INCORPORATING COAL WASTE

SAFAA ABBAS SADEJ ALSAHN

A project report submitted in partial fulfilmentof the
requirements for the award of the degree of
Master of Engineering (Structure)

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

DECEMBER 2019

DEDICATION

This project report is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time. Finally, it is dedicated to my supervisor Dr.Nor Hasanah Abdul Shukor Lim, my brothers, my sisters my wife and my children who support me to move forward.

ACKNOWLEDGEMENT

In preparing this project report, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Dr.Nor Hasanah Abdul Shukor Lim, for encouragement, guidance, critics and friendship.. Without her continued support and interest, this project report would not have been the same as presented here.

My fellow postgraduate student should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members.

ABSTRACT

This research deals with the study of coal waste in concrete. In this study, the coarse and fine aggregates are completely replaced by coal bottom ash in blended cement concrete. The physical properties of concrete are investigated by using coal waste (fly ash and bottom ash). 30% of cement are replaced by fly ash as partial replacement of cement, 100% of the fine and coarse aggregates are replaced by the bottom ash. Before using the bottom ash as a replacement material of natural aggregates, the sieve analysis test is done on the bottom ash to determine the gradient curve of the aggregates. A number of tests are carried out to investigate the hardened and fresh state properties of concrete including slump, compressive strength and flexural behaviour of concrete beam tests. Test specimens with dimensions of 100x 100 x 100 mm are subjected to compressive strength test. In order to demonstrate the structural application of coal wastes, two reinforced concrete beams with dimensions of 2200 x 200 x 150 mm containing coal waste were casted and tested in flexure. The ultimate load, deflection upon loading, cracking history and mode of failure of the beams were investigated. From the sieve analysis result, it shows that the particles distribution of coal bottom ash used in this research did follow the overall limit of standard and can be used as aggregates replacement. The results showed that the fresh and hardened properties of the conventional and coal waste concrete beams are almost similar. For example, the difference in moment capacity between bottom ash concrete and conventional concrete is 0.017%.In addition, the results of the flexural performance of the reinforced concrete beams containing coal wastes indicated better stiffness with comparable ultimate load and mode of failure to the control beam. The overall results revealed that coal wastes can be used as cement and aggregates replacement materials in concrete for construction application.

ABSTRAK

Kajian ini membincangkan kajian sisa arang batu dalam konkrit. Dalam kajian ini, agregat kasar dan halus telah digantikan sepenuhnya oleh abu bawah arang batu dalam konkrit simen campuran. Ciri fizikal konkrit disiasat dengan menggunakan sisa arang batu (abu terbang dan abu bawah). 30% daripada simen digantikan dengan abu terbang sebagai penggantian simen separa, 100% daripada agregat halus dan kasar digantikan dengan abu bawah. Sebelum menggunakan abu bawah sebagai bahan gantian agregat semulajadi, ujian analisis ayak dilakukan pada abu bawah untuk menentukan lengkung kecerunan agregat. Sejumlah ujian dijalankan untuk mengkaji sifat-sifat konkrit yang keras dan segar termasuk kejatuhan, kekuatan mampatan dan kelakuan lenturan ujian rasuk konkrit. Ujian spesimen dengan dimensi 100 x 100 x 100 mm tertakluk kepada ujian kekuatan mampatan. Untuk menunjukkan penggunaan struktur sisa arang batu, dua rasuk konkrit bertetulang dengan dimensi 2200 x 200 x 150 mm yang mengandungi sisa arang batu telah dilemparkan dan diuji dengan lekuk. Beban muktamad, pesongan semasa pemuatan, sejarah retak dan cara kegagalan rasuk disiasat. Dari hasil analisis ayak, ia menunjukkan bahawa pengedaran zarah abu bawah arang batu yang digunakan dalam penyelidikan ini mengikuti ikatan keseluruhan standard dan boleh digunakan sebagai pengganti agregat. Keputusan menunjukkan bahawa sifat-sifat yang segar dan keras dari rasuk konkrit konvensional dan arang batu konkrit hampir sama. Contohnya, perbezaan kapasiti momen antara konkrit abu bawah dan konkrit konvensional ialah 0.017%. Di samping itu, keputusan prestasi lenturan rasuk konkrit bertetulang yang mengandungi sisa arang batu menunjukkan kekakuan yang lebih baik dengan beban muktamad dan mod kegagalan yang sama dengan rasuk kawalan. Hasil keseluruhan menunjukkan bahawa sisa arang batu boleh digunakan sebagai simen dan agregat bahan gantian dalam konkrit untuk aplikasi pembinaan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CC	-	Conventional concrete
BAC	-	Bottom ash concrete
OPC	-	Ordinary Portland cement
ASTM	-	American Society for Testing and Materials
SSD	-	Saturated Surface Dry state
OD	-	Oven Dry state
WOD	-	Weight of Oven Dry state
WSSD	-	Weight of Saturated Surface Dry state
BS	-	British Standard

LIST OF SYMBOLS

Fc	-	Compressive strength
M	-	Moment
F	-	Force
fcf	-	Flexural strength
l	-	Length
d	-	Dimension

CHAPTER 1

INTRODUCTION

1.1 Introduction

In construction sector, concretes are the most famous construction materials that are commonly used in construction for long time ago because of their flexibility usage. In general, concrete mass is combined of, aggregates and, cement and water but the concrete produced by traditional method are weak to aggressive environment because it is porous. The porosity in concrete allows water and sulphates to enter the concrete and attack the reinforcement. Pozzolanic materials like fly ash can be added to the concrete mix to produce denser, high durable and strength concrete (Kim*et al*., 2016).

