UNIVERSITI TEKNOLOGI MALAYSIA
RESEARCH UNIVERSITY

RESEARCH UNIVERSITY GRANT SCHEME

Tier 2 Research Proposal

PY/2017/00573

Title of Proposal Research	:	**MECHANICAL PERFORMANCE OF POLYURETHANE FOAM FILLED WITH KENAF/GFRP RECYCLATES FOR COMPOSITES SANDWICH CORE**

A) PARTICULAR OF RESEARCHER

Name of Project Leader	:	**BALQIS BT. OMAR**	Email Address	:	**balqis@utm.my**
Identity Card	:	**660318025034**	Type of Service	:	**PERMANENT**
Staff No.	:	**8934**	Staff Classification	:	**Major Research**
Position	:	**PENSYARAH KANAN (DS52)**	Handphone No	:	
Research Alliance	:	**INNOVATIVE ENGINEERING**	Office Telephone No	:	**075531642**
Faculty	:	**FAKULTI KEJURUTERAAN AWAM**			

B) RESEARCHER INFORMATION

Start Date	:	**01/07/2017**	End Date	:	**30/06/2018**
Research Duration	:	**1 Year**			
Research Area	:	**APPLIED SCIENCE**			

Field of Research

FOR Category	:	**F3010000 - ENGINEERING AND TECHNOLOGY**
FOR Group	:	**F3010100 - Mechanical Engineering**
FOR Code & Area	:	**F3010199 - Other Mechanical Engineering n.e.c.**

Socio-Economic Objective

SEO Category	:	**ADVANCEMENT OF KNOWLEDGE**
SEO Group	:	**S5010000 - NATURAL SCIENCES AND ENGINEERING**
SEO Code & Area	:	**S5019900 - Other Natural Sciences and Engineering n.e.c.**

Sponsor

Category of Sponsor	:	**NATIONAL**
Sponsor Agency	:	**Government - GOV**
Sub Sponsor	:	**UTM**
Sub Sponsor Detail	:	**RUG OF UTM**

Keyword	:	**SANDWICH COMPOSITES, PU FOAM, KENAF CORE, RECYCLED GFRP, INTERFACIAL BONDING SKIN-CORE**
Research Classification	:	**NOT CONFIDENTIAL**
Commercialisation	:	**POTENTIAL TO BE COMMERCIALIZED**

Team Members

No	IC No	Staff No	Name	Faculty	RA	Grade	CV
1	640319075385	5244	SHUKUR BIN HJ. ABU HASSAN	FKM	INNOVATIVE ENGINEERING	DS52A	CV Dr Shukur 2017.pdf

No Record.

Researcher projects headed by the Applicant that have been completed or current ongoing in the last three (3) years.

No.	Title of research including RMC vote number	Duration	Type of Grant	Start Date	End Date	Project Status
1.	The Study of Online Construction Information System	1 years 0 months	Short Term	1999-09-30	2000-09-29	COMPLETED

Information on academic publications that has been published by the researchers for the last three (3) years.

No	Title of Publication	Source	Impact Factor (IF)	Year published
1.	JOURNAL OF BUILT ENVIRONMENT, TECHNOLOGY AND ENGINEERING	FINITE ELEMENT MODELING OF ARCAN TESTING METHOD FOR DUCTILE AND BRITTLE MATERIAL UNDER DIFFERENT LOADING CONFIGURATION	0	2016
2.	PROCEEDING OF CIVIL ENGINEERING	THE IMPORTANCE OF SUPPLY CHAIN MANAGEMENT FOR READY MIXED CONCRETE PRODUCTION AND DELIVERY PROCESS	0	2016
3.	INTERNATIONAL JOURNAL OF ADVANCED AND APPLIED SCIENCES	MECHANICAL PROPERTIES OF RECYCLED GLASS FIBRE REINFORCED NANOCLAY/UNSATURATED POLYESTER COMPOSITES	0	2017

