FINITE ELEMENT ANALYSIS OF RC BEAMS STRENGTHENED WITH BAMBOO FIBRE REINFORCED COMPOSITE PLATE USING ANSYS

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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

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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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Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

Faculty of Civil Engineering and Earth Resources

UNIVERSITI MALAYSIA PAHANG

JUNE 2018

ACKNOWLEDGEMENTS

First of all, praises be to Allah, who has given me the strength to complete this final year project as a requirement for graduation and successful award of the Bachelor Degree (Hons.) Civil Engineering and Earth Resources from University Malaysia Pahang. I would like to express my gratitude to my research supervisor, Dr. Chin Siew Choo for her guidance throughout my final year project. Lastly, I also would like give a big appreciation to my family and friends who have support me to complete this final year project.

ABSTRAK

Kehadiran pembukaan dalam rasuk konkrit bertetulang (RC) secara automatik mengurangkan kapasiti beban rasuk RC dengan ketara diikuti dengan keretakan dan pesongan berlebihan. Untuk memulihkan kehilangan kekuatan, polimer bertetulang karbon (CFRP) yang merupakan salah satu serat sintetik telah dipilih untuk digunakan sebagai bahan pengukuhan. Di samping itu, CFRP memberikan kekuatan tambahan yang agak tinggi untuk rasuk. Walau bagaimanapun, untuk mempromosikan penggunaan CFRP dalam pembinaan hari ini, kos CFRP yang tinggi telah terbukti menjadi halangan. Sebaliknya, polimer serat semulajadi yang lebih mampan dan lebih murah adalah alternatif sempurna untuk serat sintetik. Objektif utama kajian ini adalah untuk mengkaji kelakuan dan potensi plat komposit bertulang buluh sebagai bahan pengukuhan. Beberapa rasuk dengan dimensi 120 x 300 mm dan panjang 1500 mm dimodelkan dalam tiga dimensi (3D) sebagai rasuk yang disokong hanya di ANSYS + CivilFEM 12.0. Dalam kajian ini, terdapat tiga (3) jenis konfigurasi untuk rasuk yang dianalisis iaitu rasuk konvensional, rasuk yang tidak diperkukuh pada lenturan dan rasuk dengan bukaan. Rasuk ini dipertingkatkan lagi dengan BFRCP untuk memeriksa kebolehpercayaan BFRCP. Analisis unsur hujung (FEA) telah dilaksanakan untuk mendapatkan keputusan tertentu yang merupakan keluk beban pesongan, corak retak, kontur tekanan dan kontur terikan. Dari FEA, rasuk RC mengalami penurunan sebanyak 10.8% dari segi keupayaan galas beban apabila stirrups di zon lenturan dikeluarkan. Kemudian, penggunaan BFRCP sebagai bahan pengukuhan pada zon lenturan berjaya mengembalikan 71.1% kehilangan kekuatan yang hampir sama dengan kekuatan asal. Kerugian kapasiti beban besar terjadi apabila pembukaan dibuat dalam rasuk dengan peratusan kerugian sebanyak 47.4%. Penggunaan BFRCP di zon ricih berjaya mengembalikan 38% kehilangan kekuatan. Selepas itu, keputusan FEA dan keputusan percubaan telah disahkan. Bagi rasuk pepejal, lengkung-belitan beban menunjukkan persetujuan yang kuat dengan perbezaan peratusan 0.3%. Untuk rasuk yang tidak diperkukuh pada lenturan, perbezaan 1.8% yang membuktikan perjanjian yang kukuh. Rasuk yang diperkuat dengan lentur dengan BFRCP menunjukkan persetujuan yang kuat kerana perbezaan peratusan hanya 1.4%. Rasuk dengan bukaan juga dalam perjanjian yang kuat dengan perbezaan peratusan sebanyak 4.7%. Rasuk dengan bukaan yang diperkuat dengan BFRCP mencapai persamaan yang setanding dengan perbezaan peratusan sebanyak 19.5% yang masih dalam jangkauan yang dibenarkan. Dari segi corak retak, perjanjian yang kukuh antara semua keputusan FEA dan keputusan eksperimen diperolehi. Sebagai kesimpulan, plat komposit serat buluh boleh menjadi bahan pengukuhan luaran alternatif untuk pengukuhan struktur.