Generally, fly ash is in the fine residue form. It is produced from combusted powdered coal during generating electric processor from other resources. A pozzolanic material is a aluminous or siliceous material that mixing with water and lime to produce a cementations compound. Fly ash is one of the materials that has pozzolanic characteristic. For this reason fly ash occupies a wide portion in producing cement. Under the microscope, the fly ash grain is finer than cement granular. Also it has almost a totally spherical in shape. If fly ash is presence in concrete mixture, the finer granular of fly ashes will fill up many of the microscopic spaces in concrete mass that make the hardened concrete more durable and stronger. As a result, the amount of water which is required for the concrete mixture will be reduced.

On the other hand, reuse of industrial waste like coal waste is an active way to reduce costs and preserve the environment. Coal bottom ash is by product of burning of coal and is considered as waste. These wastes can be used as alternative material to natural aggregates in the concrete to obtain new properties of concrete such as light weight and durability as well as low price. Besides that, this recycling process will reduced the harmful waste to the environment that may and reduce the depletion of natural resources such as natural aggregates. Finally, to revive the economy, recycled materials are used instead of buried in landfills.

1.2 Problem Statement

In the growing demand for the construction sector, demand for concrete is also increasing. High demand for conventional concrete means higher cost and more consumption for natural resources such as natural aggregates. Besides that, natural aggregates that used in conventional concrete contribute to high density of concrete which lead to high demand of heavy machines and a lot of labours to mix, transfer and placing the concrete.

Bottom ash is acceptable material to use as an alternative for natural aggregates because it is cheap, light weight and abundant material. To produce high strength and durable concrete, materials with pozzolanic characteristic should be add in the concrete mix, which lead to produce high-density concrete that can prevent sulphates to attack the concrete. Coal fly ash is one of these pozzolanic materials that can be used.

Bottom ash which is collected from power plants will be used as a total replacement of aggregates. The maximum size of the granules will be 10 mm for the

total replacement of aggregate. Exploring coal waste as cement and aggregates replacement would create an advanced waste material.

1.3 Objectives

The main aim of this research is to use coal waste including fly ash as cement replacement and bottom ash as fine and coarse aggregates replacement. Hence the measurable objectives of this study were as follows:

i. To investigate the characteristic of coal waste in concrete production.
ii. To determine fresh and hardened state properties of concrete containing coal waste as cement and aggregates replacement.
iii. To examine the structural performance of reinforced concrete beam incorporating coal waste in term of flexural behaviour.

1.4 Scope of Research

This research investigates the structural performance of concrete incorporating fly ash as a partial replacement of cement and bottom ash as a totally substitute for fine aggregates and coarse aggregates. These characteristics were compared with properties of conventional concrete (traditional concrete made of cement and natural aggregates). In this research, ordinary Portland cement (OPC) was used and the maximum coarse aggregate size was 10 mm. In addition, 30% of the total amount of cement was replaced with fly ash as a partial replacement, but for fine and coarse aggregates, were replaced by 100% coal bottom ash. A number of tests are conducted to investigate fresh and hardened state properties like slump, compressive strength, and flexural behaviour of reinforced concrete beam. Test

specimens comprising of 18 cubes with dimensions of 100x 100 x 100 mm. The tests are done within three stages of concrete's life which are 7, 14 and 28 days. The test results of two groups are compared to each other. Besides that, two beams with dimensions of 2200 mm x 200 mm x 150 mm were casted and tested after 28 days of curing. One of these beams was casted by using fly ash and bottom ash as replacement materials and the other beam was casted with the same measurements and the quantity of reinforcement, but by using normal concrete mixture. After 28 days curing, the two beams are subjected to the bending test and the results obtained from the tests are compared to determine the flexural behaviour of the reinforced concrete beams in term of ultimate load, deflection upon loading, cracking history and mode of failure of the beams.

1.5 Importance of the study

There are a lot of important advantages can be obtained by using coal fly ash as a partial replacement of cement and coal bottom ash as a total alternative to coarse and fine aggregates. For example, coal waste will become a new type of resource that can be widely used to produce a good and acceptable quality of concrete to solve the problem of lack of building materials. Furthermore, recycling and reusing of coal waste products can reduce the impact on the environment, thereby reducing the problem of landfill and the impact of water and air pollution. On the other hand, we can reduce the increasing demand for cement and natural aggregates.