Executive Summary of Research Proposal

Polyurethane (PU) foam is one of the widely used core material in sandwich construction, however it lacks rigidity due to its porous nature and low material stiffness. In order for the PU foam to be used as core in sandwich structure for construction applications, the core needs to have high rigidity while at the same time maintains its lightweight properties. Many studies has shown that reinforcing fibres can modify the PU foam to become more rigid. Hybridization of kenaf fibre and GFRP recyclates (rGFRP) has great potential to be used as a filler to improve PU foam stiffness and rigidity while at the same time utilizing resources that are environmental friendly. The

addition of rGFRP in PU foam has high possibility to increase interfacial bonding between the skin and the core of the sandwich structure. In this research, a lightweight polymer matrix, PU foam will be used as core filled with kenaf fibre and rGFRP. The core samples will be tested to obtain its compressive properties, Young's and shear modulus. Besides that, composites sandwich samples will be prepared by binding the tested core samples with composites skins. The composites sandwich samples in the form of beam will be tested under flexural load for flexural and shear stiffness, flexural rigidity and interfacial bond strength between skin and core. The expected findings from this research will be presented in the form of graphs of beam flexural rigidity versus deflection and core thickness and local bond stress distribution along shear span and all those relationships are function of in filler weight percentages. The research outcome will be translated into engineering design database for polymer composite sandwich construction application.

Detailed proposal of research project:
(a) Research background including Hyphothesis/Research Questions and Literature Review:

Research Questions

1. What is the optimal mixture formulation for kenaf/GFRP recyclates filler in PU foam as core material for lightweight and rigidity?

2. Does the inclusion of GFRP recyclates in the sandwich core improve the interfacial bond strength between the core and the skin of the sandwich structure?

Literature Review

Sandwich panels consist of two outer skins and core in the middle. The combination of these parts offers sandwich panels a relatively high strength and stiffness at low densities. Skins can be made of composite laminate panels, aluminium alloys, titanium steel or plywood. Core is the constituent that requires low density materials such as polymer foams, balsa wood, synthetic rubbers or inorganic cements. Recently, many research have been done to utilized natural fibres as core in sandwich composites (Azmi et al., 2013; Zuhri et al., 2014; Hasnidawani et al., 2015; Jusoh et al., 2016). The lightweight properties of natural fibre makes it a good alternatives as sandwich core. Furthermore, specific strength and modulus of natural fibre composites are equivalent to many conventional fibre composite materials (Ishak et al., 2013).

Kenaf (*Hibiscus cannabinus*) has many potentials in bio-composite application. Based on their basic properties, both the bast fibres and core material of kenaf are distinctly different. While bast fibres are stiffer and low in wettability, the core material of kenaf is weaker and has excellent absorbing properties. Low density of kenaf core fibre (0.28g/cm3) makes it suitable for core material for sandwich composites (Nar et al., 2015). Previous studies have revealed the potential of kenaf core to make insulation composites (Batouli et al., 2014), medium-density particleboards (Birnin-Yauri et al., 2016), fire retardant-treated particleboards (Ayadi et al., 2016) and polymer composite. Hence, kenaf core is the preferable natural fibres to be utilized as core material in polymer sandwich composites.

Current standards suggest that PU foams utilized in sandwich core need to exhibit high stiffness in both tensile and compressive properties. Therefore, in this study, the rigidity of PU foams needs to be increased in order to be used in sandwich beam. Traditionally, to increase the rigidity of PU foams, the isocyanate content was increased. Composite theory suggests that fillers in the form of fibres embedded in a weaker matrix will improve the overall stiffness. Many recent studies (Nar et al., 2015; Yu et al., 2014; Hamilton et al., 2013; Gu et al., 2013; Shah et al., 2015; Yu et al., 2016; Wang et al., 2008; Kim et al., 2010) have discovered that introducing fibres into weaker foam matrices will improve the stiffness of the foam in compression, shear and tension. For example, Gu et al., (2013) found improvements in compressive strength when wood fibre was added to PU foams, and Siegmann et al. (1983) discovered increases in compressive modulus when virgin glass fibre and powder were added. However, previous studies have not covered the hybridization of kenaf and recycled FRP. Other than that, there is little understanding of how the fibre length and fibre aspect ratio affect fibre reinforcement in foams.

