A STUDY OF SUGARCANE BAGASSES AS REINFORCEMENT IN UNSATURATED POLYESTER RESIN BIOCOMPOSITES

by

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DECLARATION

I declare that this thesis entitled "A Study of Sugarcane Bagasses as Reinforcement in Unsaturated Polyester Resin Biocomposites" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : _____

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Date : 9 JANUARY 2017

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ABSTRACT

Bagasse was a waste of sugarcane milling process where it was very important to the fuel resource. In this study, the sugarcane bagasse was study to produced composites through the fabrication of sugarcane bagasse (SCB) as reinforcement in unsaturated polyester resin (UPR) with methyl ethyl ketone peroxide (MEKP) as the hardener. The composition ratios where 10 % of SCB and 90 % of UPR, ratio 20 % of SCB and 80 % of UPR and ratio 30 % of SCB and 70 % of UPR for treated and untreated SCB was used. Then, 4 g/L NaOH was used as the treatment for the fibre to determine the effect of the fibre treatment to the composites produced.

The sample of treated and untreated biocomposites was investigate and test using the physical and mechanical testing through tensile test, flexural test, thickness swelling, water arbsorption and density. It was found that, the tensile stress was increase with decreasing of SCB used but the tensile strain and flexural strength was increase with increasing of SCB used. The thickness swelling and water absorption by the composites also increase with increasing of SCB used compared to high percentages of UPR used. The treatment of SCB was increase the density of the composites produced compare to used untreated SCB to produced the composites.

ABSTRAK

Hampas tebu adalah satu pembaziran daripada proses pengilangan tebu di mana ia adalah sangat penting untuk sumber bahan api. Dalam kajian ini, hampas tebu tebu telah digunakan sebagai kajian untuk menghasilkan komposit melalui penggunaan hampas tebu (SCB) sebagai bahan utama, poliester resin yang tak tepu (UPR) dan metil etil keton peroksida (MEKP) sebagai pengeras. Nisbah yang berbeza telah digunakan iaitu nisbah 10 % daripada SCB dan 90 % daripada UPR, nisbah 20 % daripada SCB dan 80 % daripada UPR dan nisbah 30 % daripada SCB dan 70 % daripada UPR untuk SCB yang dikenakan rawatan dan tidak dirawat. Kemudian, 4 g/L NaOH telah digunakan sebagai rawatan untuk menentukan kesan rawatan kepada komposit yang dihasilkan.

Sampel yang dirawat dan tidak dirawat telah diuji dengan menggunakan ujian fizikal dan mekanikal melalui ujian tegangan, ujian lenturan, bengkak ketebalan, serapan air dan ketumpatan. Ia menunjukkan bahawa, tegangan meningkat dengan penurunan SCB yang digunakan tetapi terikan tegangan dan kekuatan lenturan meningkat dengan peningkatan SCB yang digunakan. Ketebalan bengkak dan penyerapan air oleh komposit meningkat dengan peningkatan SCB yang digunakan berbanding menggunakan peratusan UPR yang tinggi. SCB yang dirawat telah meningkatkan ketumpatan komposit yang dihasilkan berbanding dengan menggunakan SCB yang tidak dirawat untuk menghasilkan komposit.

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LIST OF ABBREVIATIONS

CMC	Ceramic Matrix Composites
H_2O_2	Hydrogen Peroxide
FRP	Fibre Reinforced Polymer
MEKP	Methyl Ethyl Ketone Peroxide
MOR	Flexural Strength
MOE	Flexural Modulus
MMC	Metal Matrix Composites
NaOH	Sodium Hydroxide
PMC	Polymer Matrix Composites
PRP	Particle Reinforced Polymer
PP	Polypropylene
PVC	Poly Vinyl Chloride
PS	Polystyrene
RTM	Resin Transfer Moulding
SCB	Sugarcane Bagasse
SPR	Saturated Polyester Resin
SBR LATEX	Styrene Butadiene Latex Dispersion
UPR	Unsaturated Polyester Resin

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In recent years, many researchers have carried out research on biocomposite to enhance the properties of the biocomposites. The composite are more preffered for the research due to their relatively cheaper, environmental friendly, recycleable and renewability compare to other materials such as metals and ceramics (Selvam, 2010).

Biocomposite consists of combination of two or more chemically or physically materials combined together to improve the properties (Koli, 2015). The combination are between the discontinuous phases that called as reinforcement and continuous phase that know as matrix (Pankaj et al., 2015). The discontinuous phase are more harder and strong than continuous phase since it act as reinforcement to the others material while continuous phase only embedded it together.

Natural fiber have many advantages compared to the synthetic or manmade fibre such as glass and carbon (Ishak et al., 2010). The natural fibre have low density, acceptable specific strength properties, ease of separation and carbon dioxide sequestration. The natural fibre have been used in the door panels, seat backs, headliners, dashboards, interior parts, package trays, furniture, packaging, building and construction.

Bagasse are one of the natural fibre from sugarcane residual (Rezende et al., 2011). Bagasse corresponding about 25 % of total weight and contains 60 % to 80 % of carbohydrates. The fermentation of carbohydrate from bagasse are one of the recycled waste product to produce ethanol as a fuel or energy supply. The sugarcane

are able to go through the photosynthesis fix around 55 tones of dry matter per hectare of land where it have highest bioconversion efficiency that capture the sunlight through photosynthesis (Deephand, 2005).

Sugarcane supplies more than half of the world's sugar consumption. This means that there are higher residue of sugarcane bagasse (SCB) in this world. SCB are suitable to be used with the polymer such as unsaturated polyester resin (UPR) (Oladele, 2014). The UPR are thermoset polymer that have average of mechanical properties, lower resistance to temperature, higher coefficients of expansion and low cost that make it suitable to be used with natural fibre.

Natural fibre as reinforcement to the polymer matrix are used in order to produce the biocomposite that have high performance (Oladele, 2014). The biocomposites are produce to improve the mechanical and thermal properties of the biocomposites, suitable for specific application, easy to processing and reducing cost.

In this study, the UPR and SCB was used to produce biocomposites. The physical and mechanical analysis was investigated to determine the biocomposite properties. The SCB was treated using NaOH for the treatment while distilled water was used as the solvent during the fabrication of the composites. Then, the properties of SCB as reinforcement and UPR as matrix to produce biocomposites was investigated.

1.2 Problem Statement

The use of lignocellulosic fibre as reinforcement for polymeric materials has been growing by reasearcher to replace synthetic fibre (Mishra, 2011). Bagasse are widely used with the polymer composite (Al Bakri et al., 2013). But, there is lack of study on the polymer composite using UPR as matrix with the SCB as reinforcement biocomposites due to the highly used of synthetic fibre as reinforcement in polymer. SCB is a sugarcane waste product that have lignocellulosic contain. While, UPR are suitable to used any moulding due to it properties that easily to handle during fabrication (Mohammad, 2007). Thus, the combinations of UPR and SCB are good to produce strong biocomposites due to their physical and mechanical properties.

1.3 Objectives

1) To produce UPR biocomposites reinforced with SCB.
2) To determine the effect of fibre treatment on physical and mechanical properties of the composites produced.

1.4 Significant of Study

From this study, the properties of biocomposites can be improved by using the SCB as a reinforcement and UPR as a matrix through the differents ratio that used for treated and untreated SCB. The differents ratio of SCB composition in the biocomposites are expected to produce different properties of biocomposites.

CHAPTER 2

LITERATURE REVIEW

2.1 Composites

Composite are made of two or more constituent materials (Jamaludin, 2002). Composites are derived from the biological origin plant fibre from crops such as flax or hemp, recycled wood, waste paper, crop processing by product or regenerated cellulose fibres such as viscose/ rayon.

The physical properties of composite materials are not isotropic in nature but typically orthotropic. The stiffness are dependent on the design of the panel that result in directional of the forces and moments that applied (Jamaludin, 2002).

Composite materials can be classified into three group on the basic matrix material which is metal matrix composite (MMC), ceramic matrix composite (CMC) and polymer matrix composite (PMC) (Tudu, 2009).

2.1.1 Metal Matrix Composite

MMC are usually consist of a low-density metal such as aluminium or magnesium reinforced with particulate of fibre of a ceramic material such as silicon or graphite. Compared with unreinforced metals, MMCs are offer higher specific strength and stiffness, higher operating temperature and greater wear resistance, as well as the opportunity to tailor these properties for a particular application.

2.1.2 Ceramic Matrix Composite

CMC are produced from ceramic fibre embedded in ceramic matrix. Various ceramic materials, oxide or non-oxide are used for the fibre and the matrices. The properties of CMC can be adapted to special construction task. CMC are specially valuable for components with demanding thermal and mechanical requirements.

2.1.3 Polymer Matrix Composite

PMC are comprised of a variety of short or continuous fibre bound together by an organic polymer matrix. The PMC provides high strength and stiffness than CMC. The PMC are used for the mechanical loads to which the structure are subjected in service are supported by the reinforcement. The funtion of the matrix is to bound the fibre together and to transfer load between them. There are two type of polymer composite which is fibre reinforced polymer (FRP) and particle reinforced polymer (PRP) (Tudu, 2009).

a) Fibre Reinforced Polymer

FRP is a composite material that made from polymer matrix reinforced with fibre (Mertz et al., 2003). FRP are usually used high strength fibre such as glass, carbon and aramid, paper or wood or arbestos (Oladele, 2014). The polymer used are usually an epoxy, vinylester or polyester thermosetting plastic and phenol formaldehyde resin. FRP are commonly used in aerospace, automotive, marine and construction industries.

b) Particle Reinforced Polymer

Particle can be used for reinforcing the polymer, ceramic and glases (Tudu, 2009). The particle as reinforcement may be spherical, cubic, tetragonal, pallet, or other regular or irregular shape (Vignesh & Selvam, 2015). PRP as a reinforcement are usually used to improve the properties of matrix materials such as to modify thermal and electrical conductivities, performance, wear resistance, hardness and to reduce shrinkage (Vignesh & Selvam, 2015).

2.2 Biocomposites

Biocomposite are a type of composite because it have either one or both of constituent materials as matrix or reinforcement derived from natural resources. The biocomposites are depend on the matrix and reinforcement that choosen (Jamaludin, 2002). The matrix and reinforcement that used will influence the toughness and strengthening of the end product that produced. The synergism produces material properties that unavailable from the individual constituent materials but the wide variety of matrix and strengthening materials allows the designer of the product to be high and optimum combination.

Biocomposite are environmentally friendly material in production, processing and waste due to it natural fibre production (Balaji et al., 2014). Biocomposite have low specific weight that make it higher specific strength and stiffness than glass fibre. It also produce wear of tooling, healthier working condition and no skin irritation.

The production of biocomposites are lower cost due to it used of natural fibre (Tudu, 2009). According to (Archarya et al., 2011; Tewari et al., 2012), natural fibre have higher posibility of environmental protection. This is due to the ability of the biocomposite to reduced the dependence on non-renewable energy and material source, lower pollutant emission, lower greenhouse gas emission and enhanced the energy recovery (Tewari et al., 2012).

Biocomposite are usually used in automotive industry, aerospace industry, building industry, furniture industry and bio medical industry (Balaji et al., 2014). Biocomposite are suitable in the market due to it ability to elongation and ultimate breaking force, flexural properties, impact strength, acoustic absorption, suitability for processing and crash behavior.

2.3 Matrix

The matrix are materials that surrounds and supports the reinforcement materials by maintaining their relative positions (Jamaludin, 2002). The matrix phase within the biocomposites is often from natural polymer and possibly derived from vegetables oils or starches. The synthetics fossil-derived polymers such as virgin or recycled thermoplastic are widely act as a matrix.

The matrix from polymer are usually used with the composite (Oladele, 2014). Matrix are classified as thermoplastic and thermosetting (Mohammad, 2007). Thermoplastic matrix commonly used polypropylene (PP), polyethylene, and poly vinyl chloride (pvc) for bio-fiber composite.

The thermosetting polymers such as epoxy, polyester and vinyl ester are also act as matrix. The matrix material is introduced to the reinforcement before the material placed into the cavity or molded surface. The matrix are added to improved the toughness of the composite (Jamaludin, 2002).