Since the coal bottom Ash have lightweight comparing to the natural aggregates weight, we can produce lightweight concrete compared to traditional concrete weight. Because of coal fly ash have pozzolanic characteristics, coal waste can contribute to product concrete with higher durability than the normal concrete because fly ash can contribute to produce concrete free of harmful sulphates that reduces the permanence of concrete.

REFERENCES

ASTM C618 - 08 Standard Specifications for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. ASTM International.

ASTM C 78/C 78M. Standard test method for flexural strength of concrete (using simple beam with third-point loading). West Conshohocken (PA): ASTM; 2010. p. 4

.Balakrishnan, B., Awal, A.S.M.A., (2014). Durability performances of concrete containing high volume Malaysia fly ash, International Journal of Research in Engineering and Technology, 3(4), 529-533.

British Standards Institution. Method for determination of tensile splitting strength. London: BSI,1983 (BS1881: Part 117).

Bouzoubaa N, Zhang MH, Malhorta VM. Mechanical properties and durability of concrete made with high-volume fly ash blended cement using a coarse fly ash. Cem Concr Res 2001;31:1393–402.

Baykal, G., and Doven, A. G. (2000). Resources, conservation . 30, 59-77.

Brandes MR, Kurama YC. Use of recycled concrete aggregates in precast/prestressed concrete. Proc Eng 2016;145:1338–45.

Brown V, Bartholomeu C. Long-term deflections of GFRP-reinforced concrete beams. In: First international conference on composites in infra-structure. Tucson, Arizona, USA; 1996. p. 389–400

British Standards Institution. Method for determination of flexural strength. London: BSI,1983 (BS1881: Part 117).

British Standards Institution. Method for determination of tensile splitting strength. London: BSI,1983 (BS1881: Part 117).

British Standards Institution. Methods for determination of slump. London: BSI,1983 (BS1881: Part 102).

Desai, SB and Limbachiya, MC. (2006). Coarse recycled aggregate – a sustainable concrete solution. The Indian Concrete Journal: 17–23. ACC Limited,Maharashtra, India.

innovative infrastructures, Seoul, Korea. Fraaij, A. L., Pietersen, H. S., and de Vries, J. (2002). Performance of
concrete with recycled aggregates, Dhir, R.K., Dyer, T.D., Halliday,
J.E. (Eds.), Challenges of Concrete Construction: Sustainable Concrete
Construction. ICE Publishing, Dundee, pp. 187-198.

Karim, M.R. et al., (2011) ―Strength development of mortar and concrete containing fly ash: A review‖ Intern. Jour. Of the Phys. Sci., Vol. 6 (17), 4137 – 4153.

Massazza, F. (1993). Pozzolanic cement. Cement and Concrete Composites, 15, 185-214.

Muhardi et al., (2010) ―Engineering characteristics of Tanjung Bin coal ash‖ EJGE Vol. 15, Bund. K., 1117 – 1129.

Naik, T. R., Singh, S. S., and Ramme, B. W. (2002). Effect of source of fly ash on abrasion resistance of concrete. Journal of Materialsin Civil Engineering, 14(5), 417-426.

Naganathan, S., Subramaniam, N. and Mustapha, K.N. (2012) ―Development of Brick using Thermal Power Plant Bottom Ash and Fly ash‖. Asian Journal of Civil Engineering (Building and Housing), Vol. 13 No. 1, 275-287.

Obla, K. H. (2008). Specifying fly ash for use in concrete. Concrete InFocus, 61-66.

Pazahani. K and Jeyaraj. R, "Study on durability of high performance concrete with industrial wastes", Applied technology & Innovations, vol. 2, pp. 19-28, 2010.

Reddy, P. (2014). Determination of mechanical properties of aggregates concrete with fly ash. International Journal of Advancements in Research & Technology, 3(2).

Schubert S, Hoffmann C, Leemann A, Moser K, Motavalli M. Recycled aggregate concrete: experimental shear resistance of slabs without shear reinforcement.
Eng Struct 2012;41:490–7.

Tam, Gao and Tam. (2006). Comparing performance of modified two-stage mixing approach for producing aggregate concrete. Magazine of Concrete Research,58(7), 477–484. ICE Publishing, London, UK.

Taylor, T. N., Taylor, E.L., Krings, M., (2009). Paleobotany: The biology and evolution of fossil plants.

Thomas C, Setien J, Polanco J, Alaejos P, De Juan MS. Durability of recycled aggregate

concrete. Constr Build Mater 2013;40:1054–65.

Waleed, N. and Canisius, T. (2007). WRAP - Engineering properties of concrete containing recycled aggregates, WRAP, Oxon, UnitedKingdom.

Yang, K.-H., Chung, H.-S., and Ashour, A. F. (2008). Influence of type and replacement level of aggregates on concrete properties. ACI Materials Journal, 105(3), 289–296