The investigation of adding milled glass fiÂbres (280 micron) and nanoparticles (montmorillonite-carbon nanotubes) at different mass fractions into PU foams shows positive results in increasing the rigidity and stiffness of the PU foam (Hamilton et al., 2013). The analysis reveals nanoclay-PU foams exhibit up to an 11.1% degree of reinforcement, and glass fibres-PU foams up to 18.7%. This study can be improvise by replacing the milled glass fibres with recycled GFRP (rGFRP) because the fibre length and fibre aspect ratio of rGFRP is similar to the milled glass fibres. According to Hanan et al. (2017), fibre length of grounded rGFRP in the form of powder is approximately below 1000 micron. Further sieving process of rGFRP powder can be used to select appropriate fibre length and to be utilized as filler in PU foam.

Nar et al. (2015) explores the possibility of using kenaf core as reinforcement in PU foam. The compressive and flexural properties show improvement for PU foams with kenaf core at all loading percentages due to dense packing of more number of smaller foam cells as seen from ESEM images. This dense packing has contributed positively to the compressive and flexural properties. However, this study only limited to three type of weight percentage of kenaf core which 5, 10 and 15 wt.% only and did not consider the effect of kenaf fibre at various fibre length for reinforcing the PU foam.

Recently, study shows how the reinforcing fibre length can have an effect on the mechanical properties of PU foam. Hussain and Kortschot (2015) investigate the effect of fibre length and fibre aspect ratio on the reinforcement of soybean-based PU foams. Micro-crystalline cellulose fibres (50-μm) and 260-μm long glass fibres embedded inside PU foams were studied separately. The fibre reinforcement provided by the short MCC fibres was significant, but still much lower than the reinforcement observed in previous studies (Hussain et al., 2014) using 470-μm glass fibres in the same matrix foam system. The inclusion of 260 mm glass fibres, in contrast, produced almost no reinforcement. The 260 mm fibres were not long enough to form a mechanically percolating network, as confirmed by the tomography and the measured foam moduli. Furthermore, the 260μm fibres do not embed or reinforce the struts as observed for the MCC fibres.

South Koreans researchers (Yu et al., 2014), study the PU foam reinforced with chopped E-glass fibre at four different weight percentages of chopped E-glass which are 2.5, 5.0, 7.5 and 10.0 wt.%. The chopped glass fibre used in this study is 7mm in length. From the experimental results, it was found that the compressive strengths of the PU foam increased 35% and 54% at the room and cryogenic temperatures, respectively when the weight percentage of chopped glass fibre was 10%, while the tensile strengths increased 220% and 210% with the same weight percentages of 10% at the room and cryogenic temperatures, respectively. Based on this study, the use of rGFRP can be applied as reinforcement in PU foam. Study by Hanan et al. (2017) indicate that the grounded rGFRP of coarse grade has an average fibre length of 4-15mm which can provide a good reinforcement for PU foam.

Hybridization of kenaf core and rGFRP as lightweight particle board using urea formaldehyde binder has been studied (Amin, 2015). The study compared the internal bonding strength and bending properties of kenaf core particle board with hybrid kenaf core-rGFRP (70:30 wt/wt). The hybrid particle board shows an increase of 20% in term of flexural strength and modulus when the mixture of kenaf core and rGFRP is uniform as examined under optical microscopy. Furthermore, the internal bonding strength shows slight improvement in hybrid samples. The inclusion of rGFRP in the hybrid particle board increases slightly the board density by about 10% compared to kenaf only particle board.

The study on structural integrity effect of interleaf glass fibre mat and recycled GFRP waste (rGFRP) in woven kenaf reinforcement polyester composite was conducted by Jamal et al.(2017). Three types of composites samples were fabricated; 2 layers (2L) kenaf name as (KL00), 2L-kenaf/glass mat composites with chopped stand mat glass fibre (CSM) interleaf name as (KLCSM) and 2L-kenaf/rGFRP with the weight same as areal weight density as CSM name as (KLF100). Results revealed that the flexural strength and flexural shear measured for KLF100 were increased compared to KL00 and KLCSM. For instance, the flexural strength of KL00, KLCSM, KLF100 is 123.39 MPa, 124.07 MPa and 181.98 MPa respectively. The bending properties of woven kenaf composites using rGFRP as interleaf reinforcement shows good interlocking between kenaf and rGFRP. Based on this study, the use of rGFRP in PU foam core can possibly increase the interfacial bonding of core to the skin of the sandwich composites structure.