2.4 Reinforcement

Reinforcement is the major part in the biocomposite where it act as a strengthening of the biocomposites. Reinforcement in the composite are usually the fibre or particulate of reinforcement (Jamaludin, 2002). The reinforcement has special mechanical and physical properties to enhance the matrix properties.

2.5 Sugarcane

Sugarcane in Figure 2.1 are very tall grass with big stems and larger grown in countries like Brazil, Cuba, Australia, South Africa, Peru, Mexico and India (Paulo et al., 2011). Sugarcane is mostly grown on estates and by smallholder. Sugarcane is belongs to the genus *Saccharum L* of the tribe Andropogoneae in the grass family (poaceae) and also include tropical and subtropical grasses and the cereal genera Sorghum and Zea (corn).

Figure 2.1 : Sugarcane

Sugarcane is complicated as plant from five genera that have characteristic and form a closely related interbreeding group known as the 'Saccharum complex'. The Saccharum complex comprises of Saccharum, Eriatus Section Ripidium, Miscanthus Section Diandra, Narenga and Sclerostachya.

These genera are characterised by high levels of polyploidy and frequently unbalanced numbers of chromosomes (aneuploidy) that making it difficult to determine the taxonomy and resulting in many previuos revisions of the taxonomic relationships. The Saccharum genus compromises six species *s.spontaneum, s.officinarum, s.robustum, s.edule, s,barberi* and *s.sinense.*

Sugarcane is mainly produce of ethanol and sugar production (Rezende et al., 2011). The sugarcane are transfer into ethanol to produce two main product which is thermal energy and bagasse.

2.5.1 Sugarcane Bagasse

SCB are the fibre from sugarcane *(saccharum officinarum)* waste (Lois-Correa et al., 2010). Figure 2.2 below shows that bagasse are biomass that left after the extraction of the sugarcane juice (Al Bakri et al., 2013).

Figure 2.2 : Sugarcane bagasse

Bagasse are lignocellulosic waste from sugar mills and agricultural processing (Maryana et al., 2014). The lignocellulosic fibre are present high length and thickness relation (Silva et al., 2012). The lignocellulosic from the sugarcane produce the bagasse with biodegradable and usually utilizes molasses as raw material for ethanol production and its derivaties (Maryana et al., 2014).

The bagasse extraction from sugarcane stalk will give advantages in energy supply in sugarcane industry (Archarya et al., 2011). It is by product of sugar milling (Rasul et al., 1999) that composed of fibre and pith (Agunsoye et al., 2013). Bagasse are suitable for making non-woven products (Tewari et al., 2012).

2.5.2 Sugarcane Bagasse Properties

The properties of SCB can be determined by the particle density, size and drag co-effecient (Rasul et al., 1999). The density are depend on the size of the fibre. Bagasse have three component which is pith, fibre and rind mixed in different proportion (Rasul et al., 1999). The shape of the fibre with length/ width ratio can be used to form unity arrangement of fibre.

SCB have softer structure compare to others residual that easily to breakdown (Maryana et al., 2014). SCB are form by two carbohydrates which is cellulose and hemicellulose that embeded in the lignin (Rezende et al., 2011). SCB have composition that depend on the variety, maturity, method that used and efficiency of the crushing the bagasse (Mishra., 2011). SCB have high content of cellulose, hemicellulose, and lignin where it is 50, 27.5 and 9.8 % respectively (Ahmed et al., 2012). The fibrous also have low density and wide range of particle sizes and high moisture content.

2.5.3 Sugarcane Bagasse Treatment

The pretreatment method are used to breakdown the highly ordered cellulose structure and the lignin carbohydrates complex (Ahmed et al., 2012). The pretreatment have ability to remove lignin, increase surface area that produce to enzymes, promote hydrolysis, an increase the rate and extent of hydrolysis of cellulose in various lignocellulosic (Ahmed et al., 2012).

2.5.4 Effect of NaOH Treatment on Sugarcane Bagasse

Sodium hydroxide occurs in the forms of crystal form called sodium hydroxide (NaOH) and anhydrous form called sodium hydroxide (anhydrous). Sodium hydroxide (crystal) is a mixture of sodium hydroxide (NaOH) and sodium hydroxide monohydrate ($NaOH.H_2O$). According to Siregar et al. (2010), the alkali treatment of cellulosic fibres are used to produced high quality of fibres to reinforced the polymer matrix.

The NaOH treatment can reduces the moisture absorption, poor wettability characteristic and improve the mechanical properties of the green composites (Ubi et al., 2015). According to Rajasekaran et al. (2016), the treatment with NaOH produced high mechanical properties of SCB and better result on tensile compare to untreated.

2.5.5 Sugarcane Bagasse as Reinforcement

The SCB was used as reinforcemet to Portland cement with bagasse fibre and water (Ghazali et al., 2008). To promote the homogenization between the cement and bagasse. The styrene butadiene latex dispersion (SBR latex) was used as binding agent (Ghazali et al., 2008). The polymer emulsion was used to the mixture of fibre-cement composites after complete addition of water for 10 minutes with weight percentages 3, 6, 9, 12, 15, 18 and 21 % respectively.

The result showed that, the ratio and adhesion behavior give impact on the composites produced. According to Ghazali et al. (2008), the composites with 6 % of SBR give high tensile strength and high hardness properties. The mechanical

properties of irriated composite have been improve than unirradiated composite and composite without SBR latex.

SCB also have been used as reinforcement to recycled polyethylene biocomposites (Agunsoye et al., 2013). The composite were produced by the compounding and compressive moding method. The composites that produced was uncarbonized and carbonized bagasse particle by using bagasse particle from 10 to 50 wt % (Agunsoye et al., 2013).

The result shows that the mechanical properties of the composite produce are depend on the form of bagasse used (Agunsoye., 2013). The homogenize of both reinforcement and the matrix produce good result on the strength and hardness. The highest contain of bagasse have high strength on tensile and bending test. The wt % of bagasse also give impact on the fracture toughness due to it bagasse containity. According to Agunsoye et al. (2013), the best properties range is 30 % wt bagasse and must be less than 30 %.

2.5.6 Advantages of Sugarcane Bagasse

Natural fibre such as SCB give many advantages compared to synthetic fibre. Natural fibre have the ability to reduced green house gas emission, low energy consumption, low cost, low density and acceptable specific strength properties make it suitable to be used with polymer composites.

SCB are usually core material that replacing high density and expensive wood-based fiberboard (Al Bakri et al., 2013). This natural fibre used due to it various advantages compared to other natural resources since it have good

environmentally friendly, light weight, less expensive sources, easy of processing, high specific modulus and biodegradable.

Bagasse have high moisture absorption, poor wettability and poor fibre matrix adhesion (Acharya et al., 2011). The liginin that content in the SCB is high which is 21 % on average. The bagasse without treatment will produce weak interface between the bagasse and the resin matrix. According to Acharya et al. (2011), the lignin that content in the bagasse will produce good surface wettability between polymer matrix material and natural fibre and improve the resistance to the chemical and microbial attack.

2.5.7 Application of Sugarcane Bagasse

SCB are one of the natural fibre that have potential in engineering applications. SCB can be used in the automotive industry such as automobile interiors. The SCB will improve the fuel efficiency, strength and lower the cost used. SCB also suitable materials in construction building to make panel, cellings, blocks and partition board such as wood and flooring tiles. SCB also applied in wide range automobiles and railway coaches and buses for public transport system (Mishra, 2011). Figure 2.3 shows the application of the SCB.

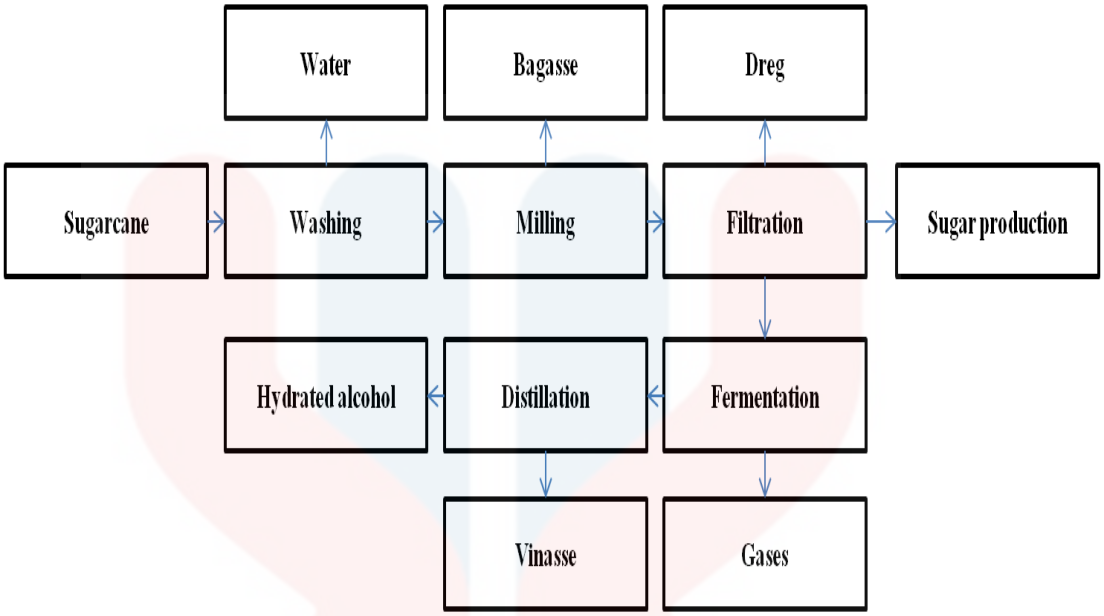

Figure 2.3 : Application of sugarcane bagasse

2.6 Resin

2.6.1 Polyester

Polyester resin are polyester that have been cured by treating with a monomer to produce crosslink. The crosslinking that produce are usually make resin became thermosetting polymer. Figure 2.4 shows the polymerization reactions within the polyester resin.

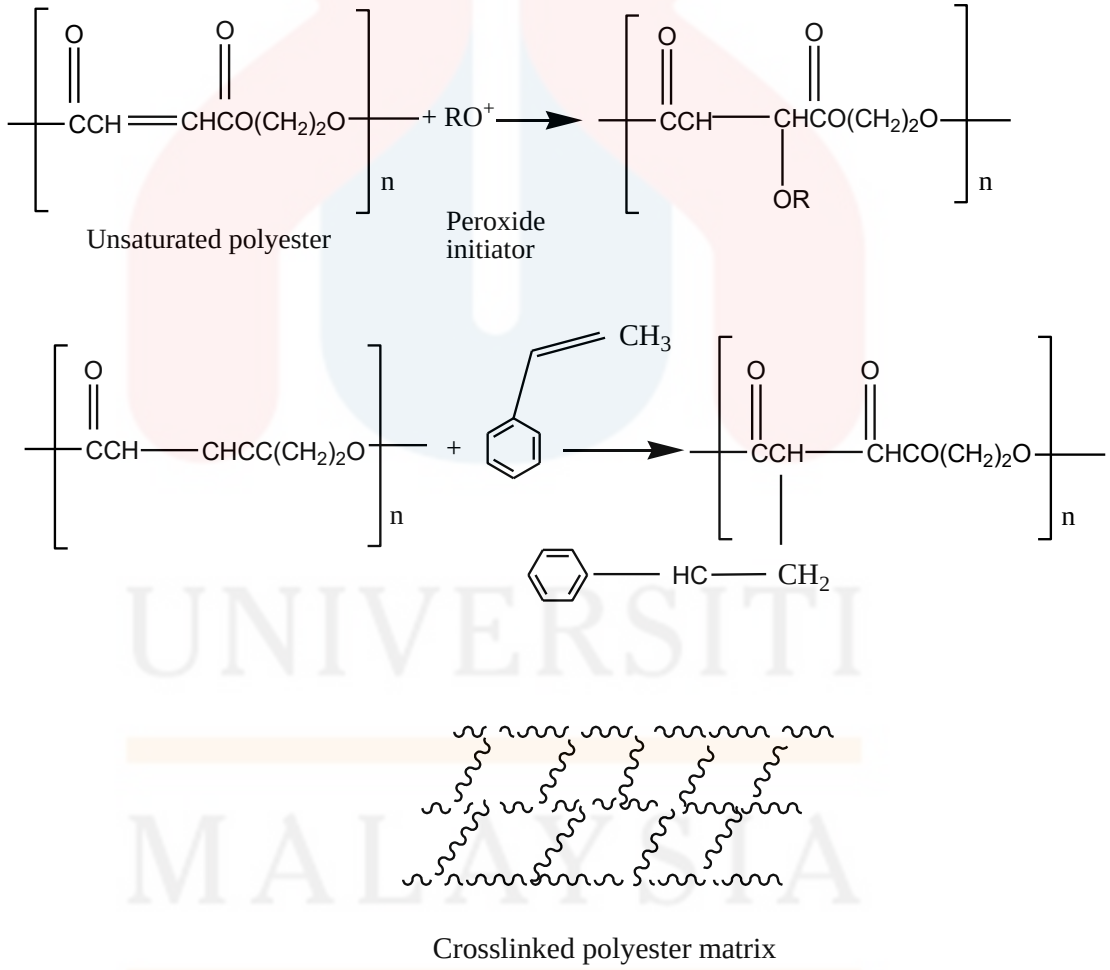

Figure 2.4 : Polymerization reactions within a polyester resin

The resin that produce became more strong and higher durability and difficult to change the structure during heating. This is due to the crosslinking that produce are not easily to break down. Polyester resin are used as fibre, plastic, composite and in coating application (Dholakiya, 2012). Polyester resin are mostly used the resin systems in marine industry (Davallo et al., 2010).