ABSTRACT

Presence of opening in reinforced concrete (RC) beam automatically reduce the load capacity of the RC beams significantly followed by excessive cracking and deflection. To recover the loss in strength, carbon reinforced polymer (CFRP) which is one of synthetic fibre was opted to be used as strengthening material. In addition, CFRP provide a relatively high additional strength for beam. However, in order to promote the usage of CFRP in construction today, the high cost of CFRP was proved to be a hindrance. On the contrary, natural fibre polymer which is more sustainable and cheaper was a perfect alternative to synthetic fibre. The main objective of this research was to study on the behaviour and potential of bamboo reinforced composite plate as the strengthening material. Several beams with dimensions of 120 x 300 mm and a length of 1500 mm were modelled in three-dimensional (3D) as simply-supported beams in ANSYS+CivilFEM 12.0. In this research, there were three (3) types of configurations for beams that were analysed which are conventional beam, beam unstrengthened at flexural and beam with openings. The beam was further enhanced with BFRCP to check the reliability of BFRCP. Finite element analysis (FEA) was implemented to obtain certain results which are the load-deflection curve, crack pattern, stress contours and strain contours. From FEA, the RC beam undergone a reduction of 10.8% in terms of load bearing capacity when the stirrups at the flexural zone were removed. Then, application of BFRCP as strengthening material at flexural zone managed to regain 71.1% of the strength loss which almost the same as the original strength. A huge load capacity loss occured when opening was created in the beam with a percentage loss of 47.4%. Application of BFRCP at the shear zone managed to regain 38% of strength loss. After that, FEA results and experimental results were validated. For solid beam, the load-deflection curve showed a strong agreement with percentage difference of 0.3%. For beam unstrengthened at flexural, the difference 1.8% which proved a strong agreement obtained. Beam strengthened at flexural with BFRCP showed a strong agreement as the percentage difference was 1.4% only. Beam with openings also in a strong agreement with percentage difference of 4.7%. Beam with openings strengthened with BFRCP reached a comparable agreement with percentage difference of 19.5% which is still within permissible range. In terms of crack patterns, a strong agreements between all results of FEA and experimental results were obtained. As conclusion, bamboo fibre composite plate can be an alternative external strengthening material for structural strengthening.

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LIST OF ABBREVIATIONS

3D	Three-dimensional
CFRP	Carbon Fibre Reinforced Polymer
FEA	Finite Element Analysis
FEM	Finite Element Method
FRP	Fibre Reinforced Polymer
GFRC	Glass Fibres Reinforced Composite
RC	Reinforced Concrete

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Reinforced concrete (RC) beams with openings are widely used for construction of high rise building. The opening became a pathway for utility purposes such as the pipes, electricity cables and sewage. The utilization of the dead space will allow for engineers to produce a more efficient building design (Aykac, Kalkan, Aykac, and Egriboz, 2013). Nevertheless, these web openings also will impact the strength of the RC beam itself as it reduces its bearing capacity. Consequently, researchers trying to implement glass fibres reinforced composite (GFRC) to strengthen the beam. However, it is found that GFRC not only harmful when peoples inhaled it but also need a higher cost (Paul Wambua, Jan Ivens and Department, 2003). To cater this problem, natural fibre polymer has been proposed as an alternative for GFRC as it is not harmful to peoples and also need lower cost. Realising the effectiveness of natural fibre polymer as alternative to GFRC, a study has investigated the mechanical properties of bamboo fibre in order to determine the validity of the claim (Abdul Khalil et al., 2012). But, most of studies involving bamboo fibre reinforced polymer only emphasis on experimental approach rather than finite element analysis. Thus, in this research will focus on a simulation on bamboo fibre plate reinforced with epoxy to strengthen around the openings by using ANSYS software.

