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**COCONUT COIR AS A REINFORCEMENT IN
POLYESTER BIOCOMPOSITE**

by

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A report submitted in partial fulfilment of the requirements for the degree of
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DECLARATION

I declare that this thesis “Coconut Coir as a Reinforcement in Polyester Biocomposite” 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

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COCONUT COIR AS AN REINFORCEMENT IN POLYESTER COMPOSITE

ABSTRACT

The purpose of this research is to study the mechanical and physical properties of coconut coir reinforced with polyester matrix composite by differencing their percentage of fibre loading and their coir fibre condition. The characterization of mechanical properties for the composition samples was determined by using tensile test machine and bending test machine. Compression moulding was used to produce the composites which consists of seven sample of composites with different fibre loading along with different fibre conditions which are treated coir and untreated coir for fibre loading of 10%, 20% and 30%. Water absorption test such as water uptake and thickness swelling were carried out by immersing the specimens in the water for 24 hours at room condition and the specimens also been put into oven for 24 hours at 105⁰C to determine their moisture content. The density of composites was also calculated by using density of coir fibre and polyester resins which are 1.20 gcm⁻³ and 1.09 gcm⁻³. Overall, the study shows that treated coir fibre composites resulted in higher mechanical properties as increased fibre loading until they reached their maximum point compared to untreated coir fibre composite, this is due to interface bonding , adhesion, voids, arrangement between reinforced fibre an matrix resins. Meanwhile the water absorption and thickness swelling of coir fibre composites increased with higher fibre loading and untreated coir fibre composites shows higher results compared to treated coir fibre composite. This results also same as in moisture content. As more fibre content was added into the composite, more hydrophilic side mode available for water absorption of water which can lead to moisture build-up of water content in the fibre cell that resulting in fibre swelling.

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SABUT KELAPA SEBAGAI PENGUKUHAN DALAM POLIESTER KOMPOSIT

ABSTRAK

Tujuan kajian ini adalah untuk mengkaji sifat mekanikal dan fizikal kompositsabut kelapa yang diperkukuhkan dengan poliester matrik dengan perbezaan peratusan sabut kelapa serta keadaan serat sabut kelapa. Pencirian ciri-ciri fizikal sampel diuji menggunakan mesin ujian tegangan dan mesin lenturan. Mesin mampatan digunakan untuk menghasilkan tujuh komposit yang berbeza peratusan sabut kelapa serta berbeza keadaan serat sabut kelapa yang mana terdiri daripada sabut kelapa yang dirawat dan tidak dirawat untuk peratusan sabut kelapa 10%, 20% dan 30%. Ujian penyerapan air seperti pengambilan air dan pembengkakan ketebalan telah dijalankan dengan merendamkan specimen di dalam air selama 24 jam dalam keadaan bilik dan specimen juga dimasukkan ke dalam ketuhar selama 24 jam pada suhu 105°C untuk menentukan kandungan kelembapan. Ketumpatan komposit juga dikira dengan menggunakan ketumpatan serat sabut kelapa dan poliester yang mempunyai ketumpatan 1.20 gcm^{-3} dan 1.09 gcm^{-3} . Secara keseluruhan, kajian ini menunjukkan bahawa komposit sabut kelapa yang dirawat mempunyai sifat-sifat mekanikal yang lebih tinggi apabila peratusan serat meningkat hingga mencapai tahap maksimum berbanding komposit sabut kelapa yang tidak dirawat. Ini adalah disebabkan oleh ikatan antara permukaan, lekatan, lompong, susunan antara fiber dan matriks. Sementara itu, penyerapan air dan pembengkakan ketebalan komposit sabut meningkat dengan muatan sabut yang lebih tinggi. Sabut kelapa yang tidak dirawat menunjukkan keputusan lebih tinggi berbanding composite sabut kelapa yang dirawat. Ini juga sama seperti dalam kandungan kelembapan. Semakin tinggi peratusan sabut kelapa, semakin meningkat mod hidrifilik untuk penyerapan air yang mana kandungan air tersebut akan membawa kepada pembentukan kelembapan kandungan air didalam sel fiber yang menyebabkan pembengkakkan fiber.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

For the past ten years, plastics, composite and ceramics has been dominant in engineering materials. The modern areas of applications for composite materials has been growing rapidly and be found in new markets. There have been significant developments on composite due to the booming of the aviation industry in the mid-20th century. This is because several industry applications require properties that are not found in neat materials. Therefore, composite materials can be feasible to meet industrial requirement presenting useful mechanical properties through system synergy (Maya J John and Sabu Thomas, 2012).