Polyester can be either saturated and unsaturated polyester. The saturated polyester are polyester that have double bonds in the structure while the unsaturated polyester have no double bonds in the structure. Polyester are heterochain macromolecules that used carboxylate ester groups as their integral component in polymer backbones (Dholakiya, 2012).

Polyester resins are depend on the macromolecules with polyester backbone where both saturated acid and unsaturated acid condensed with dihydric alcohol (Mohammad, 2007). Saturated polyester resin (SPR) are the reaction product of dibasic acids or dibasic acid chlorides with diols (Dholakiya, 2012). Figure 2.5 shows the structure of saturated polyester resin.

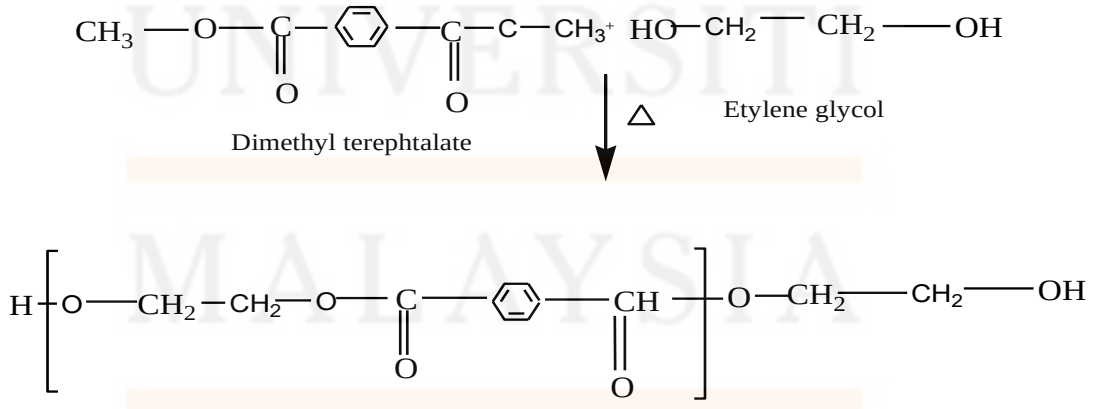

Figure 2.5 : Structure of saturated polyester resin

UPR are formed by introduction of maleic anhydride into the polyester backbone and isomerization the structure to produce furmarate ester or unsaturated polyester. According to Dudgeon. (2013), the polymer is dissolved in styrene to produce the solution with viscosity range 0.2 to 2 Pa.S (200-2000 P). The viscosity is depend on the application and specific process such as for the fabrication that obtained the cured through free radical process. Figure 2.6 shows the structure of unsaturated polyester resin.

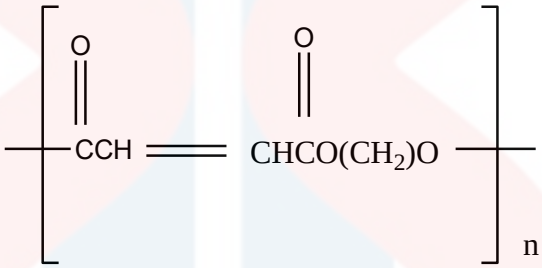

Figure 2.6 : Structure of unsaturated polyester resin

UPR are usually used for making fibre reinforced plastics (Mohammad, 2007). UPR are suitable to used any moulding due to it properties that easily to handle during fabrication and low cost. According to Richard et al. (2013), UPR are suitable in application such as marine structures, automotive repair, fibre glass construction product and renewable energy.

2.7 Hardener

2.7.1 Methyl Ethyl Ketone

Methyl Ethyl Ketone (MEKP) is an organic peroxide that commercially available as 40 % to 60 % solution. MEKP are colorless, oily-liquid and slightly less sensitive to shock and temperature where it more stable in storage. The hardener MEKP are measured in drops or fraction of teaspoons for the lay-up handling.

According to Davallo et al. (2004), MEKP can be used in the resin transfer moulding (RTM) where the polymer matrices used moulding sheet of resin based on Synolite 1077-N-3 with low viscosity UPR. The cobalt naphthenate accelarator/ MEKP initiator system of 0.40/ 1.0 weight ratio respectively was used as the curing agent.

The MEKP was choosen to allow cure occur at specific time and sheet before gelation occurs. MEKP are also suitable to be used as curing agent of UPR for the biocomposite materials (Davallo et al., 2010). The UPR will cure when the hardener is added even at room temperature when using the MEKP as cure or harden to the resin.

2.8 Example of Composite Fabrication

2.8.1 Sugarcane Bagasse in Cement Composites

SCB was used as reinforcement to cement that act as matrix and styrene butadiene (SBR) latex as binding agent (Ghazali et al., 2008). The composite fabrication was obtained by crushing the sugarcane and washed under running water to remove dust. The crushed sugarcane was then dried at 105 ºC for 24 hours. The dried SCB then sieve to produce small fibre in range 5 mm and diameter 300-500 µm.

The properties of the composite that produce showed that different percentages of matrix will produce different result for composite (Ghazali et al., 2008). SCB with higher percentage of SBR latex, 6 % give high strength and hardness properties to the composite produced.

2.8.2 Sugarcane Bagasse with Polystyrene Composites

SCB was used as the reinforcement to the polystyrene (PS) (Al Bakri et al., 2013). The PS are thermoplastic polymer that have good electrical properties and optical clarity, good thermal and dimensional stability and relatively low cost. PS was used because it available to perform with SCB during the fabrication.

The composite was fabricate by immersed the SCB in NaCl solution for three days for alkali teratment and then dried at room temperature for a few days. The dried SCB was crushed using universal power blender and sieve the size to range 425

µ and 300 µ. The short fibre and granules fibre was divide and dried using oven at temperature 50 ºC for 24 hours.

The different ratio of resin with MEKP which is 80:20, 70:30 and 60:40 was mixed for 1 hours to make polystyrene solvent. The SCB was mixed with the polystyrene solvent and dried for 15 minutes using oven at temperature 70 ºC before sampled using hot press. According to Al Bakri. (2013), the bending strength and compressive strength was increased with decreasing of bagasse fibre used.

CHAPTER 3

MATERIAL AND METHOD

3.1 Material

From this study, the material that used for this study was SCB, UPR, NaOH and distilled water. UPR was used as a matrix while SCB was used as a reinforcement of the biocomposites. UPR was purchased from Dr. Rahmatullah Holdings Sdn. Bhd. While SCB was obtained from local community around Tanah Merah Kelantan. NaOH was used for the treatment of SCB while distilled water as solvent throughout in this research.

3.2 Method

3.2.1 Fibre Treatment

The sugarcane was crushed using universal sugarcane machine. Then, the SCB was washed to remove dust using distilled water. This was followed by drying at 105 ºC for 24 hours using oven. Table 3.1 shows the percentages of dried SCB that was weighed and treated using NaOH (4 g/L) for 20 minutes at 80 ºC.

Table 3.1 : Percentages of NaOH for sugarcane bagasse treatment

Fibres (%)	NaOH (g) (4 g/L)	Distilled water (L)
10	4	1
20	8	2
30	12	3

After treatment, the suspension was left to cool at room temperature. This treatmant followed by neutralization of the SCB by washing with distilled water until it reaches pH 7. The treated SCB was drying at 105 ºC for 24 hours using oven. After 24 hours, the treated SCB was crushed using blender to form a powder by 5 minutes per rolling.

3.2.2 Composite Fabrication

In order to fabricate the composite, the mould with dimension of 150 × 150 × 10 mm was used. The SCB reinforced UPR composite was crushed using blender for 5 minutes to form a powder and fit to the mould in Figure 3.1 using the differents ratio of SCB and UPR in Table 3.2.

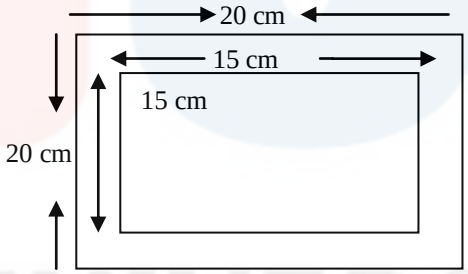

Figure 3.1 : Mould for composite fabrication

Table 3.2 : Composites weight fraction

Fibre Condition	UPR Content (%)	SCB Content (%)	MEKP (g)
100 % UPR	100	-	1.4
Treated	90	10	1.4
	80	20	1.4
	70	30	1.4
Untreated	90	10	1.4
	80	20	1.4
	70	30	1.4

The weighed SCB was put into the container. Then, the UPR was mixed with MEKP to promote homogenization between this solution. The mixture was put on the SCB to act as a matrix. The composite was mixed together and put on the mould for fabrication. The composites was put on the cool press machine in Figure 3.2 for 24 hours to compact it together.

Figure 3.2 : Cool press machine

After 24 hours, the composite was removed from the mould and stared until characterization. The composites was left on the oven for 1 hours at temperature 60 ºC to remove moisture and left to be cooled at room temperature.

3.3 Analysis

The SCB and UPR biocomposites was analyzed through mechanical testing and physical analysis using universal testing machine for tensile test, flexural test, water absorption test, thickness swelling test and density test. This testing has been repeated for three times for each composition in order to take the average of measurement for accuracy.

3.3.1 Mechanical Analysis

The mechanical analysis was used using sample size 150 mm x 10 mm x 10 mm that tested using tensile test and flexural test. Tensile testing of composites tested using testing rate 1 mm/min and 5 kN load cell. Tensile test performed using testometric, 5 kN load cell in accordance with ASTM D3039 standard (Wambua et al., 2003). The displacement measured with a 50 mm. The specimens was tested at a rate of 5 mm per minutes.

Flexural testing of composites was tested using rate of 5 mm/min and 5 kN load cell. The preload that used was 1.00 N with span 80 mm. Flexural test performed using Instron model 4505 using 3 point bending method by follow ASTM D790-03 standard (Wambua et al., 2003). Figure 3.3 shows the 3 point bending machine.