References

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(b) Objective (s) of the Research

No	Objective
1	To investigate the effect of filler fibre length and weight fraction on mechanical properties of PU foam filled Kenaf/GFRP recyclates core.
2	To study the bending behaviour of the sandwich composites beam using PU foam filled with Kenaf/GFRP recyclates core.

(c) Methodology
1.Description of Methodology

1. PU foam filled with Kenaf/GFRP recyclates (PU/KrGF) Core Material

1. Kenaf Core (KC) fibrous in the form of chips of various sizes.
2. GFRP recyclates (rGF) of various fibre sizes.
3. High density polyurethane (PU) Foam
4. Various core thicknesses (10, 20 and 30mm)

2. PU/KrGF Core Fabrication

The polyurethane foam will be produced by mixing the polyol and isocynates. When the mixture of polyol and isocynate is being prepared, KC and rGF ranging from 0 wt% to 20 wt% will be added and stirred to ensure the that KC and rGF are uniformly distributed. This mixture of various components will be poured into a mould and cured at room temperature under compression load. The PU/KrGF core sample will be left under load for 24 hours in order to ensure a perfect curing cycle.

3. Skin Material

1. Glass fibre/Epoxy (GFRP)
2. Sugar Palm Fibre/Epoxy
3. Fibre to matrix (epoxy) weight ratio is fixed to 45:55

4. Skin Fabrication

Sandwich skin will be prepared by using compression moulding technique by impregnating reinforcing fibres with low viscosity epoxy system. The skin will be left under constant load for 24 hours to ensure perfect curing cycle.

5. Sandwich Fabrication

The composite sandwich test samples will be prepared by applying epoxy adhesive layer between skins (top and bottom) and core. The samples will be left under constant compression load at least for 8 hours to ensure perfect bonding.

6. Testing

A series of mechanical testing will be conducted namely:

1. Tensile test for skin material (ASTM D3039)
2. Flexural and shear test for sandwich beam stiffness (ASTM D7250)
3. Bond test to determine interfacial bond strength between skin and core (BS 4994-1987).
4. Compression test for core (ISO 844 or ASTM Standard D1621)
5. Arcan test for core

The tests above will be conducted to determine the following properties:

1. Skin Young Modulus, Es
2. Flexural and shear stiffness of sandwich beam
3. Flexural rigidity sandwich beam

4. Core Young Modulus, Ec
5. Core Shear Modulus, Gc
6. Bond strength between skin and core, τs

2.Flow Chart of Research Activities (Please enclose in the Appendix)
3.Grantt Chart of Research Activities

Project Schedule

No	Task	Start Date	End Date
1	Literature Review	2017-07-01	2018-06-30
2	Experimental Design	2017-07-02	2017-08-31
3	Material and Rig Preparation	2017-08-01	2017-09-30
4	Test Samples Fabrication	2017-09-01	2017-12-31
5	Experimental Work	2017-10-01	2018-02-28
6	Results Analysis and Discussion	2017-12-01	2018-06-30
7	Report Writing	2018-05-01	2018-06-30

Project Milestone

No	Milestone	Date (YYYY/MM/DD)
1	Test Samples Completed	2017-12-31
2	Experimental Work Completed	2018-02-28
3	Report Writing Completed	2018-06-30

C) ACCESS TO EQUIPMENT AND MATERIAL

No	University	Place
1	10kN Universal Testing Machine	P23, Centre for Composites, UTM JB
2	Sieve Shaker	D04, Faculty of Civil Engineering, UTM JB
3	Rotary Fibre Mixer	P23, Centre for Composites, UTM JB
4	100kN Universal Testing Machine	E04, Mechanics of Materials and Structures Lab, FKM, UTM JB

No Record.