A composite material is made by combining two or more materials to give a unique combination of properties that results in better properties than those of the individual components used alone. According to the American Society for Testing and Materials (ASTM), composite materials are the combination of two or more different materials to form a new and useful engineering materials, differing from the neat materials that originated them (Maya J John and Sabu Thomas, 2012).

Composite materials can be produce by combining metals, ceramics or polymers and most composites have been better mechanical behavior than these phases or even new properties that emerged from their combination.

The interest in using fibre such as different wood and plants fibre as reinforcement in plastics has increasing during past years as possible replacement of glass fibres as reinforcement in structural applications. Through researches, natural fibres have proven to be a competitor for glass fibre in terms of strength performance, cost and sustainability. The advantage of natural fibres as reinforcements in polymer composites compared to synthetic fibres include low cost, low density, unlimited and sustainability and low abrasive wear of processing machinery (Mulinari et al., 2011).

The surfaces of natural fibres are rough, uneven and provide good adhesion to the matrix in a composite structure (Maya J John and Sabu Thomas, 2012). Surface fibres form protective layers on stems, leaves, fruits and seeds of plants such as coconut, acai and cotton. Additionally, natural fibres are renewable raw materials and have high relatively strength and stiffness and the low density allows producing composite that have good mechanical properties (M.Sakthivei and S.Ramesh, 2013).

A natural fibres has a length that is much greater than its diameter. The length-to-diameter ratio is known as the aspect ratios, whereas discontinuous fibres have low aspect ratios. Fibre composite normally have a preferred and specific orientation, while discontinuous fibres generally have a random orientation (Majid Ali, 2010).

Polymer has existed in natural form since life began and is widely used as matrices for fibre reinforced composite and as structural adhesives (J. Sahari and S.M. Sapuan, 2011). Polymer is a substance composed of molecules which have long sequences of one or more species of atoms or groups of atoms linked to each other (Robert J.Young and Peter A.Lovell, 2011). As known, polymer is used to be as matrix in biocomposite and the first type of synthetic polymer composite developed were formaldehyde-based resins filled with mineral particles or sawdust. The resins now mostly commonly used as a matrix materials in fibres-reinforced composite (Robert J.Young and Peter A.Lovell, 2011).

Polyester is a polymer that have been more attended at academic and industrial field as it is a thermoplastics that only based on economic interest (Mohd Hafiz Zamri et al., 2016).

Concerning polyester as the matrix in composite making because polyester incorporates very cheap resin, is easily available, has good mechanical properties and has been used in many applications such as transport, maritime, and sport. The combination of polyester and natural fibre such as coir as reinforcement in composite will cater the demand for environmentally friendly materials (Tamer Hamouda et al., 2015).

1.2 Problem Statement

Nowadays, there is an increasing environmental consciousness and awareness of the need for sustainable development, which has raised interest in using natural fibres as reinforcement in polymer composites to replace synthetic fibers. Although glass and other synthetic fibre-reinforced plastics possess high specific strength, their field of application are very limited because of their inherent higher cost of production. An attempt has been made to utilize the coir, as natural fibre. The advantage of natural fibres include low cost, low density, unlimited and sustainable availability, low abrasive wear of processing machinery and this fibre can be found abundantly as waste material (Mulinary et al., 2011).

In industry and domestic generate huge biomass waste of coconut coir as they discarded coconut husk after selling coconut water and resulted the husk as inexpensive and prospective substrate to be used for biofuel production due to presence of high content of cellulose and hemicellulose in it (Shuaib M.Laghari, 2015).