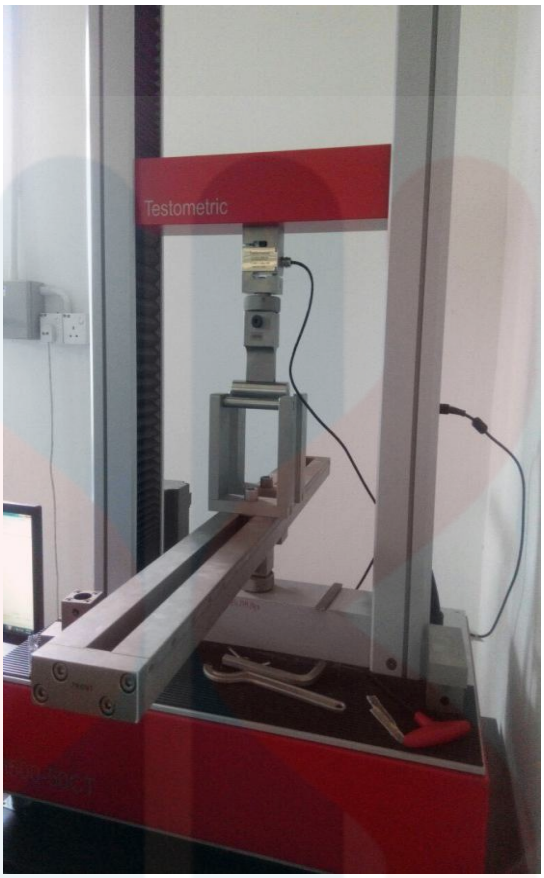

Figure 3.3 : 3 point bending machine

3.3.2 Physical Analysis

Physical analysis was determined by using water absorption test, thickness swelling test and density test. The water absorption of composites was tested using sample size 50 mm x 50 mm x 10 mm. This method are according to ASTM D570-98.

The thickness swelling of composites sample was cut to the sample size 50 mm x 50 mm x 10 mm according to ASTM D570-98. The thickness of the sample before and after was measured using digital calliper for three times for each specimens of each sample.

The density of biocomposite was determined according to Archimedes principle using electronic balanced (density meter). Sample with the dimension of 10 mm x 10 mm x 10 mm was prepared according to ASTM D792. The biocomposite was manually weighed in the air, m_0 by using electronic balance and the weight was recorded. After that, the sample was suspended in the distilled water. The weight of the sample was completely submerged in a distilled water. Density of the sample was calculated according to following Equation (3.1) :

$$\rho = \frac{m_0}{m_0 - m_1} \times \rho_w \qquad (3.1)$$

where,

m_0 = weight of biocomposite in the air, g

m_1 = weight of biocomposite in the water, g

ρ_w= density of water, 1.0000 g/cm^3

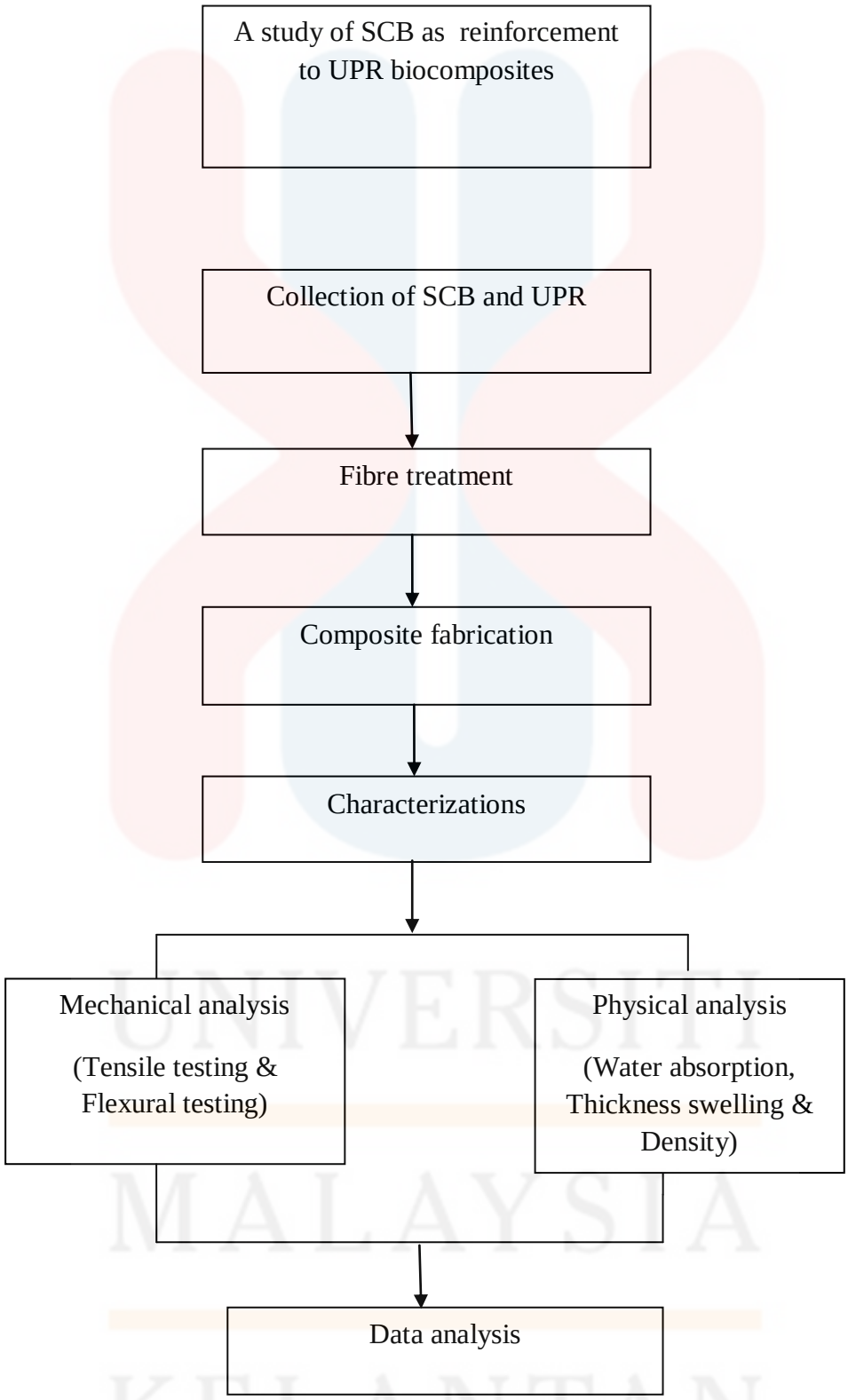

Figure 3.4 : Research flowchart

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Mechanical Analysis

4.1.1 Tensile Testing

Tensile testing has been conducted to knows the ability of the composites strength when tension was introduced until it failure. Table 4.1 shows the means value of the tensile testing for treated and untreated SCB biocomposites.

Table 4.1: Means value of tensile testing for treated and untreated SCB biocomposites based on differents ratio

Sample		Means	
		Stress (MPa) ± SD	Strain (MPa) ± SD
100 % UPR	100 % UPR	13.00 ± 5.23	1.038 ± 0.42
Treated	10:90	9.82 ± 5.13	1.66 ± 0.49
	20:80	13.05 ± 0.48	1.72 ± 0.05
	30:70	6.45 ± 0.44	1.72 ± 0.17
Untreated	10:90	8.67 ± 3.73	1.92 ± 0.02
	20:80	2.57 ± 0.14	1.92 ± 0.14
	30:70	6.08 ± 0.88	1.98 ± 0.16

a) Stress and Strain for Treated and Untreated SCB Biocomposites

The strength of the composites produced was determine using the tensile testing to investigated the stress and strain that can be obtained by the composites that produced. The Figure 4.1 and Figure 4.2 shows for tensile properties of treated and untreated SCB.

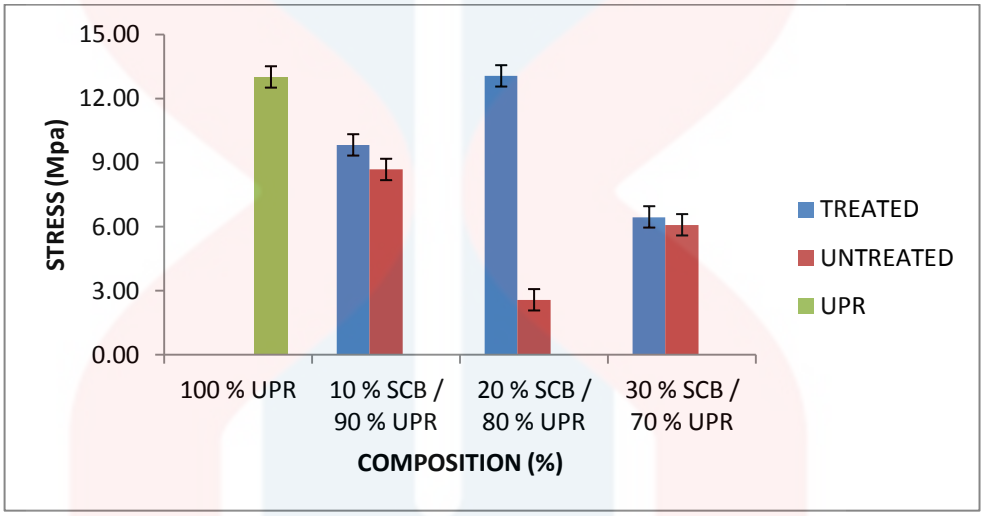

Figure 4.1 : Tensile stress of treated and untreated SCB biocomposites

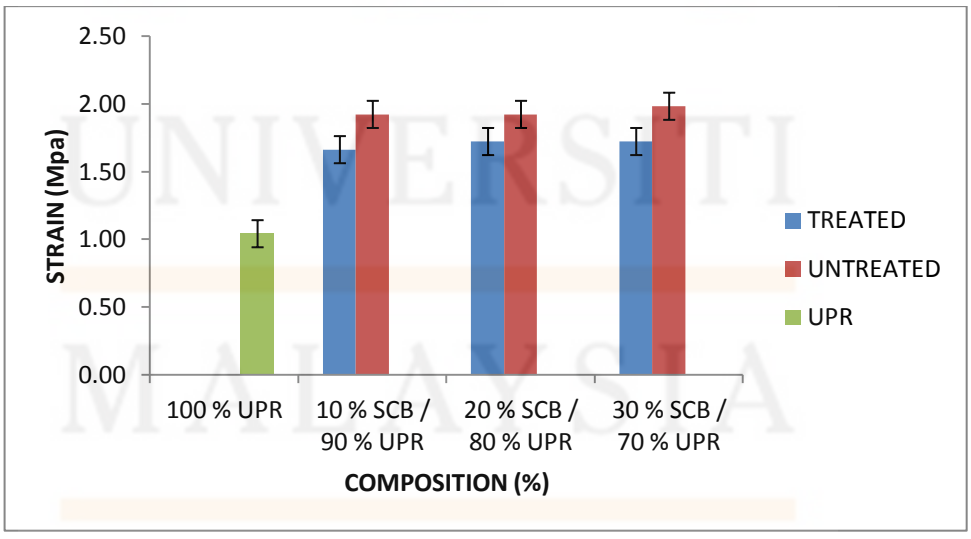

Figure 4.2 : Tensile strain of treated and untreated SCB biocomposites

Based on Figure 4.1 and Figure 4.2, the graph shows that the tensile properties was depend on the fibre content in the composites where the different ratio that used was showed different values of stress and strain. The treated SCB was showed that the composites with highest fibres content have the lowest value of stress and highest value of strain.

The ratio of 30 % of SCB with 70 % of UPR shows that the value of stress are the lowest among others ratio with only 6.45 MPa but have higher strain than othes ratio with 1.72 MPa of strain. This was happen maybe because of the fibre content on the ratio of 30 % of SCB and 70 % of UPR was higher than others ratio that make it less stress but high strain than others ratios.

For ratio of 20 % of SCB and 80 % of UPR, the graph shows that the values of SCB was increase immediately from lower to highers tensile strength. The stress and strain of 20 % of SCB and 80 % of UPR was 13.05 MPa and 1.72 % respectively. Besides that, for ratio of 10 % of SCB and 70 % of UPR was showed that 9.82 MPa and 1.66 % of stress and strain respectively. The lower ratio of SCB with UPR was produced lower stress and strain of the composites produced. This was happen maybe because of the fibre content that was less compared to 20 % and 30 % ratio of SCB used in the composites fabrication.

While, for untreated SCB composites, it was showed the different result compared to treated biocomposites. The treated biocomposites have lower result of strain for all ratio compared to untreated biocomposites that more higher than treated bicomposites. This happen maybe because of the treatment that used where it was lower the fibre weight during treatment and higher the fibre used in fabrication. The treatment of NaOH that used was break down the bonding on the SCB where it was

remove all the lignin, cellulose and hemicellulose on the SCB that make it lower weight than untreated SCB.

