STRUCTURAL BEHAVIOUR OF FIBERS AS PART OF SHEAR REINFORCEMENT IN REINFORCED CONCRETE SLAB

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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 degree of Master of Science.

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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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ABSTRAK

Kajian ini membentangkan keupayaan serat sebagai sebahagian daripada kekuatan ricih didalam lantai konkrit bertetulang. Objektif utama kajian ini adalah untuk menyelidik potensi kesan satu jenis dan gabungan dua jenis serat yang ditambah kedalam lantai konkrit bertetulang, dengan mengurangkan atau tidak mengurangkan ketebalan lantai. Selain itu, kebolehan dan potensi serat untuk menjadi sebagai sebahagian kekuatan ricih juga dikaji. Kajian ini juga dijalankan untuk mengenalpasti kadar pecahan optimum untuk gabungan dua jenis serat (kenaf dan besi) di dalam lantai konkrit bertetulang. Kerja-kerja eksperimen mengfokuskan kepada tiga parameter, iaitu ketebalan lantai, jenis serat yang digunakan dan jumlah serat yang dimasukan ke dalam konkrit melalui pengiraan berasaskan kadar isipadu lantai (V_f). Dua kumpulan lantai dengan ukuran yang berbeza, yang telah direkabentuk berasaskan Eurocode 2 digunapakai dalam kerja-kerja eksperimen. Lantai kumpulan yang pertama telah direkabentuk supaya memenuhi keperluan karakter kekuatan dan keupayaan daya ricih, sementara lantai kumpulan yang kedua telah direka bentuk dengan dikurangkan ketebalan lantai sebanyak 17% daripada keperluan, supaya kumpulan ini akan mengalami kegagalan ricih. Perbezaan ketebalan lantai ini adalah supaya kajian keberkesanan serat sebagai sebahagian kekuatan ricih di dalam lantai dapat dijalankan. Kedua-dua kumpulan lantai ini kemudiannya dikaji dengan menambah sebanyak 0%, 1% dan 2% satu jenis serat (serat kenaf atau serat besi secara berasingan) kedalam konkrit. Sementara itu, untuk gabungan dua jenis serat, hanya 1% serat sahaja digunakan dengan mengambilkira tiga kadar pecahan gabungan serat kenaf-besi iaitu 0.75:0.25, 0.5:0.5 dan 0.25:0.75, setiap satu. Lantai yang tidak ditambah serat (0%) dan tidak dikurangan ketebalannya dijadikan sebagai lantai rujukan. Sebanyak tiga puluh dua lantai telah dibina dan diujikaji sehingga gagal menggunakan ujikaji bengkokkan empat titik. Hasil kajian menunjukan bahawa penambahan satu jenis (2%) dan gabungan dua jenis (0.5:0.5) serat kedalam lantai dengan ketebalan yang telah dikurangkan menunjukkan peningkatan yang memberangsangkan terhadapan keupayaan struktur lantai seperti kekuatan menahan beban (meningkat sebanyak 32% dan 27% setiap satu), kemuluran (meningkat sebanyak 87% dan 50% setiap satu) dan keupayaan menyerap tenaga (meningkat sebanyak 250%). Serat menunjukan keberkesanan dalam mengawal keretakan konkrit. Malahan, hasil kajian menunjukan satu jenis dan gabungan dua jenis serat berjaya mengembalikan kekurangan daya ricih dalam lantai kumpulan kedua yang disebabkan oleh pengurangan ketebalan lantai, kecuali serat kenaf yang mungkin disebabkan oleh rawatan kenaf yang kurang cukup. Manakala, keputusan kajian menunjukan kadar optimum gabungan dua jenis serat didapati daripada 0.5:0.5 yang menunjukkan peningkatan yang memberangkan didalam kekuatan menahan beban, kemuluran dan keupayaan menyerap tenaga untuk kedua-dua kumpulan lantai dibandingkan dengan lantai rujukan. Tambahan pula, kadar pecahan ini menunjukan keputusan keupayaan struktur yang lebih kurang sama dengan keputusan daripada 1% serat besi, terutamanya untuk kekuatan dan kemuluran yang meningkat sebanyak 19% dan 50% setiap satu didalam lantai kumpulan kedua dibandingkan dengan lantai rujukan. Kesimpulannya, kajian ini telah menunjukkan perubahan keupayaan struktur yang memberangsangkan untuk lantai konkrit bertetulang yang ditambah dengan satu jenis dan gabungan dua jenis serat.