However, the natural fibres have a lot of drawback in several aspects thus they are not able to fulfill the need of demand in its applications. Natural fibre have hydrophilic properties, it show lack of compability with the hydrophobic polymers. The load are not enough transferred between reinforcement and matrix. The fibre-matrix interfacial adhesion is the main problem in natural fibre reinforced polymer. This problem is handled by conducting pre-treatment on fibres to improve the interfacial adhesion. Many methods were used to enhance the adhesion between fibre and matrix in natural fibre composite in chemical method by varying time of treatment and concentration (Vinay V, 2013). Thus to

improve compability between matrix and fibres and reduce water absorption, alkaline treatment with sodium hydroxide (NaOH) with fixed time of treatment and concentration will be used as to produce better modification of properties on coir fibre composite.

Fibre loading definitely effect the mechanical and physical properties of the coir fibre polyester composite as increasing fibre loading, decreasing mechanical properties of the composite (P.N.E Navin and M Yassaswi, 2013). Thus this study is to determine the optimum point of fibre loading for the coir fibre composite with different condition of coir fibre.

1.3 Research Objective

The objectives on carrying this study research are stated below:

- 1) To determine the effect of utilizing 10 wt%, 20 wt% and 30 wt% coconut coir composition as reinforcement in polyester biocomposite.
- 2) To determine the effect of fibre pre-treatment using alkaline treatment on the coconut coir reinforced in polyester biocomposites.

1.4 Significant of Study

This study research is to determine the effect of fibre treatment by using alkaline treatment on coconut coir fibre that act as reinforcement in polyester biocomposites. Besides determining the effects of fibre treatment on coir fibre of polyester composites, the effect of utilizing different fibres loading also will be study. Hence from these utilizing, this study will come out with possible outcomes properties of biocomposite when using coconut coir fibres as reinforcement with polyester resins as the matrix of composites.

CHAPTER 2

LITERATURE REVIEW

2.1 Natural Fibre

Natural fibres are derived from a renewable resource and do not have a large energy requirement to process and are biodegradable. Fibres are a class of hair-like material that are continuous filament in discrete elongated piece that similar to pieces of thread (D.Chandramohan and K.Marimuthu, 2011). Natural fibres or known as biofibres are the fibrous material derived from minerals, plants, or animal sources. The plants which produced natural fibres are classified as primary and secondary depending on their utilization. Plants are grown for their content are called primary plants such as kenaf, jute, sisal, henp, and cotton. Meanwhile, secondary plant are those where fibres are by product from some other primary utilization such as pineapple, oil palm, rice straw, coconut and coir (Omar Faruk et al., 2012).

Natural fibres are categorized into vegetable fibres that generally comprised mainly of cellulose, animal fibres that generally comprised of protein and minerals fibres that are naturally occurring fibre or slightly modified fibre procured from minerals (D.Chandramohan and K.Marimuthu, 2011). There are basically six types of natural fibres which are bast fibre, leaf fibre, seed fibre, core fibre, grass and reed fibre and all other types such as woods and roots (Omar Faruk et al., 2012).

2.1.1 Natural Fibre Chemical Composition

The chemical composition of the natural fibre varies depending upon the types of fibres. Natural fibre such as jute, kenaf, hemp, sisal, coir, abaca and pineapple leaf have chemical composition for each of these components varies for different fibres. The fibres are basically a rigid, crystalline cellulose microfibril-reinforced amorphous lignin or with hemicellulosic matrix (Bledzki et al., 1999). Generally, the fibres contain 60% - 80% cellulose, 5% - 20% lignin, and up to 20% moisture content (D.Nabi Saheb and J.P.JOG, 1999).

2.1.2 Natural Fibre Microstructure

Plants fibres are a composite material designed by nature. Biofibre themselves are cellulose fibre reinforced that consists of microfibrils in an amorphous matrix of lignin and hemicellulose. The biofibres microstructure consists of several fibrils that run all along the length of the fibres. The hydrogen bonds and other linkages provide the necessary strength and stiffness to the fibres (D.Nabi Saheb and J.P.Jog, 1999).