The higher value of SCB used where 30 % of SCB and 70 % of UPR was showed the higher value of strain than others ratio with 1.98 % that make it high strength than other ratio. But, the stress of this ratio was higher than ratio 20 % of SCB and 80 % of UPR where the ratio of 20 % SCB and 80% of UPR only have 2.57 MPa of stress while the ratio of 30 % of SCB and 70 % of UPR was 6.08 MPa. This was happen maybe because of the low homogenization between the matrix and reinforcement during the preparation of composites fabrication that make it high stress and high strain during testing for 30 % of SCB and 70 % of UPR compared to 20 % of SCB and 80 % of UPR.

But for ratio 10 % of SCB and 90 % of UPR, the strain of this ratio was same with ratio 20 % of SCB and 80 % of UPR where it was 1.92 % but higher stress where it was 8.67 MPa while the ratio ratio 20 % of SCB and 80 % of UPR only have 2.57 MPa of stress. This was make the composites with ratio 10 % of SCB and 90 % of UPR was lower strength than composites with ratio 20 % of SCB and 80 % of UPR. This was happen maybe because of low dispersion of SCB with the UPR during the mixture where the polyester was higher than SCB that make the SCB can be homogenize but not well disperse around the composites.

Besides, both result of treated and untreated biocomposites showed that the ratio of treated 30 % of SCB and 70 % of UPR was lower in stress than others treated ratio of composites fabrication but higher in strain values while the untreated 30 % of SCB and 70 % of UPR was showed the higher strain but middle of stress values

which was 6.08 MPa compared to ratio 10 % of SCB and 90 % UPR and ratio 20 % of SCB and 80 % of UPR that have same strain but different stress.

The stress and strain for treated ratio 30 % of SCB and 70 % of UPR was less strength than untreated ratio ratio 30 % of SCB and 70 % of UPR with stress and strain was 1.72 MPa and 6.45 % respectively compared to untreated ratio ratio 30 % of SCB and 70 % of UPR that have good stress and strain with value 1.98 MPa and 6.08 % respectively. This was happen maybe because of the lack of homogenization between the matrix and reinforcement for treated and untreated biocomposites.

The composite with 100 % of UPR was shows the highest stress but lower strain where it only 1.04 MPa. According to Davallo et al. (2010), the used of polyester resin without reinforcement produced the lower strain of tensile test. This was happen maybe due to the properties of the composites that produced where it was became brittle and high fracture toughness compare to composites with reinforcement.

The result shows that the ratio of both treated and untreated ratio 30 % of SCB and 70 % of UPR have high strength compared to others ratios. This was happen maybe due to the wt % of the bagasses that used was give the impact on the fracture toughness due to the bagasse contain. According to Agunsoye et al. (2013), the best range of bagasse contain was 30 % and not lesss than 30 %. So, the used of SCB contain was give the major effect to the composites that produced.

4.1.2 Flexural Testing

Flexural testing was used to determine the flexural modulus and flexural strength of the composites that produced. Table 4.2 shows means value of the flexural test for treated and untreated SCB biocomposites based on different ratio.

Table 4.2 : Means value of flexural test for treated and untreated SCB biocomposites based on differents ratio.

Sample		Means	
		MOR (MPa) ± SD	MOE (MPa) ± SD
100 % UPR	100 % UPR	10.77 ± 0.60	262.17 ± 20.01
Treated	10:90	18.09 ± 0.62	842.19 ± 23.34
	20:80	19.82 ± 1.28	846.36 ± 35.53
	30:70	11.62 ± 0.65	541.35 ± 36.87
Untreated	10:90	13.85 ± 5.47	473.44 ± 196.72
	20:80	10.37 ± 1.04	355.14 ± 57.14
	30:70	9.87 ± 3.36	431.62 ± 113.89

a) MOR and MOE for Treated and Untreated SCB Biocomposites

The flexural test has been conducted to treated and untreated biocomposites where the strength of both treated and untreated SCB biocomposites with difference ratio have been shows through Figure 4.3 and Figure 4.4. The flexural strength (MOR) and flexural modulus (MOE) of the composites have been calculate where it shows the strength of the composites before break down and the deformation rate of the composites.

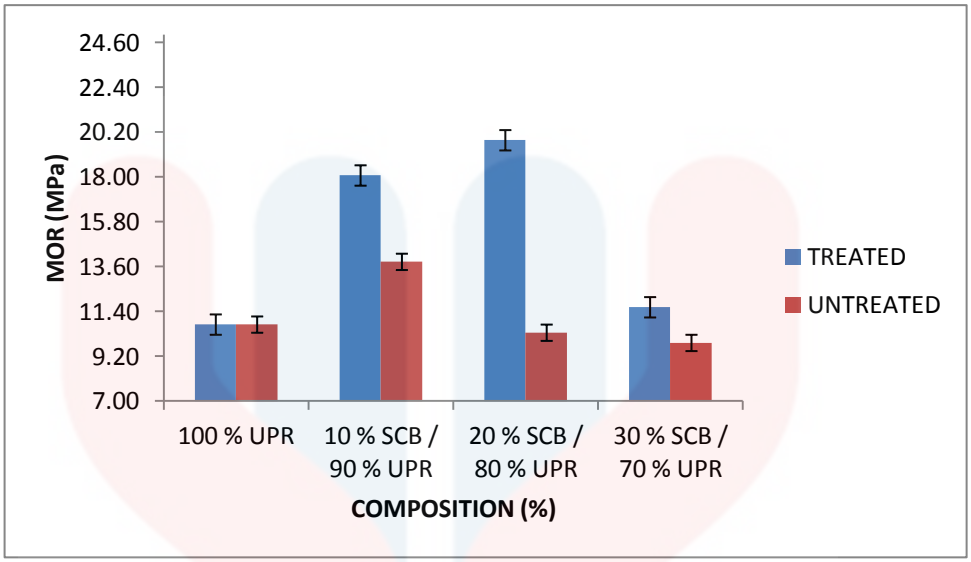

Figure 4.3 : MOR of treated and untreated SCB biocomposites

Based on Figure 4.3, the graph MOR showed that the 100 % of UPR have lower MOR compared to other ratios. According to Davallo et al. (2010), the used of 100 % UPR have lower value of modulus strain. This happen maybe due to the properties of the polymer that produced became brittle than composites with the SCB as reinforcement.

Besides, the untreated SCB have the lowest MOR compare to treated SCB. For untreated SCB, the highest ratio of SCB with ratio 30 % of SCB and 70 % of UPR have the lowest MOR with 9.87 MPa compared to others. This was happen maybe due to the higher fibre content ratio on the composites fabrication that used which lower the MOR.

For the treated SCB, the graph showed that the lower content of SCB with ratio 10 % of SCB and 90 % of UPR have lower MOR where it was 18.09 MPa while for the ratio 20 % of SCB and 80 % of UPR have the highest MOR where it was 19.82 MPa. The treated ratio 30 % of SCB and 70 % of UPR have rapidly decrease from ratio 20 % of SCB and 80 % of UPR where it was only 11.62 MPa.

This was happen maybe due to the lack of homogenization between the matrix and reinforcement of the biocomposites.

For untreated biocomposites, the graph showed that the ratio 10 % of SCB and 90 % of UPR have the highest MOR where it was 13.85 MPa then decrease the MOR to 10.37 MPa with ratio 20 % of SCB and 80 % of UPR and MOR 9.87 MPa with ratio 30 % of SCB and 70 % of UPR. This was happen maybe because of the homogenization between the matrix and reinforcement where the lowest ratio of SCB was produce good mixture between the bagasse and polyester during fabrication of biocomposites.

The treated and untreated SCB give the different MOR among the all ratio. The treated SCB was give the higher MOR compared to untrated SCB for all ratio where MOR for treated SCB with ratio 10 % of SCB and 90 % of UPR was 18.09 MPa while for untreated SCB have MOR only 13.85 MPa for ratio 10 % of SCB and 90 % of UPR. For ratio 20 % of SCB and 80 % of UPR, the treated SCB have higher MOR compared to untreated SCB where the treated have MOR 19.82 MPa while untreated have MOR 10.37 MPa. This is maybe due to the treatment of the SCB and well dispersion during the composites fabrication.

The ratio 30 % of SCB and 70 % of UPR for both treated and untreated SCB have lower MOR but MOR for treated was higher than untreated SCB for this ratio where the treated have 11.62 MPa while untreated only 9.87 MPa. This was due to the fibre content that higher used in this ratio that make the composites became lower MOR. According to Al Bakri et al. (2013), the strength of the composites was increase with the decrease of bagasse fibre used. Besides, the MOE of the composites shows in Figure 4.4.

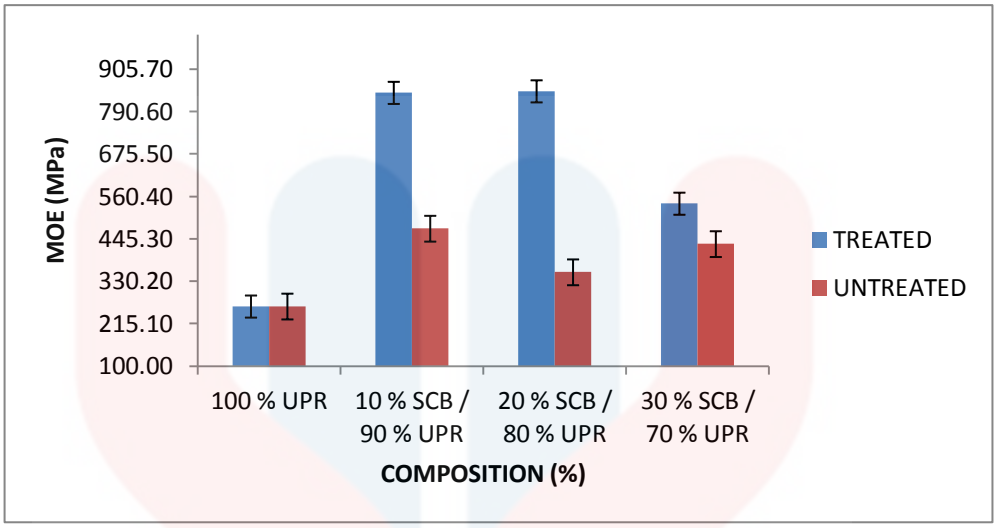

Figure 4.4 : MOE of treated and untreated SCB biocomposites

Based on Figure 4.4, the graph shows that the MOE for the treated and untreated SCB where the highest MOE produced good deformation rate. From the graph, the lowest MOE was shows when using 100 % of UPR while the treated SCB shows the higher MOE for all ratio either ratio 10 % of SCB and 90 % of UPR, ratio 20 % of SCB and 80 % of UPR and ratio 30 % of SCB and 70 % of UPR ratio used compared to the untreated SCB.

The treated SCB have the highest value in ratio 20 % of SCB and 80 % of UPR where the MOE was 846.36 MPa while the lowest MOE was 541.35 MPa when using ratio 30 % of SCB and 70 % of UPR. This maybe happen because of the fibre content that used to form the biocomposites where the higher fibre content ratio 30 % of SCB and 70 % of UPR produce lower MOE while the middle of SCB used , ratio 20 % of SCB and 80 % of UPR produce higher MOE.

For the untreated SCB, the highest MOE was 473.44 MPa which using the ratio of 10 % of SCB and 90 % of UPR while the lowest MOE was 355.14 MPa using ratio of 20 % of SCB and 80 % of UPR. For this untreated SCB biocomposites, the MOE was high for the decrease of SCB content compared to treated SCB where

the the MOE for treated ratio 10 % of SCB and 90 % of UPR was 842.19 MPa then increase to 846.36 MPa of MOE when using ratio 20 % of SCB and 80 % of UPR but different to untreated SCB that decrease of MOE with the increasing of fibre content.

The less MOE strength in the composites maybe because of the error during the fabrication and handling the composites during preparation of the sample that make the composite with ratio 20 % of SCB and 80 % of UPR was drop down in MOE compare to ratio 10 % of SCB and 90 % of UPR and ratio 30 % of SCB and 70 % of UPR that have MOE 473.44 MPa and 431.62 MPa respectively.

Both treated and untreated SCB of ratio 20 % of SCB and 80 % of UPR have different MOE where the treated ratio 20 % of SCB and 80 % of UPR have highest MOE where it was 846.36 MPa while the untreated ratio 20 % of SCB and 80 % of UPR have the lowest MOE where it was 355.14 MPa. This maybe due to the treatment that used was increase the MOE of the composites and improve the properties. According to Al Bakri et al. (2013), the bending and compression strength increase with decreasing of bagasse fibre used.