ABSTRACT

Due to the brittle behaviour of plain concrete in tension, shear failure of the slab is generally catastrophic. An increase in the thickness of the slab is recommended in many instances to increase the shear capacity of the slab and avoid such failure in the slab. Hence, this study investigated the behaviour of fibers as a part of shear reinforcement in reinforced concrete slabs. The main objective was to investigate the potential effect of single and hybrid fibers added with reinforced concrete (RC) slabs with and without a reduction in the slab thickness and its potential to serve as part of shear reinforcement. Moreover, the optimum ratio of hybrid fiber (kenaf and steel) in RC slabs was as well studied. The experimental work focuses on three parameters, which include the thickness of the slab, types of fibers and volume fraction of fiber (V_f). Two series of slabs with different dimensions were designed in accordance with the Eurocode 2 for the experimental study. The first series of the slab was designed to fulfil shear capacity characteristic, while the second series of the slab was designed with 17% less thickness than required, intended to be failed in shear. The difference in the slab thickness was to cater for the potential of the fibers and serve as part of shear reinforcement in the RC slab. Both series of slabs were added with the single fibers (steel fiber and kenaf fiber separately) using different volume fraction of fiber such as V_f = 0%, V_f = 1% and V_f = 2%. However, the volume fraction considered was V_f =1% with ratios 0.75:0.25, 0.50:0.50 and 0.25:0.75 for the slab with hybrid kenaf-steel fiber. The RC slab without fiber V_f = 0% and no reduction in thickness was taken as the control slab. A total number of thirty-two slabs were constructed and tested to fail under the four-point bending test. The results show that the addition of single and hybrid fibers to RC slabs have a significant contribution to improve the structural performance of the FRC slabs such as load-carrying capacity (32 and 27%), ductility (87 and 50%) and energy absorption (250%) for the second series of slabs with V_f = 2% of steel fiber and V_f = 0.5:0.5 of hybrid fiber, respectively. Fibers were found more effective in controlling the crack propagation and altering the failure mode of the slab from brittle to a more ductile manner. In addition, it was observed that the inclusion of single fibers and hybrid were able to fully compensate for the loss in concrete shear capacity due to thickness reduction which had the potential of serving as part of shear reinforcement in RC slabs except for the kenaf fiber which was probably due to insufficient treatment. Furthermore, these findings show that the optimum ratio of hybrid fiber at V_f = 0.5:0.5 produced the best structural performance in RC slabs such as load-carrying capacity (41 and 27%), ductility (29 and 50%) and energy absorption (200 and 250%) for the first and second series of slabs, respectively compared to control slab. Moreover, this ratio of hybrid fiber recorded the similar behaviour of structural performance to the steel fiber at V_f =1%, especially in strength and ductility which improved to 19 and 50% in the second series of the slab compared to control slab. Overall, this investigation demonstrated a significant enhancement of the structural performance of RC slabs with the addition of single and hybrid fibers.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

V_f	Volume fraction of fiber
L	Length of slab
b	Width of slab
d	Depth of slab
c	Nominal cover
f_{ck}	Concrete strength
f_{yk}	Reinforcement strength
V_{ED}	Design shear force
$V_{Rd,c}$	Design shear resistance
M_{ED}	Design moment
P_y	Yielding load
$P_{y,0}$	Yielding load of the control specimen
P_{max}	Maximum load carrying capacity
$P_{max,0}$	Maximum load carrying capacity of the control specimen
P_u	Ultimate load
δ_y	Deflection at yield
δ_{max}	Deflection at maximum load
δ_u	Ultimate deflection
μ	Ductility ratio
$\mu_{,0}$	Ductility ratio of the control specimen
E_a	Energy absorption
$E_{a,0}$	Energy absorption of the control specimen
H	High strength steel bar
l	Length of fiber
d	Diameter of fiber
A_s	Area of steel
E_c	Modulus of elasticity of concrete

LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BS	British Standards
CA	Coarse aggregate
EC	Eurocode
FA	Fine aggregate
FRC	Fiber reinforced concrete
HE	Hooked ends
HF	Hybrid fiber
HyFRC	Hybrid fiber reinforced concrete
HyKSF	Hybrid Kenaf-steel Fiber
HyKSFRC	Hybrid Kenaf-steel Fiber Reinforced Concrete
KF	Kenaf fiber
KFRC	Kenaf fiber reinforced concrete
LVDT	Linear Variable Differential Transducer
M	Molarity
NaOH	Sodium hydroxide
OPC	Ordinary Portland cement
PP	Polypropylene
PPF	Polypropylene fiber
RC	Reinforced concrete
SF	Steel fiber
SFRC	Steel fiber reinforced concrete
SP	Super Plasticizers
W	Water

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