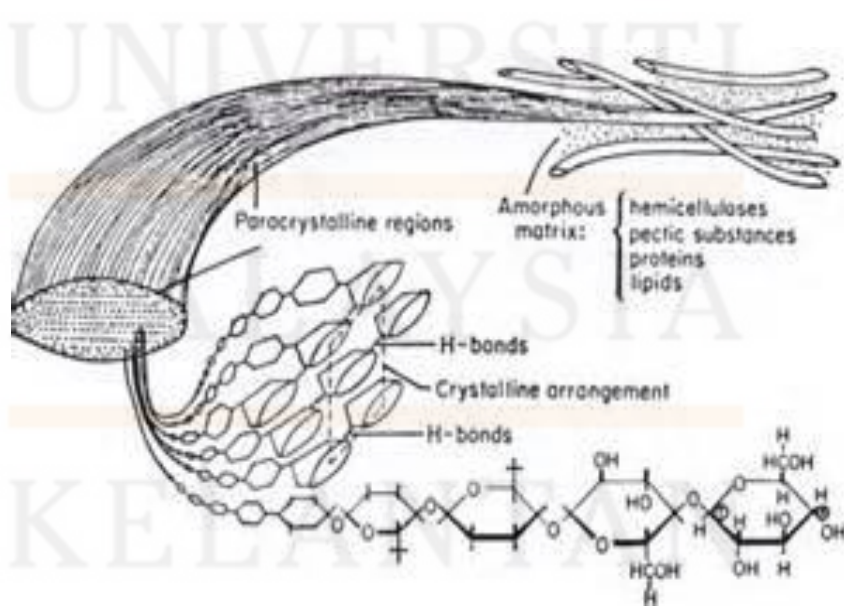


Figure 2.1 : Microfibrils in Fibre.

2.2 Coconut Coir Fibre

2.2.1 Coir Origin



Figure 2.2 : Coconut Tree, Coconut Fibres (Majid Ali,2010).

The scientific name for coconut tree of coconut coir fibre is *Cocos Nucifera* and *Arecaceae* (palm). Coconut coir fibres are obtained from outer shell of a coconut. The coir from coconut is used as reinforcement in the composite materials. It is natural abundantly fibres that mostly can be obtain from tropical region and throughout the world (Majid Ali, 2010). Coir is a natural filler of the coconut husk where it is a thick and coarse but durable fibre (I.Z.Bujang et al., 2007). Technically, coir is fibrous material found between hard internal shell and the outer coat of a coconut fruit. Coir natural fibre extracted from the husk and outer shell of the fruit of the coconut palm (Maya J John and Sabu Thomas, 2012).

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Coir exists in two types which are brown coir and white coir. Brown fibres are extracted from matured coconut that are thick, strong and have high abrasion resistance. White fibres extracted from immature coconut that are smoother and finer but also weaker (Majid Ali, 2010). To obtain coconut coir, the fruit are dehusked on a spike and after retting, the fibres are extracted from the husk by beating and washing (Maya J John and Sabu Thomas, 2012).

As we know, coir is a natural fibre extracted as fibre bundles from the husk surrounding the seed of a coconut and the seed is separated from the husk for extraction of the oil-rich kernel for various food production (Chitrangani Jayasekara and Nalinie Amarasinghe, 2010). Coir fibres are formed by encrustation of cellulose chain of lignin, which gives strength to the fibre that make it stiff and usually use for production of flor mats, doormats, brushes and mattress (Shuaib M.Laghari et al, 2015).

2.2.2 Coir World Production

Total world coir fibre production is 530,000 tonnes which is 250,000 long tons and 280,000 short tons. Coir fibres make up about a third of the coconut pulp. The rest called peat, pith or dust is biodegradable but takes 20 years to decompose. According to official website of International Year for Natural Fibres 2009, approximately 500,000 tons of coconut fibres are produced annually (Majid Ali, 2010).

Out from 250,000 tonnes, 80% of the fibre is contributed by the coastal region of Asia (Eldho Abraham et al., 2012). Originally, coir extraction was a domestic industry that perhaps originated centuries ago as it started famous in east coast of South India and the north-western coastal belt of Sri Lanka. In the last three decades, the application of coir has expanded tremendously (Chitrangani Jayasekara and Nalinie Amarasinghe, 2010).

2.2.3 Coir Dimension

The diameter of coconut fibres is approximately same and magnitudes of tensile strength are quite different. The density of coconut fibres is $0.67 - 1.0 \text{ g/cm}^3$ (Toledo et al., 2005). Coir fibre obtained from coconut husk is one of the major underutilized raw materials which is composed of cellulose nanofiber which constitutes 32 – 43% of its dry weight (Eldho Abraham et al., 2012).

