# FLEXURAL STRENGTHENING OF REINFORCED CONCRETE BEAMS USING HEMP SHEET WITH DIFFERENT WRAPPING CONFIGURATIONS

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Report submitted in partial fulfilment of the requirement

for the award of the degree of

B.ENG (HONS) CIVIL ENGINEERING

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

JUNE 2016

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# LIST OF SYMBOLS

| | |
|---|---|
| ∅ | Diameter |
| ° | Degree |
| c/c | Centre to centre |
| σ | Stress |
| P | Load |
| A | Cross sectional area |
| Ɛ | Strain |
| ΔL | Change in length |
| $L_o$ | Original Length |
| b | Width |
| h | Height |
| d | Effective depth |
| $f_{ck}$ | Compressive strength |
| $f_{cu}$ | Concrete strength |
| C | Nominal concrete cover |
| $F_{cc}$ | Stress in concrete in compression |
| $F_{st}$ | Stress in steel in tension |
| $f_{yy}$ | Shaer link strength |
| $f_{yk}$ | Reinforcement strength |
| $Ɛ_{st}$ | Steel strain |
| ϰ | Neutral axis depth |
| z | Lever arm |
| $∅_{Bar}$ | Diameter of reinforcement of main bar |

| | |
|---|---|
| $Ø_{Link}$ | Diameter of reinforcement of shear link |
| $A_s$ | Area of reinforcement |
| n | Modulus of elasticity transformation coefficient for steel to concrete |
| $I_{cr}$ | Moment of Inertia of cracked, transformed section |
| E | Modulus of elasticity |
| I | Moment of inertia |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| RC | Reinforced concrete |
| CA | Contact Adhesive |
| FRP | Fibre Reinforced Polymer |
| CFRP | Carbon Fibre Reinforced Polymer |
| LHS | Left hand side |
| RHS | Right hand side |
| ACI | American Concrete Institute |

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## ABSTRACT

Reinforced concrete structure is the rigid structure of varying quality and function but they are all ageing and deteriorating over time and the structure may also found to perform unsatisfactorily for a variety of reason. Hence, the strengthening of reinforced concrete members either to increase their service life or their restoration is becoming a universal construction practice. This study investigates the flexural behaviour of reinforced concrete beams strengthened using hemp sheet with different wrapping scheme which included U wrapping, side wrapping and bottom wrapping scheme. One controlled and three strengthened beams were casted and tested under four point-load system and subjected to loading continuously until failure. The aim of this study was to determine the effect of the hemp on flexural capacity of reinforced concrete beams with different wrapping scheme and determination of the best wrapping configuration among the wrapping scheme applied. Generally, this study showed that the application of hemp sheet on the reinforced beam improved the flexural performance of the beams. The result of this study depicted that hemp sheet has providing an increase in the load carrying capacity by 21.31% with U wrapping scheme, 11.14% with side wrapping and 8.73% with bottom wrapping. Besides that, in comparison to the different wrapping scheme, the U wrapping scheme can be concluded as the better model as it's have a more visible load carrying capacity improvement.

# ABSTRAK

Struktur konkrit bertetulang merupakan struktur tegar yang mempunyai pelbagai kualiti dan fungsi. Namun begitu, struktur ini akan mengalami penuaan dan kemerosotan dengan peningkatan usia struktur dan ia juga selalu terdedah kepada pelbagai faktor yang akan menyebabkan struktur tersebut hilang kualiti fungsi. Oleh sebab demikian, aktiviti memperkuatkan konkrit bertetulang untuk meningkatkan hayat perkhidmatan dan pemulihan konkrit telah menjadi satu amalan yang biasa dalam industri pembinaan. Kertas kerja ini mengkaji tentang kelakuan lenturan rasuk konkrit bertetulang yang diperkukuhkan dengan kaedah pembalutan helaian hemp yang berbeza-beza. Kaedah tersebut merangkumi keadah pembalutan U, pembalutan tepi dan pembalutan bawah. Satu rusuk kawalan dan tiga rusuk yang diperkukuhkan dengan helaian hem telah dibuat dan diuji bawah system ujian lenturan empat titik sehingga kegagalan rusuk berlaku. Kajian ini telah memperlihatkan kesan kepada keupayaan lenturan rusuk konkrit bertetulang dengan balutan yang berbeza dan menunjukkan kaedah yang terbaik. Secara umumnya, kajian ini menunjukkan bahawa penggunaan hemp atas rasuk konkrit bertetulang meningkatkan pretasi lenturan rasuk. Hasil kajian ini menunjukkan kapasiti rasuk membawa beban telah meningkat sebanyak 21.31% dengan menggunakan kaedah pembalutan U, 11.14% dengan menggunakan kaedah pembalutan tepi dan 8.73% dengan menggunakan kaedah pembalutan bawah.Selain itu, keadah pembalutan U boleh disimpulkan sebagai model yang lebih baik kerana ia mempunyai peningkatan kapasiti membawa beban yang lebih jelas berbanding dengan kaedah yang lain.

