

FINITE ELEMENT ANALYSIS ON THE
EFFECT OF HOLLOW SECTION ON THE
STRENGTH OF FOAMED CONCRETE BEAM

CHONG BENG WEI

B. ENG(HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG



SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Degree of Civil Engineering

(Supervisor's Signature)

Full Name : Pn. Rokiah Binti Othman

Position : Lecturer

Date : 30 May 2019



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 : CHONG BENG WEI

ID Number : AA 15208

Date : 30 May 2019

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CHONG BENG WEI

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ABSTRAK

Rasuk berongga diperkenalkan untuk mengurangkan berat daripada struktur dan memudahkan penggunaan IBS yang boleh menjimat kos pembinaan. Rongga juga boleh digunakan sebagai ruang untuk kerja-kerja elektrik dan mekanikal. Konkrit ringan yang mempunyai ketumpatan 1600 kg/m^3 dihasilkan daripada PSBE yang mengantikan 30% berat simen. Processed Spent Bleaching Earth (PSBE) merupakan bahan pozzolan yang di proses selepas digunakan untuk penapisan minyak. Kajian ini dijalankan untuk menganalisis bentuk dan posisi rongga yang terbaik dengan menggunakan simulasi perisian ANSYS. Kajian ini juga akan menyokong dapatan hasil kajian eksperimen makmal. Lenturan ujian empat titik disimulasikan pada enam spesimen rasuk. Rasuk S1, S2 dan S3 mempunyai berongga persegi yang bersaiz 50mm manakala Rasuk C1, C2 dan C3 mempunyai rongga bulatan dengan diameter 50mm. Rongga spesimen Nombor 1 berada pada tengah paksi neutral. Spesimen Nombor 2 mempunyai rongga di atas paksi neutral dan spesimen Nombor 3 mempunyai rongga di bawah paksi neutral. Saiz rasuk didalam kajian ini adalah 150mm x 200mm x 1500mm. Finite Element Analysis dilakukan pada spesimen dengan penggunaan perisian ANSYS. Nilai maksimum beban kegagalan dan perubahan bentuk specimen di kaji. Dari hasilnya, rasuk berongga bulatan boleh menahan beban yang lebih tinggi dan mempunyai pesongan yang lebih kecil berbanding dengan rasuk berongga persegi. Selain itu, kedudukan yang paling baik bagi rongga adalah di atas paksi neutral, manakala rasuk dengan berongga di bawah paksi neutral adalah yang paling lemah. Rasuk C2 menghasilkan beban tertinggi di kalangan semua spesimen, iaitu 4.015kN. Rasuk paling lemah ialah S3, yang gagal pada 3.338kN. Untuk rasuk dengan bahagian berongga persegi, rasuk menghasilkan peningkatan 1% dalam pemuatan apabila bahagian berongga berada di atas paksi neutral, tetapi kehilangan kekuatan sebanyak 15.3% diperhatikan apabila bahagian berongga berada di bawah paksi neutral. Untuk rasuk dengan ronggar bulatan, bahagian berongga di atas paksi neutral menghasilkan peningkatan 0.65% dalam pemuatan, manakala bahagian berongga di bawah paksi neutral menyebabkan kehilangan kekuatan sebanyak 3.79%. Corak keputusan bersetuju dengan hasil eksperimen makmal. Konkrit lemah dalam ketegangan, jadi dalam rasuk yang tidak diperkuatkan, rasuk kehilangan kekuatan yang ketara apabila bahagian berongga berada di bawah paksi neutral, iaitu zon ketegangan. Pergeseran bahagian berongga ke atas paksi neutral menguatkan rasuk kerana konkrit adalah baik dalam mampatan dan seksyen berongga di zon mampatan tidak mempunyai kesan kepada prestasi rasuk. Penyelidikan ini bertujuan untuk memberi pemahaman tentang bentuk dan kedudukan yang terbaik untuk rongga konkrit berbuih. Ia juga mengesahkan keupayaan Finite Element Analysis untuk meramalkan prestasi struktur berongga dalam potensi kajian skala penuh.

ABSTRACT

Hollow section is introduced on beam to reduce a dead load of the structure, which can ease the usage of IBS and hence minimize construction cost. It can also act as a pathing for mechanical and electrical works. Lightweight concrete produced by replacing 30% cement with PSBE with a density of 1600 kg/m³. Processed Spent Bleaching Earth (PSBE) is a residue from an oil-refining process that can be used to replace cement in the concrete mix. The study is conducted to analyse the best shape and position of the hollow section using ANSYS software. The study will also verify the results of previous experimental studies. Four-point bending test simulated on six beams samples. Beam S1, S2 and S3 have a square opening of size 50mm while beam C1, C2, and C3 have a circular opening of 50mm diameter. Samples Number 1 has opened right on the neutral axis. Samples Number 2 has opening above neutral axis while samples Number 3 have opening below the neutral axis. The size of all six beams is 150mm x 200mm x 1500mm. Finite element analysis performed on the samples with the usage of ANSYS software. The failure load and maximum total deformation are determined. From the result, beams with circular hollow section could withstand higher loading and had smaller deflection compared to its square hollow section counterpart. Also, the best position of the hollow is located above the neutral axis, while beams with hollow below the neutral axis were the weakest. Beam C2 produced the highest load among all sample, which was 4.015kN. The lowest beam was S3, which failed at 3.338kN. For beams with square hollow section, the beam produced a 1% increase in loading when the hollow section was above the neutral axis, but a strength loss of 15.3% observed when the hollow section was below the neutral axis. For beams with circular section, the hollow section above the neutral axis produced a 0.65% increase in loading, while the hollow section below neutral axis caused a strength loss of 3.79%. The resulting pattern agreed with experimental results. Concrete is weak in tension, so in unreinforced beams, the beam loses significant strength when the hollow section is below the neutral axis, which is the tension zone. Shifting the hollow section to above neutral axis strengthened the beams because concrete is good in compression and hollow section at the compression zone has little effect on the performance of the beams. The research aims to provide an understanding of the best shape and position of the hollow for a foamed concrete beam. It also verifies the ability of Finite Element Analysis to predict the performance of the hollow structure in the potential full-scale study.