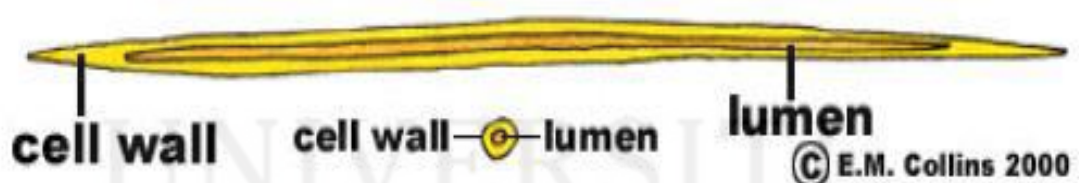


Figure 2.3: Longitudinal and Cross-Section of a Fibre Cell (E.M.Collins,2000)

Coir fibre possessing the highest elongation at break among typically natural fibres which is also capable of taking strain 4-6 times more than other fibres (Libo Yan et al., 2016). A single coir fibre has a mean width of 0.02 mm and a mean length of 2.5 mm, and these short fibres exist as aggregated fibre bundle (Chitrangani Jayasekara and Nalinie Amarasinghe, 2010).

Coconut coir fibres are composed of cellulose, lignin, pectin, hemicellulose and ash (Akbarningrum Fatmawati et al., 2012). Coir is mainly multicellular fibre which contains 30 – 300 or more cells in its cross section. Cells in coir are the crystalline cellulose arranged helically in a matrix consisting of a noncrystalline cellulose-lignin complex (Libo Yan et al., 2016).

2.2.4 Coir Properties

The coconut coir fibres consists of water, fibres and small amount of soluble solid. The high lignin in coir fibres make it more durable compared to other natural fibres (D. Verma et al., 2013). The general advantage of using coconut coir are the coir are moth-proof, resistant to fungi and rot, provide excellent insulation against temperature and sound, not easily combustible, flame-retardant, unaffected by moisture and dampness, tough and durable, resilient, springs back to shape even after constant use, totally static free and easy to clean (Majid Ali, 2010).

As a fibre, coir has high aspect ratio and high strength-to-mass ratio, is low in energy conversion and has good insulation properties and some of the advantages of coir fibre are that it is non-abrasive, stiff, resilient, hydroscopic, viscoelastic, biodegradable, compostable and combustible, and a natural product amenable to chemical changes (Chitrangani Jayasekara and Nalinie Amarasinghe, 2010). Coir occupies a prominent position owing to its qualities such as resilience, extensibility, fungi and rot resistance, moth-proof, excellent insulation against temperature and sound, which enhance its commercial and industrial application (Libo Yan et al., 2016). The fibres are strong, light and can easily withstand heat and salt water (Maya J John and Sabu Thomas, 2012).

2.2.5 Coir Fibre Treatment

The composition of fibre such as cellulose, hemi-cellulose and ligning affect the different properties of coconut fibres. The pre-treatment of fibres changes the composition and ultimately changes not only its properties but also the properties of composites. Sometimes it improves the behavior of fibres but sometimes its effects is not favourable (Majid Ali, 2010). Pre-treatment method can be classified into physical, chemical, and biological types. Physical treatment for using mechanical action, to disrupt cell wall components of the lignocellulosic biomass.

Chemical pretreatment involves using chemical to dissolve the lignins, celluloses, and hemicellulose found. Biological pretreatment uses microorganisms for the disruption of lignin and hemicelluloses. However, this method is not very effective as the degradation process is very slow compared to other methods (Shuaib M.Laghari et al., 2015). Thus, fibres treatment is carry out using chemical modification. (Majid Ali, 2010)

The chemical treatment is used to improve and enhance the adhesion between the polymer matrix and surface of the fibres and their strength. This treatment also reduce the amount of water in fibres as by reducing the water capacity and it is also helps to increase the mechanical properties. Alkaline treatment is used in this chemical modification of coir fibres (N.Anupama Sai Priya et al., 2014).