4.2 Physical Test

4.2.1 Water Absorption

The water absorption was used to determine the amount of water absorb by the composites in percentages. Table 4.3 below shows the means value of water absorption for the treated and untreated SCB biocomposites for 5 hours.

Table 4.3 : Means value of the water absorption for treated and untreated SCB biocomposites based on different ratio.

Sample		Means				
		1H	2H	3H	4H	5H
100 % UPR	100 % UPR	0.00	0.00	0.14	0.14	0.28
Treated (%)	10:90	0.53	0.53	0.53	0.84	0.95
	20:80	0.76	0.86	1.13	1.34	1.43
	30:70	1.29	2.73	3.20	3.80	4.27
Untreated (%)	10:90	0.22	1.40	1.61	1.61	1.61
	20:80	0.30	1.64	2.16	2.26	2.57
	30:70	0.40	1.89	2.18	2.28	2.48

a) Water Absorption for Treated and Untreated SCB Biocomposites

Water absorption was conducted for 5 hours to observed the percentages of water uptake by the composites with treated and untreated SCB with UPR using ratio 100 % of UPR, ratio 10 % of SCB and 90 % of UPR, ratio 20 % of SCB and 80 % of UPR and ratio 30 % of SCB and 70 % of UPR for both treated and untreated SCB. The result have been shows in Figure 4.5 for both treated and untreated biocomposites.

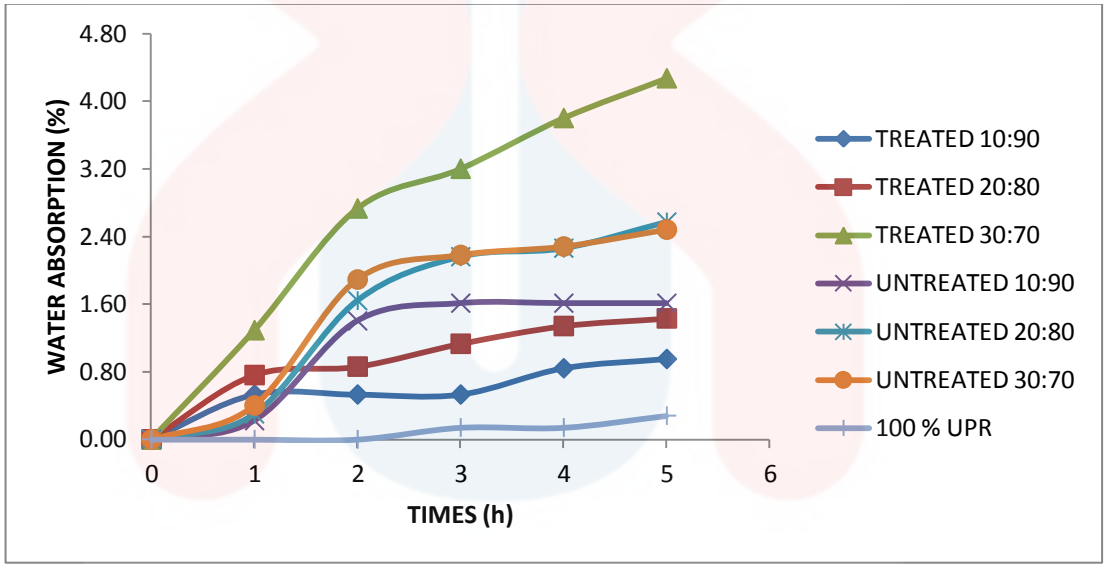

Figure 4.5 : Water absorption of treated and untreated SCB biocomposites against times

Based on Figure 4.5, the graph indicates that the water absorption was higher in composites with ratio 30 % of SCB and 70 % of UPR for treated SCB. The times taken, 1 hours to 5 hours shows that the increasing of the water absorption for treated SCB. The water absorption was increase due to the incresing of the fibre content where the higher fibre content have the ability to absorb the water than lower fibre content.

For treated SCB, the graph shows that the highest contain of bagasse have higher water absorption than lower fibre content. The composites with ratio 30 % of

SCB and 70 % of UPR showed the water absorption for this ratio was the highest compared to the others ratio where the water absorption was increase immediately from initial value for every hours where it was 1.29 %, 2.73 %, 3.20 %, 3.80 % and 4.27 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours of times taken respectively. The water absorption of the treated composites with ratio 30 % of SCB and 70 % of UPR was higher maybe due to the highest bagasse used and the treatment that used to remove all the lignin, cellulose and hemicellulose on the bagasse that higher the ability of the bagasse to improve the water absorption.

For treated composites with ratio 20 % of SCB and 80 % of UPR, the graph shows that the composites with this ratio have less water absorption where it was only 0.76 %, 0.86 %, 1.13 %, 1.34 % and 1.43 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively compared to ratio 30 % of SCB and 70 % of UPR but higher than the composites with ratio 10 % of SCB and 90 % of UPR where the ratio 10 % of SCB and 90 % of UPR was the lower water absorption where it was 0.53 %, 0.53 %, 0.53 %, 0.84 % and 0.95 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively. This was due to the less of fibre content that used in the composites fabrication that make it less water absorption for ratio 10 % of SCB and 90 % of UPR and ratio 20 % of SCB and 80 % of UPR compared to ratio 30 % of SCB and 70 % of UPR.

Besides, the composite with 100 % of UPR was shows the lowest result for water absorption where it only 0.00 %, 0.00 %, 0.14 %, 0.14 % and 0.28 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively. The used of 100 % of UPR maybe was produced the composite with hydrophobic behaviour where the composite have less ability to absorb water compared to composite that fabricate

with SCB where the SCB have the ability to absorb water compare to polymer. This also happen maybe due to the properties of UPR that less of water absorption.

While, for untreated SCB, the highest water absorption was also the ratio 30 % of SCB and 70 % of UPR where it was increasing from initial value to 1.29 %, 2.73 %, 3.20 %, 3.80 % and 4.27 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively. The fibre content was influence the water absorption of the composites where the lower fibre content with ratio 10 % of SCB and 90 % of UPR and ratio 20 % of SCB and 80 % of UPR have lower water absorption where the ratio 10 % of SCB and 90 % of UPR only absorb 0.22 %, 1.40 %, 1.61 %,, 1.61 % and 1.61 % while ratio 20 % of SCB and 80 % of UPR was absorb 0.30 %, 1.64 %, 2.16 %, 2.26 and 2.57 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively.

The water absorption for treated SCB was higher than untreated SCB for all ratios either ratio 10 % of SCB and 90 % of UPR, ratio 20 % of SCB and 80 % of UPR or ratio 30 % of SCB and 70 % of UPR. The highest water absorption was shows when using ratio 30 % of SCB and 70 % of UPR with treated SCB compared to used untreated SCB where the treated shows that the water absorption was 1.29 %, 2.73 %, 3.20 %, 3.80 % and 4.27 % compared to untreated that absorb only 0.40 %, 1.89 %, 2.18 %, 2.28 % and 2.48 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively.

The treated SCB with ratio 30 % of SCB and 70 % of UPR have high water absorption because the treatment that used was improved the ability of the composites to increase the properties in their mechanical properties by break down the bonding during the treatment and improve the ability of water absorption.

The untreated SCB have low water absorption compared to treated SCB. According to Archarya et al. (2011), a good fibre and matrix bonding can decrease the rate and amount of moisture absorption by the composites. The composites with lower percentages of water absorption will produce good composites product that have high durability to be used compared to composites with higher water absorption.

4.2.2 Thickness Swelling

Thickness swelling was conducted to knows the weight of water contained in the composites that have been shows in percentages. Table 4.4 below was shows the means value of thickness swelling for both treated and untreated SCB biocomposites based on differents ratio.

Table 4.4 : Means value of the thickness swelling for treated and untreated SCB biocomposites based on different ratio.

Sample		Means				
		1H	2H	3H	4H	5H
100 % UPR	100 % UPR	0.00	0.13	0.13	0.27	0.40
Treated (%)	10:90	0.23	0.47	0.58	0.58	0.82
	20:80	0.00	0.34	0.56	0.56	0.56
	30:70	0.00	0.11	0.44	0.66	1.10
Untreated (%)	10:90	0.00	0.23	0.34	0.45	0.56
	20:80	0.11	0.45	0.45	0.67	0.67
	30:70	0.32	0.53	0.85	0.96	1.07

a) Thickness Swelling for Treated and Untreated SCB Biocomposites

The ability of the composites was determine by using different ratio of treated and untreated SCB with ratio 100 % of UPR, ratio 10 % of SCB and 90 % of UPR, ratio 20 % of SCB and 80 % of UPR and ratio 30 % of SCB and 70 % of UPR to increase the thickness of the composites after 5 hours of observation. The result have been calculated and shows by Figure 4.6 for thickness swelling of treated and untreated SCB biocomposites.

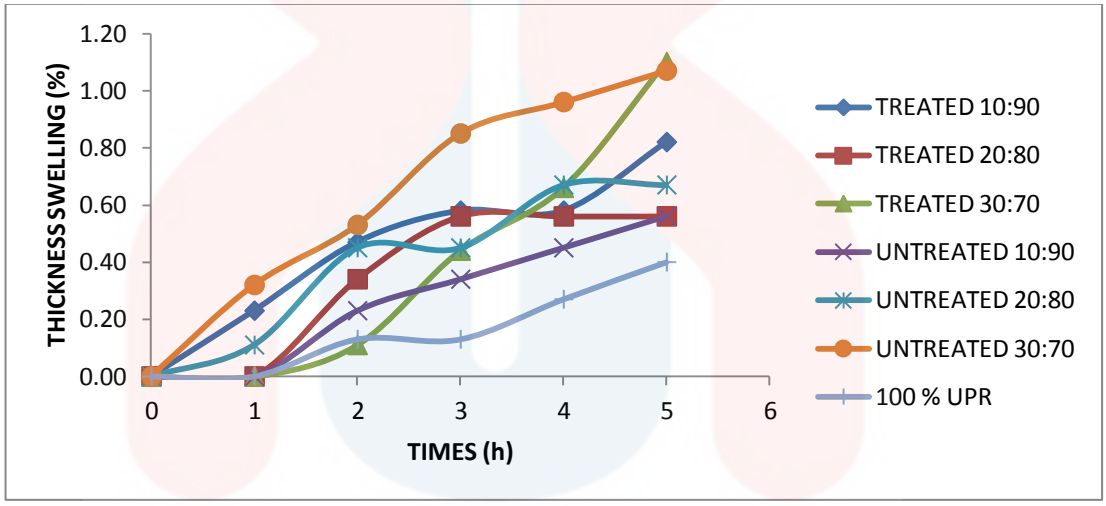

Figure 4.6 : Thickness swelling of treated and untreated SCB biocomposites against times

The graph indicated that the higher ratio of the SCB with ratio 30 % of SCB and 70 % of UPR for both treated and untreated SCB have the highest increasing of the thickness after 5 hours of observation while the lowest ratio of bagasse with ratio 100 % of UPR, ratio 20 % of SCB and 80 % of UPR and ratio 10 % of SCB and 90 % of UPR have less thickness increasing compared to ratio 30 % of SCB and 70 % of UPR. This was happen maybe due to the ratio of SCB and UPR used during fabrication that was effect the thickness of the composites where the higher ratio of SCB with lower UPR was more easily to increase the thickness compared to used the higher ratio of UPR with lower ratio of SCB.

For treated SCB, the graph shows that the highest thickness swelling was ratio 30 % of SCB and 70 % of UPR while the lowest thickness swelling was ratio 20 % of SCB and 80 % of UPR. The highest ratio of composites with ratio 30 % of SCB and 70 % of UPR was increase the thickness from initial value to 0.00 %, 0.11 %, 0.44 %, 0.66 % and 1.10 % while the ratio 20 % of SCB and 80 % of UPR was increasingthe thickness to 0.00 %, 0.34 %, 0.56 %, 0.56 % and 0.56 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively. This was happen maybe because of the highest contain of fibre was improve the mechanical properties of the composites due to the absorption of the water in the composites that produced compared to lower contain of fibre.