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LIST OF SYMBOLS

%	Percentage
σ	Flexural Strength
δ	Deflection
Y_c	Vertical Distance to Centroid
I	Second Moment of Area

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Material
BS	British Standard
EN	Europäische Norm
FEA	Finite Element Analysis
FEM	Finite Element Method
IBS	Industrialised Building System
MS	Malaysian Standard
PSBE	Processed Spent Bleaching Earth
SBE	Spent Bleaching Earth

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Concrete is the most-used material in the construction industry. However, the concept of foamed concrete has created a new alternative to the conventional concrete mix. Lightweight foamed concrete has various advantages, such as high strength-to-weight ratio, low density, and cost-effectiveness (Amran, Farzadnia, & Ali, 2015). Replacement of cement using waste material such as waste plastic and palm oil shell has also been introduced to reduce the usage of cement – which contributes to CO₂ emission and dust pollution. Processes Spent Bleaching Earth (PSBE), a waste product from the oil industry used to produce foamed concrete. PSBE will replace 30% cement to in the sample simulated in this paper. To further reduces a dead load of structure and usage of cement, the hollow section introduced on beam. The decrease in weight allows the usage of Industrialized Building System (IBS) in construction, which also reduces the usage of labour and formwork. The hollow section can also be used as a pathing for mechanical and electrical related work (A. Jabbar, Alshimmeri, Nasir, & Al-Maliki, 2014). In this research, the Finite Element Method (FEM) is used to simulate the models of hollow foamed concrete beams. ANSYS software was used to perform the modeling of the hollowed beams.

1.2 Problem Statement

Rapid urbanization has led to a sharp increase of construction and hence cement usage, a material which contributes significantly to greenhouse gas emission due to high energy consumption. Production of cement is also a very dusty process due to crushing, drilling and grinding of various materials. Dust particle from about 1 to 100 µm in diameter is a hazard to human health and also causes smog (Ahmad & Ismail, 2014).

Hence, new building material such as lightweight foam concrete is raising demand due to the principle of sustainable development (Decký et al., 2016). Apart from reducing cement usage, structural innovation such as hollow section is also utilized to achieve lighter weight structure. Spent Bleaching Earth (SBE) is a hazardous waste that causes environmental degradation. About 2,000,000 tons of SBE has generated annually (Beshara & Cheeseman, 2014). However, in Malaysia, SBE is disposed of mainly into landfill. By the usage of the hollow section on beams and SBE as a cement replacement, the dead load of structure can be minimized, cutting down on cost due to labour and formwork. Reducing reliability on formwork will lead to a reduction in construction cost. It also allows Industrialize Building System (IBS) to be utilized in more construction project to achieve sustainable development. It is beneficial to the construction industry as it has stated that IBS is a construction method that is faster, safer and cheaper (Kamar & Hamid, 2011). Increased usage of IBS also helps to lower the reliance on foreign workers (Wong & Lau, 2015). According to Ko, Wang, & Kuo (2011), the cost of formwork contributes to about one-third of the construction, and IBS has the potential to cut down the cost on formwork.

1.3 Objectives

The purpose of the study is to determine the best shape and position of the hollow section on the strength of a foamed concrete beam with processed spent bleaching earth as partial cement replacement. The objectives have shown below:

- i. To determine the ultimate load of flexural beams using ANSYS software
- ii. To determine the maximum deflection of flexural beams using ANSYS software
- iii. To compare the result of finite element analysis with experimental and theoretical data.

1.4 Scope of the Study

The research conducted by using ANSYS software to generate 3-Dimensional models and 4-points load test was simulated onto six beam specimens to study their loading bearing capacity and deflection curve. The dimension of the beam specimens was

150mm × 200mm × 1500mm with circular and square shaped hollow section. The dimension of square hollow section was 50mm × 50mm, while the size of the circular hollow was 50mm diameter. This study aims to investigate the effect between location and shape of hollow and the ultimate loading and maximum deflection of the foamed concrete beam. For every shape of hollow, three positions of hollow were modelled by referring to the neutral axis of the specimens. The hollow was located right on the center of the neutral axis, above the neutral axis and below the neutral axis. The result of the study has compared with laboratory data and theoretical value.

1.5 Significance of the Study

The research aims to determine the best shape and position of the hollow section of the foamed concrete beam. The finite element analysis of the models provides detailed information about the stress distribution and deflection curve of the beam under different hollow condition. This will allow the most efficient structural model to be adopted when utilizing the concept of hollowed form concrete beam. The research also aims to promote the performance of formed concrete as an effort to reduce the usage of cement and formwork for a greener construction practice.

1.6 Thesis Outlines

The thesis consists of five chapters. Chapter 1 introduced the topic of research along with the problem that inspired the endeavour to be taken. The scope and significant research also included. Chapter 2 discussed the topics related to the research and reviewed past works and experiments that helped to determine the suitable method to carry out the research. Chapter 3 explained the steps taken to set up the Finite Element modelling software and the process in which the models have generated and analysed. Chapter 4 and 5 were the finding of the analysis followed by the conclusion of the research.

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