2.2.6 Coir Applications

Recent advance in material science through research in European and in the Philippines have highly technical and sophisticated application of coir as coir composites, fibreboards, coir-based building materials, insulation products and others. The easy extraction method of producing coconut coir fibre, modern machinery were introduced over recent decades and new and more versatile application of coir as a result of technological advance have been the main milestones enabling the natural fibre, especially coir fibre industry to progress from its humble beginnings (Chitrangani Jayasekara and Nalinie Amarasinghe, 2010).

Moreover, the achievement of coir fibre extraction and applications paved the way for the coir industry to expand tremendously in the past 25 years and to maintain its position in the global market of hard fibre trade (Chitrangani Jayasekara and Nalinie Amarasinghe, 2010). Because of its biodegradable character, coir fibers were selected nowadays to fabricate composites to substitute wood and other materials (Huang Gu, 2009).

2.3 Polyester

2.3.1 Polyester Origin

Polyester is a synthetic polymer which has been a popular thermoset used as the polymer matrix in composites. The family of polyester comprises all polymers with ester functional groups in the polymer backbone. The chemistry of the structural units connecting the ester groups can be varied over an immensely broad range, making the polyesters a diverse group covering everything from labile biomedical matrices to liquid crystal, fibres and temperature resistant performance materials. Polyesters were historically the first family of synthetic condensation polymers (Maryam Salleh Mohammadnia et al., 2012).

Polyester is attractive in different ways. This material is being used efficiently as folding resin, blend forming, film, fiber, surface covering, rubber and plasticizer. The common factor in these different materials is that all of them contain some joint in their main chain (Hossein Mighani, 2012). Polyester is a manufacture fiber in which the fiber-forming substance in any long-chain, synthetic polymer composed of at least 85% of an ester of a substituted aromatic carboxylic acid. This can include but is not restricted to substituted terephthalic units and parasubstituted hydroxy-benzoate units (Florence Smith et al., 2012).

Polyester was commercialized in the 1950s transforming the wash and wear novelty into a revolution in textile product performance. As polyester garments emerged from the dryer wrinkle-free, consumers increasingly bought more garments made from polyester (Florence Smith et.al, 2012).

Polyester are condensation polymers with ester or carboxylate repeating units in the main chain. The first major commercial polyester were PET discovered by Whinfield and Dickson and polyadipates (for polyurethane resins). Commercial polyester resins are classified as general purpose orthophthalic, isophthalic resins and dicylopentadiene. This polyester are generally produced via four main process which are fusion process, azeotropic solvent process, inert as transport process and vacuum process (Jaylin Mitch Simpson, 2010).

In other hand, polyester can be cured by using styrene. Polyester can be crosslinked with styrene via suspension polymerization resulting in a dispersion of micro-particles or beads in water. Depending on the production process, these particles may contain single or multiple air voids or vesicles which are used as organic opacifying particles. These particles can be used as a partial replacement for pigments, extenders and additives in surface coatings. Suspension polymerization theory and the production of the vesiculated micro particles (Johnson et al., 2003). The crosslinking normally takes place at room temperature with a combination of catalyst or initiator usually methyl- ethyl ketone peroxide (MEKP) and accelerator, usually cobalt naphthenate (4% solution in styrene) (Amoco Chemical Co,1989).