Besides, the treated SCB with ratio 10 % of SCB and 90 % of UPR have higher thickness increasing where it was 0.23 %, 0.47 %, 0.58 %, 0.58 % and 0.82 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively compared to the ratio 20 % of SCB and 80 % of UPR. The ratio 20 % of SCB and 80 % of UPR have less thickness swelling than the lower content of SCB with ratio 10 % of SCB and 90 % of UPR of SCB. The higher ratio of SCB was shows the lower thickness swelling of the composites maybe because of th error during the fabrication of the biocomposites where the mixture of the matrix and reinforcement was not homogenize together and well disperse before put on the moulding due to the higher SCB with lower UPR was difficult to mix together for the homogenization. The thickness swelling of the ratio 20 % of SCB and 80 % of UPR maybe lower due to this factors. Besides, for untreated biocomposites, Figure 4.7 below was showed the result.

The thickness swelling for untreated SCB was also higher with ratio that have higher content of fibre where it was composites with ratio 30 % of SCB and 70 % of UPR while the lowest thickness swelling was ratio 10 % of SCB and 90 % of UPR.

The graph shows that the thickness swelling of the composites was increase due to the fibre content that used while decrease when using higher ratio of UPR during the composites fabrication.

The untreated SCB with ratio 30 % of SCB and 70 % of UPR was have the highest value of thickness swelling where it was 0.32 %, 0.53 %, 0.85 %, 0.96 % and 1.07 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively. The higher ratio of SCB was influence the composites to increase the thickness swelling maybe due to the properties of the composites that easily to absorb water and increase the thickness of the composites.

SCB with ratio 20 % of SCB and 80 % of UPR have lower thickness swelling for compare to ratio 30 % of SCB and 70 % of UPR but higher than ratio 10 % of SCB and 90 % of UPR. The composites with ratio 20 % of SCB and 80 % of UPR was shows that the thickness swelling for this ratio was increase from the initial value where it was 0.11 %, 0.45 %, 0.45 %, 0.67 % and 0.67 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively. The lack of thickness swelling for composites with ratio 20 % of SCB and 80 % of UPR compared to ratio 30 % of SCB and 70 % of UPR was maybe due to the less fibre content that used during fabrication.

While, the composites with ratio 10 % of SCB and 80 % of UPR was shows the lowest thickness swelling compared to the ratio 30 % of SCB and 70 % of UPR and ratio 20 % of SCB and 80 % of UPR where it was shows that the thickness swelling was increase slowly from the initial value to the 0.00 %, 0.23 %, 0.34 %, 0.45 % and 0.56 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively. This was happen maybe because of the highest content of the UPR in the composites

with ratio 10 % of SCB and 90 % of UPR compared to other ratio that used less UPR and high SCB where the higher used of UPR was produce the composites with properties that more harder and low thickness swelling than others ratio.

The thickness swelling for the 100 % of UPR was shows the lowest result of thickness swelling compared to others ratio with SCB where it only 0.00 %, 0.13 %, 0.13 %, 0.27 % and 0.40 % for 1 hours, 2 hours, 3 hours, 4 hours and 5 hours respectively. The used of 100 % of UPR was produced the composites with lower thickness swelling due to it properties that less water absorption.

The thickness swelling for both treated and untreated biocomposites shows that the thickness swelling was highest increase when using the ratio 30 % of SCB and 70 % of UPR where it was give the higher result for the 5 hours of observation. This was happen maybe due to the ratio of SCB that content in the composites was influence the thickness swelling of the composites. But, the composites with untreated SCB was shows higher thickness swelling compared to the treated SCB.

According to Juliana Anggano et al. (2015), the increasing of SCB in composites was increase the thickness of the composites but alkaline treatment with NaOH on the SCB was caused the diameter of composites became decrease due to the removing of hemicellulose and lignin during the treatment that make the composites became more crystalline compared to untreated SCB.

4.2.3 Density

The density test was conducted using the density testing machine to find the highest density of composites when using the difference ratios and treatment. Table 4.5 shows the means value of the treated and untreated SCB biocomposites based on differents ratio.

Table 4.5 : Means value of density test for treated and untreated SCB biocomposites based on different ratio

Sample	Compositions	Means
100 % UPR	100 % UPR	0.34
Treated (%)	10:90	0.70
	20:80	1.11
	30:70	2.75
Untreated (%)	10:90	0.74
	20:80	1.06
	30:70	1.05

a) Density for Treated and Untreated SCB Biocomposites

The density test was obtained by using three specimens for each sample for treated and untreated composites with ratio 100 % of UPR, 10 % of SCB and 90 % of UPR, ratio 20 % of SCB and 80 % of UPR and ratio 30 % of SCB and 70 % of UPR have been calculated to take the accurated result. Figure 4.9 shows the result of density for both treated and untreated biocomposites.

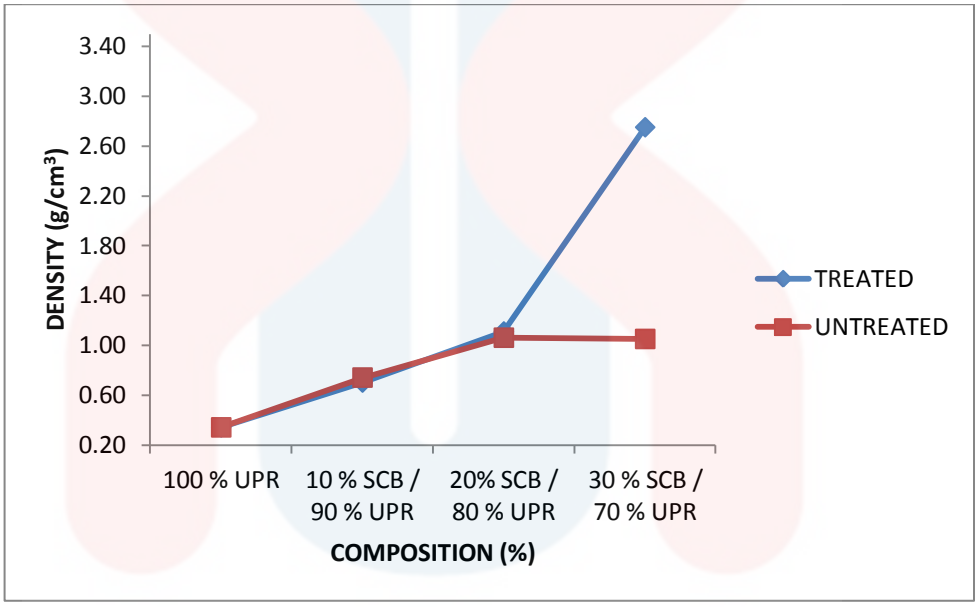

Figure 4.7 : Density of treated and untreated SCB biocomposites

Based on Figure 4.7, the graph shows that the density of SCB for treated are difference than untreated SCB where the treated SCB with ratio 10 % of SCB and 90 % of UPR was 0.70 g/cm^3 compared to untreated SCB with same ratio that have density of 0.74 g/cm^3. The untreated SCB have high density value for this ratio maybe because of the environment humidity that influence the wettability of the composite that make the treated became low density than untreated for ratio 10 % of SCB and 90 % of UPR.

For ratio 20 % of SCB and 80 % of UPR, the density for treated SCB was 1.11 g/cm^3 while the density for untreated SCB was 1.06 g/cm^3. The density of treated SCB was higher than untreated SCB because of the bonding on the SCB that have being break down during the treatment make it high density while the SCB without treatment have low density due to the cellulose and hemicellulose that contain inside the bagasse.

The density for ratio 30 % of SCB and 70 % of UPR shows that the untreated SCB have lower density where it was 1.05 g/cm^3 compared to treated SCB that have the highest value of density where it was 2.75 g/cm^3. The highest content of SCB compared to highest content of UPR give the different result of density, where the ratio 30 % of SCB and 70 % of UPR was high density than ratio 10 % of SCB and 90 % of UPR and ratio 10 % of SCB and 90 % of UPR. This was happen due to the ability of the bagasse to absorb the water depends on the fibre content that used.

The composite with high used of SCB was shows the higher density than the composite without the SCB with ratio of 100 % of UPR where the density was only 0.34 g/cm^3. This was happen maybe due to the lack of homogenization between the UPR with MEKP during fabrication that produced polymer with lower properties. The used of matrix without reinforcement have produced the composites that low strength than composite with reinforcement.

The treatment that used on the SCB also give the effect to the density of the composites. The treated SCB was shows the highest result of density compared to untreated SCB. The treatment was make the composites became dense due to the higher weight loss during after the treatment that make it higher of SCB that used during fabrication compared to the untreated SCB.

According to Ahmed et al. (2012), the SCB have high content of cellulose, hemicellulose and lignin that make it low density. Thus, the treatment that used on the SCB was higher the density because it was break down the cellulose, hemicellulose and lignin of the SCB.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

Based on the experimental result of a study on SCB as reinforcement in UPR biocomposites that have been tested under physical and mechanical testing using tensile test, flexural test, thickness swelling, water arbsorption and density test, it can be conclude that the SCB reinforced in UPR was successfully fabricated and developed by hand lay-up moulding.

Then, it found that the dispersion of the fibres between matrix and reinforcement was importance factors that influence the hardness and wear resistance of the composites produced. The homogenization between the matrix and reinforcement was important during the fabrication to produce good strength properties of composites that produced.

The ratio of the fibre contain used also was influence the properties of the composites that produced where the addition of the bagasse was increase the strength of the composites. Besides, it was succesfully shows that the treatment that used was effect the properties of the composites produced where the treatment was make the composites have good properties than untreated SCB because of the removing of all lignin, cellulose and hemicellulose during the treatment of the SCB was improve the strength of the SCB.

5.2 Recommendation

In future, this research should be followed by adding the others materials with SCB to produce hybrid composites to study its properties either in their physical or mechanical properties. This study also can be followed by using the hot press machine where it will produce better homogenization between the matrix and reinforcement.

The different percentages of NaOH also can be used for the treatment through this study to study the effect of different percentages of treatment on the SCB as reinforcement in UPR biocomposites. Then, this study also can be followed by study the thermal properties of the SCB as reinforcement in UPR to study the effect of the composite that produced through the thermal analysis.

REFERENCES

Agunsoye, J. O., & Aigbodion, V. S. (2013). Bagasse filled recycled polyethylene bio-composites: Morphological and mechanical properties study. *Results in Physics*, *3*, 187-194.

Ahmed, F. M., Rahman, S. R., & Gomes, D. J. (2012). Saccharification of sugarcane bagasse by enzymatic treatment for bioethanol production. *Malays J Microbiol*, *8*, 97-103.

Anggono, J., & Sugondo, S. (2015). *alkali treatment on sugarcane bagasse to improve properties of green composites of sugarcane bagasse fibers-polypropylene* (Doctoral dissertation, John Wiley).

Al Bakri, A. M., Liyana, J., Norazian, M. N., Kamarudin, H., & Ruzaidi, C. M. (2013). Mechanical properties of polymer composites with sugarcane bagasse filler. In *Advanced Materials Research* (Vol. 740, pp. 739-744). Trans Tech Publications.

Acharya, S. K., Mishra, P., & Mehar, S. K. (2011). Effect of surface treatment on the mechanical properties of bagasse fiber reinforced polymer composite. *BioResources*, *6*(3), 3155-3165.

Balaji, A., Karthikeyan, B., & Raj, C. S. (2014). Bagasse fiber–the future biocomposite material: a review. *International Journal of ChemTech Research*, *7*(01), 2014-2015.

Deephand, K. (2005). sugarcane bagasse cogeneration- lessons from mauritis. Paper Presented to the Parlimentarian Forum on Energy Legislation and Sustainable Development, Cape Town, South Africa.

Davallo, M., Wilkinson, A.N., & Ziarati, P. (2004). *Mechanical Properties of Polyester Resin Formed by Resin Transfer Moulding (RTM)*. Iran University of Sciences and Technology.

Davallo, M., Pasdar, H., & Mohseni, M. (2010). *Mechanical Properties of Unsaturated Polyester Resin*. International Journal of Chemtech Research. Vol. 2, No. 4, Pp2113-2117.