1.2 Problem Statement

In order to allow utilities to pass through the beam but without increasing the height of the floor building itself, openings in the RC beams are required. Generally, it is desirable to provide an RC beam with openings that have the same strength of a solid beam with the same dimension. In theory, openings in RC beams will surely reduce its compressive strength which then leads to lower load bearing capacity compared to its counterpart without openings. There are several characteristics of openings in beam that should be concern. Firstly, the location of opening as it has been proven that opening in flexural will cause lower deduction of ultimate capacity compared to opening in shear. Secondly, the size of openings in the beams will affect the cracking pattern in the beam in which too large opening size may cause instantly shear failure. Third, different shape of opening will affect the stiffness of the beam structure. There are currently two types of openings that commonly used which are the square and circular shape. Consequently, in order to regain the lost strength in RC beams, Fibre Reinforced Polymer (FRP) is opted to be used as the strengthening material. Researcher trying to use Carbon Fibre Reinforced Polymer (CFRP) as strengthening material due to its high tensile strength. However, it is known that synthetic fibre need relatively higher cost compared to conventional beam without opening. Thus, natural fibre, which is more sustainable and cheaper, has been opted as alternative to synthetic fibre. Although the strength inherit by natural fibre polymer is lower than synthetic fibre, but most of researcher agreed that the increase in strength produced is enough and practical to be used.

1.3 Objectives of Research

The objectives of this research are as follows:

i) To identify the properties of all elements in Finite Element Analysis (FEA)

ii) To determine the behaviour of RC beams with and without strengthening with BFRCP in term of load-deflection, cracking patterns, stress contours and strain contours in FEA

iii) To validate the experimental results and finite element results.

1.4 Scope of Study

In this study, a three-dimensional (3D) modelling using ANSYS software was conducted. The behaviour of RC beams with and without openings were analysed as well as the beams behaviour after strengthening using BFRCP. Those behaviour included stresses-strains contours, load-deflection curve and crack pattern. There were two (2) types of beams had been included to be analysed in this thesis which were RC beams unstrengthened with BFRCP and RC beams strengthened with BFRCP. RC beams unstrenghtened with BFRCP consisted of solid control beam (CB), solid beam unstrengthened at flexural (CBUF) and RC beam with openings (CBO. For RC beams strengthened with BFRCP, solid beam strengthened at flexural (SBF) and beam with openings strengthened at shear (SBO) were analysed. Then, the load-deflection curve, crack pattern and stress-strain contour diagram obtained from simulation were compared with experimental results for validation. The concrete grade used for modelling the RC beams with and without opening in this research was grade 30 (G30). All types of RC beams modelled have the same dimension. The width and height of the RC beams was 120 mm x 300 mm respectively with the length of 1500 mm. As for the openings, there were 2 openings with diameter of 120 mm located at shear zone. The distance from centre to centre of the circular openings to the end of the beam is 310 mm. The main steel reinforcement used for the RC beams were two steel bars with diameter of 10 mm for both tension and compression regions. The shear link used was steel reinforcement with diameter of 6 mm at 100 mm centre to centre. Lastly, BFRCP will have width of 120 mm and length of 450 mm.

1.5 Significance of Research

Due to limited space to build houses in Malaysia especially in Kuala Lumpur, most of the developers opted to build high rise building such as a flat house. Nevertheless, as the number of floor needed increases so does the cost and the time needs to build it. Henceforth, beams with openings have the capability to solve the issue as it needed lesser cost and time as materials used will be reduced. To cater the losses in strength and shear capacity due to the openings, researcher trying to implement various techniques to satisfy the strengthening requirement. For this purpose, the development of FRP materials offers an alternative design approach to strengthen the existing structures. As a result, one of the FRP which is BFRCP is opted to be used in these research. There were much research proved that BFRCP able to replace synthetic fibre such as Carbon Fibre Reinforced Polymer as it does not only improve the strength of RC beams but also need lower cost and eco-friendly. The decision to run FEA instead of experimental approach is that it provides result in lesser time compared to experimental approach. This is because it does not require to undergo a tedious procedure to obtain the data. FEA also does not need

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