# CHAPTER 1

# INTRODUCTION

## 1.1 INTRODUCTION

Reinforced concrete is a structural material that widely used in all over the world due to its desirable mechanical properties. Reinforced concrete structure is the rigid structure that made up of cement and stone aggregate mixture with the addition of water and embedded steel bars, plates, or fibres that strengthen the material. The structures are of varying quality and function, but they are all ageing and deteriorating over time and the structure may also, for a variety of reasons, be found to perform unsatisfactorily.

This could manifest itself by poor performance under service loading in the form of excessive deflections and cracking, or there could be inadequate ultimate strength. In the present economic climate, the strengthening of existing concrete structures to carry higher permissible loads, seem to be a more attractive alternative to demolishing and rebuilding. Therefore, there is a need for upgrading or strengthening the structures to bring them back to their originally or better intended service mode (D.N. Shinde, Pudale Yojana M, Nair Veena V, 2014).

Therefore, throughout this chapter, the background, problem statements, objectives, scopes and significance of this study on the hemp fibres which serve as strengthening material to flexural strengthen the beam will be clarified to give the basic overview for this entire study.

## 1.2 BACKGROUND OF STUDY

The strengthening and repair or rehabilitation of reinforced concrete members either for increase the service life or for their restoration is becoming a common trend (Grantham, Basheer, Magee & Soutsos, n.d.). Structural deterioration caused by exposure to adverse environmental conditions, overloading, usage of poor quality construction materials, faulty design practices and others related factors are the reason why repair and rehabilitation of the existing structures becoming a very universal constructional practice as the cost and environmental impact for repair or upgrade the structure by retrofitting is relative lower than full structural replacement. Repair/retrofit methods can helps to reduce maintenance requirements, increase life safety and the entire service life of concrete structures (Sen & Reddy, 2014).

Besides improving the strength of the structure, it is to be bear in mind that the chosen retrofitting material should has the ability to cause of sustainability and a better quality for example these materials should not bring negative impact to the environment and endanger bio reserves. Carbon fibre composites and glass fibre composites are most frequently used as retrofitting material in previous retrofitting field applications because of their high tensile strength properties. There is very little work being imparted in improving structures using natural fibres.

The application of composites in structural facility is more concentrated on enhancing the strength of structure instead the issue of sustainability of these raw materials used for strengthening purposes. The need for strengthening's raw materials that would satisfy the demand on the world market is rapidly growing in an expanding world population and with the increase of the purchasing potentials. In times when we cannot expect the fibre reinforced polymer prices to come down, with the consumption growing day by day (Sen & Jagannatha Reddy, 2013).

Therefore, a new cheaper material that offer equal or better properties and have enhancement in structural improvement should be developed and used for structural strengthening. Fibres which are basically bio-fibres have reported good performances by various researchers (Dhawan, Singh & Singh, 2013, Mathur, 2006). The natural fibre such as hemp fibre have excellent potential to be strengthening materials as it is one of the strongest and durable natural fibres. It also holds its shape having one of the lowest

percent elongations of any natural fibre and has the best ratio of heat capacity of all fibres giving it superior insulation properties. Furthermore, they can be recycled, can be grown ecologically and have no waste disposal problems (Binhaitimes.com, 2015).

Here an attempt is made to study the possibilities of using hemp fibre in field of structural retrofitting and strengthening which not only tries to improve the flexural strength but also would address various environmental issues associated with the use of natural products over synthetic products.

## 1.3 PROBLEM STATEMENT

Under the rapid industrialization, the reinforced concrete was widely used as structural materials due to its greater compressive and tensile strength. It has a relatively low cost compare to other material such as steel and it also provides long service life with low maintenance cost. However, during the service life, these structures are often subjected to impact loads from external surrounding, causing the service life of structures become shorten. These structures need an adequate fatigue flexural strength and energy absorption capacity. Therefore, a lot of repair or retrofit method was introduced in or on the reinforced concrete structure to enhance the performance of structure. This study presents an experimental study on suitability of the natural fibre, hemp fibre as a strengthening material in enhance the flexural strength of the reinforced concrete beam.

## 1.4 OBJECTIVES

The objectives of this study include:

- To examine the effectiveness and suitability of hemp fibre in enhancing the flexural strength of concrete beams
- To study the failure modes and load deflection behaviour of RC beams bonded externally with hemp fibre
- To compare the different method of applying hemp fibre i.e. U wrapping, sides wrapping and bottom wrapping scheme