Dholakiya, B. (2012). *Unsaturated polyester resin for specialty applications*. INTECH Open Access Publisher.

Dudgeon, C. D. (2013). *Polyester Resins*. Tim Papper and Asland Chemical Company.

Fink, D. (2006). *Optimizing Peroxide Performance For Vacuum Infusion*. Convention and Trade Show American Composites Manufacturing Association, October 18-20, St. Louis MO USA.

Ghazali, M. J., Azhari, C. H., Abdullah, S., & Omar, M. Z. (2008). Characterisation of natural fibres (sugarcane bagasse) in cement composites. In *Proceedings of the World Congress on Engineering* (Vol. 2, pp. 2-4).

Ishak, M. R., Leman, Z., Sapuan, S. M., Edeerozey, A. M. M., & Othman, I. S. (2010). Mechanical properties of kenaf bast and core fibre reinforced unsaturated polyester composites. In *IOP Conference Series: Materials Science and Engineering* (Vol. 11, No. 1, p. 012006). IOP Publishing.

Jamaludin, J. (2002*). Effect of Fibre Size Modification on The Mechanical Properties of Kenaf Fibre Reinforced Polyester Composite*. (Degree of Bachelor of Engineering (Honours) Manufacturing (Engineering Materials)), University Teknikal Malaysia Melaka.

Koli, A. (2015). *A study on thermal and acoustic characteristics of bagasse fibre reinforced epoxy composites* (Doctoral dissertation, National Institute of Technology Rourkela).

Lois-Correa, J., Flores-Vela, A., Ortega-Grimaldo, D., & Berman-Delgado, J. (2010). Experimental evaluation of sugar cane bagasse storage in bales system. *Journal of applied research and technology*, *8*(3), 365-375

Maryana, R., Ma'rifatun, D., Wheni, A. I., Satriyo, K. W., & Rizal, W. A. (2014). Alkaline pretreatment on sugarcane bagasse for bioethanol production. *Energy Procedia*, *47*, 250-254.

Mulinari, D. R., Voorwald, H. J., Cioffi, M. O. H., Da Silva, M. L. C., da Cruz, T. G., & Saron, C. (2009). Sugarcane bagasse cellulose/HDPE composites obtained by extrusion. *Composites Science and Technology*, *69*(2), 214-219.

Mertz, D., Chajes, M. J., Gillespie, J. W., Kukich, D. S., Sabol, S. A., Hawkins, N. M.,.. & Deen, T. B. (2003). NCHRP Report 503: Application of Fiber Reinforced Polymer Composites to the Highway Infrastructure. *Transportation Research Board of the National Academies, Washington, DC*.

Mishra, P. (2011). *Development and Characterization of Low Cost Composites from Sugarcane Bagasse Waste*. Degree. National Institute of Technology Rourkela.

Mohammad, N. A. (2007). *Synthesis, Characterization and Properties of the new Saturated Polyester Resins for Composites Applications*. Degree of Master of Sciences. University Sciences Malaysia.

Oladele, I. O. (2014). Effect of bagasse fibre reinforcement on the mechanical properties of polyester composites. *J. Assoc. Prof. Eng. Trinidad Tobago*, *42*(1), 12-15.

Paulo H. Fernandes Pereira., Herman Cornelis Jacobus., Voorwald., Maria Odila H. Cioffi., Daniella Regina Mulihari., Sandra M. Da Luz., & Maria Lucia Caetano Pinta Da Silva. (2011). *Sugarcane Bagasse Pulping and Bleaching : Thermal and Mechanical Characterization.*

Pankaj, T., Rav.B., Kumar. D., & Kumar. B. (2015). *Study on Mechanical Behavior of Sugarcane Bagasse Fibre Reinforced Polymer Matrix Composites*. Vol. 1, P.P 118-125.

Rasul, M. G., Rudolph, V., & Carsky, M. (1999). Physical properties of bagasse. *Fuel*, *78*(8), 905-910.

Rajasekaran, T., & Gokul, K. Evaluation of mechanical characteristics of treated and untreated sugarcane fiber composites.

Rezende, C. A., de Lima, M. A., Maziero, P., Ribeiro deAzevedo, E., Garcia, W., & Polikarpov, I. (2011). Chemical and morphological characterization of sugarcane bagasse submitted to a delignification process for enhanced enzymatic digestibility. *Biotechnology for Biofuels*, *4*(1), 1.

Richard A. Poilucci., & Assistant Professor Christopher J.Hansen, J. A. P. C. (2013). *Reducing use of Styrene Monomer in Unsaturated Polyester Resins.* Department of Mechanical Engineering University of Massachusett Lowell.

Silva, A. J. P., Lahr, F. A. R., Christoforo, A. L., & Panzera, T. H. (2012). Properties of sugar cane bagasse to use in OSB. *International Journal of Materials Engineering*, *2*(4), 50-56.

Siregar, J. P., Sapuan, S. M., Rahman, M. Z. A., & Zaman, H. M. D. K. (2010). The effect of alkali treatment on the mechanical properties of short pineapple leaf fibre (PALF) reinforced high impact polystyrene (HIPS) composites. *J. of Food, Agriculture & Environment*, *8*(2), 1103-1108.

Selvam, R. (2010). *Fabrication and testing of bagasse particle reinforced biocomposite* (Doctoral dissertation, Universiti Malaysia Sarawak, UNIMAS).

Tudu, P. (2009). *Processing and characterization of natural fiber reinforced polymer composites* (Doctoral dissertation, National Institute Of Technology Rourkela).

Tewari, M., Singh, V. K., Gope, P. C., & Chaudhary, A. K. (2012). Evaluation of mechanical properties of bagasse-glass fiber reinforced composite. *J. Mater. Environ. Sci*, *3*(1), 171-184.

Ubi, P. A., & Asipita, S. A. R. (2015). Effect of Sodium Hydroxide Treatment on the Mechanical Properties of Crushed and Uncrushed Luffa cylindrica Fibre Reinforced rLDPE Composites. *World Academy of Science, Engineering and Technology, International Journal of Chemical, Molecular, Nuclear, Materials and Metallurgical Engineering*, *9*(1), 203-208.

Vingesh, J., & Selvam, C. M. (2015). *Experimental Evaluation of Wood Dust Particulate Reinforced Polymeric Composites.* Department of Mechanical Engineering, W College of Engineering Tuticorin, Tamilnadu, India.

Wambua, P., Ivens, J., & Verpoest, I. (2003). Natural fibres: can they replace glass in fibre reinforced plastics?. *composites science and technology*, *63*(9), 1259-1264.

APPENDIX

A1 : Raw data of tensile testing

Sample		Specimens	Stress (MPa)	Strain (MPa)
Treated	100 % UPR	1	12.501	1.012
		2	13.481	0.981
		3	13.018	1.120
	10:90	1	3.927	1.107
		2	12.205	1.860
		3	13.321	2.013
	20:80	1	12.882	1.751
		2	13.591	1.753
		3	12.683	1.665
	30:70	1	6.642	1.830
		2	6.755	1.803
		3	5.950	1.517
Untreated	10:90	1	4.373	1.926
		2	10.543	1.947
		3	11.098	1.898
	20:80	1	2.418	2.120
		2	2.688	1.798
		3	2.617	1.842
	30:70	1	6.204	1.842
		2	6.883	2.160
		3	5.143	1.932

A2 : Raw data of flexural testing

Sample		Specimens	MOR (MPa)	MOE (MPa)
Treated	100 % UPR	1	10.812	284.60
		2	11.481	298.16
		3	10.021	203.76
	10:90	1	18.81	866.639
		2	17.76	839.769
		3	17.70	820.148
	20:80	1	20.450	875.482
		2	18.350	806.773
		3	20.660	856.816
	30:70	1	11.830	578.675
		2	12.140	540.422
		3	10.900	504.946
Untreated	10:90	1	17.050	599.543
		2	7.540	246.770
		3	16.970	574.016
	20:80	1	9.510	294.365
		2	11.520	407.771
		3	10.070	363.295
	30:70	1	10.580	379.651
		2	6.220	352.978
		3	12.820	562.224

A3 : Raw data of water absorption test

Sample		Specimens	Hours (h)					
			Initial	1h	2h	3h	4h	5h
Treated (%)	100 % UPR	1	7.18	7.18	7.19	7.20	7.20	7.21
		2	7.20	7.20	7.20	7.20	7.21	7.22
		3	7.19	7.19	7.19	7.19	7.20	7.21
	10:90	1	9.69	9.68	9.72	9.72	9.73	9.76
		2	9.12	9.23	9.20	9.22	9.25	9.26
		3	9.69	9.73	9.72	9.72	9.75	9.76
	20:80	1	10.33	10.50	10.50	10.54	10.56	10.58
		2	10.51	10.51	10.55	10.59	10.60	10.61
		3	10.53	10.54	10.59	10.61	10.63	10.64
	30:70	1	8.47	8.59	8.71	8.77	8.84	8.86
		2	8.43	8.53	8.65	8.70	8.74	8.77
		3	8.38	8.49	8.61	8.63	8.66	8.73
Untreated (%)	10:90	1	9.24	9.23	9.33	9.36	9.34	9.31
		2	9.01	9.12	9.24	9.27	9.28	9.31
		3	9.65	9.61	9.71	9.72	9.74	9.73
	20:80	1	9.56	9.61	9.73	9.78	9.79	9.82
		2	9.73	9.77	9.91	9.94	9.95	9.98
		3	9.92	9.94	10.07	10.12	10.13	10.17
	30:70	1	10.12	10.13	10.28	10.32	10.32	10.33
		2	10.08	10.15	10.31	10.31	10.32	10.37
		3	10.00	10.05	10.20	10.25	10.26	10.25

A4 : Raw data of thickness swelling test

Sample		Specimens	Hours (h)					
			Initial	1h	2h	3h	4h	5h
Treated (%)	100 % UPR	1	7.24	7.24	7.25	7.26	7.27	7.27
		2	7.39	7.39	7.40	7.40	7.41	7.42
		3	7.77	7.77	7.78	7.79	7.80	7.80
	10:90	1	8.57	8.61	8.62	8.62	8.62	8.67
		2	8.53	8.53	8.55	8.56	8.56	8.57
		3	8.59	8.61	8.64	8.65	8.64	8.66
	20:80	1	8.85	8.86	8.88	8.89	8.90	8.90
		2	8.85	8.88	8.90	8.93	8.92	8.91
		3	8.87	8.85	8.88	8.90	8.90	8.90
	30:70	1	9.08	9.08	9.07	9.13	9.13	9.21
		2	9.11	9.14	9.14	9.15	9.19	9.21
		3	9.10	9.09	9.12	9.14	9.15	9.17
Untreated (%)	10:90	1	8.94	8.94	8.97	8.95	8.96	8.98
		2	8.84	8.84	8.84	8.89	8.90	8.89
		3	8.84	8.84	8.85	8.87	8.88	8.88
	20:80	1	8.94	8.96	9.01	9.01	9.00	9.04
		2	8.99	9.00	9.00	9.01	9.00	9.01
		3	8.97	8.99	9.01	9.00	9.10	9.02
	30:70	1	9.35	9.40	9.40	9.41	9.39	9.42
		2	9.48	9.48	9.54	9.56	9.58	9.60
		3	9.33	9.39	9.38	9.43	9.46	9.46

A5 : Raw data of density test

Sample		Specimens	In air	In liquid	Result
Treated (%)	100 % UPR	1	2.01	0.06	-1.03
		2	2.32	0.05	1.02
		3	2.02	0.05	1.03
	10:90	1	1.92	0.07	1.04
		2	1.75	0.05	1.03
		3	1.94	0.07	1.03
	20:80	1	1.49	0.15	1.11
		2	1.93	0.20	1.11
		3	1.84	0.18	1.10
	30:70	1	1.51	-0.08	0.95
		2	1.25	-0.20	0.86
		3	1.82	-0.10	0.94
Untreated (%)	10:90	1	1.34	-0.75	0.64
		2	1.53	-1.12	0.58
		3	1.79	0.02	1.01
	20:80	1	2.00	0.20	1.12
		2	2.16	0.08	1.04
		3	1.63	0.04	1.02
	30:70	1	2.45	0.15	1.06
		2	2.16	0.01	1.00
		3	2.33	0.19	1.08