D) BUDGET

V-Series	SODO Type	Description	Cost Year 1 (01/07/2017 - 30/6/2018)	Justification	Total Per Item	RA Recommend
V11000 Salary & Wage / Overtime (Capping 0.0%) Salary Rate	B11000 Salary & wages		0.0			
	Total Per SODO		**0.00**		**0.00**	
	B12000 Fixed allowances		0.0			
	Total Per SODO		**0.00**		**0.00**	
	B13000 Statutory contributions to public staff		0.0			
	Total Per SODO		**0.00**		**0.00**	
	B14000 Overtime		0.0			
	Total Per SODO		**0.00**		**0.00**	
	B15000 Other financial benefits staff		0.0			
	Total Per SODO		**0.00**		**0.00**	
Total Per VSeries			**0.00**		**(0.00%)** 0.00	**0.0**
V21000 Travelling expenses & Subsistence (Capping 20.0%)	B21000 Travel & subsistence	CONFERENCES	1000.0			
	Total Per SODO		**1000.00**		**1000.00**	
	B22000 Transport of goods	RAW MATERIALS (KENAF CORE, RECYCLED GLASS FIBRE)	1000.0			
	Total Per SODO		**1000.00**		**1000.00**	
Total Per VSeries			**2000.00**		**(10.26%)** 2000.00	**0.0**
V24000 Rentals	B23000 Transportation & utilities		0.0			

(Capping 0.0%)						
	Total Per SODO		**0.00**		**0.00**	
	B24000 Rentals		0.0			
	Total Per SODO		**0.00**		**0.00**	
Total Per VSeries			**0.00**		**(0.00%)** 0.00	**0.0**
V26000 Research Materials & Supplies (Capping 0.0%)	B26000 Raw materials & spare parts	KENAF CORE, GFRP RECYCLATES, PU FOAM, EPOXY RESIN, SUGAR PALM FIBRES, GLASS FIBRE FABRICS	8500.0			
	Total Per SODO		**8500.00**		**8500.00**	
	B27000 Supplies & consumable goods	STRAIN GAUGES, P.P.E., RUBBER GLOVES, MOLD RELEASE SPRAY, ROLLER, MIXING CONTAINERS, ACETONE.	3000.0			
	Total Per SODO		**3000.00**		**3000.00**	
Total Per VSeries			**11500.00**		**(58.97%)** 11500.00	**0.0**
V28000 Maintenance & Minor Repair Service (Capping 0.0%)	B28000 Maintenance & repairs		0.0			
	Total Per SODO		**0.00**		**0.00**	
Total Per VSeries			**0.00**		**(0.00%)** 0.00	**0.0**
V29000 Professional Services (Capping 0.0%)	B29000 Professional services & hospitality	TESTING SERVICES, FABRICATE TEST RIG, MOULD FOR CORE FABRICATION	6000.0			
	Total Per SODO		**6000.00**		**6000.00**	
Total Per VSeries			**6000.00**		**(30.77%)** 6000.00	**0.0**
V35000 Special Equipment & Accessories (Capping 40.0%)	B35000 Assets & equipments		0.0			
	Total Per SODO		**0.00**		**0.00**	
	B36000 Inventory & furnitures		0.0			
	Total Per SODO		**0.00**		**0.00**	
Total Per VSeries			**0.00**		**(0.00%)** 0.00	**0.0**
V40000 Biasiswa, Dermasiswa dan Bantuan Pelajaran (Capping 0.0%)	B41000 Biasiswa, Dermasiswa dan Bantuan Pelajaran		0.0			
	Total Per SODO		**0.00**		**0.00**	
Total Per VSeries			**0.00**		**(0.00%)** 0.00	**0.0**
V50000 Other Charges & Distribution (Capping 0.0%)	B52000 Other Charges & Distribution		0.0			
	Total Per SODO		**0.00**		**0.00**	
Total Per VSeries			**0.00**		**(0.00%)** 0.00	**0.0**
GRAND TOTAL					19500.00	

E) EXPECTED OUTPUT

Indexed Paper = 1

Matching Grant (External) = RM 19500

F) DECLARATION BY APPLICANT

- [x] 1. All information given are correct. UTM has the right to reject or to cancel the offer without prior notice if there is any incorrect information given.

Name: BALQIS BT. OMAR
Date: 2017-05-08

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