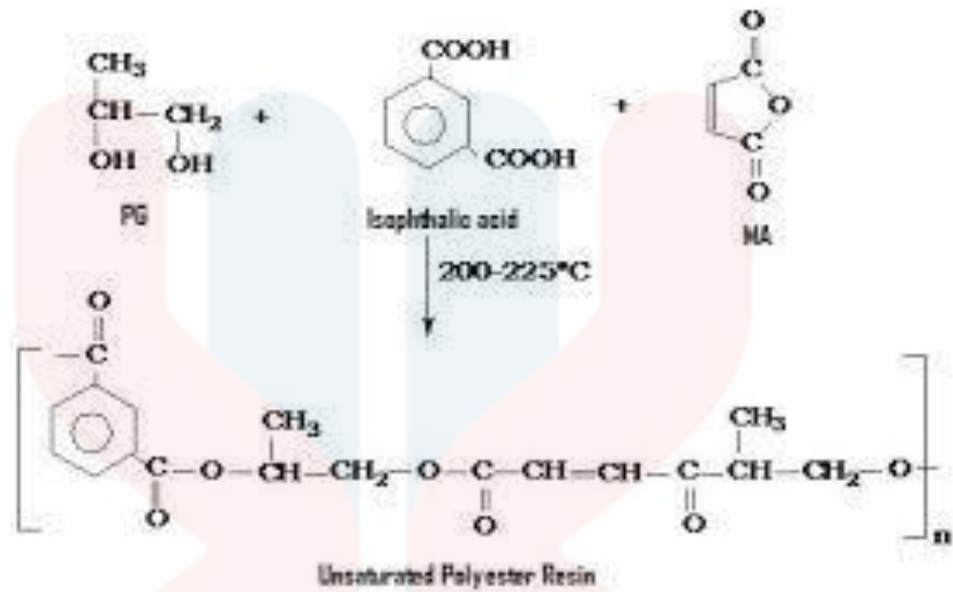


Figure 2.4: Curing Mechanisms of Polyester

Figure above shows the curing mechanisms for polyester. Polyester contains double bonds (ethylenic group) along the polymer chain. Because of these double bonds, they are classified as vinyl types. Polyester are cured by cross-linking the long linear chains by vinyl monomers such as styrene. The formation contains polyester resins dissolved in vinyl monomer which is cross linked and cured in catalyst.

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2.3.2 Polyester Structure and Dimension

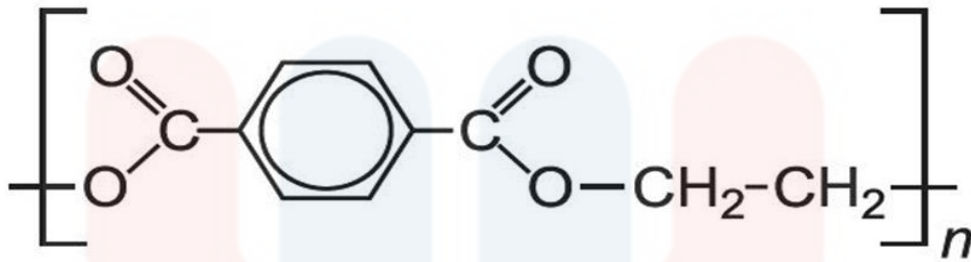


Figure 2.5: Chemical Structure of Polyester

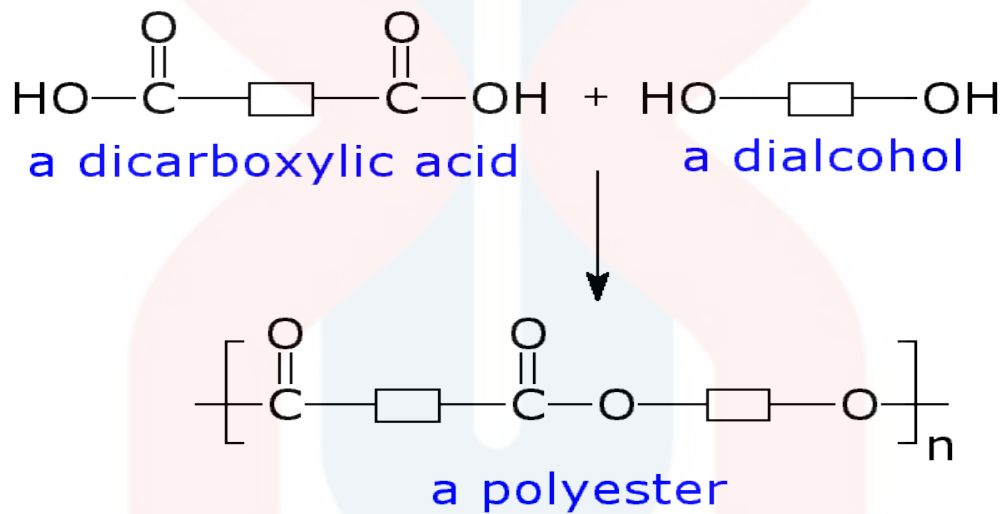


Figure 2.6: Polyesterification of Polyester

Polyester are defined as polymers containing at least one ester linking group per repeating unit. They can be obtained by a wide range reactions, the most important being polyesterifications between dibasic acids and diols or their derivatives (Hossein Minghani,2012). Polyester is also a long- chain polymer which chemically composed of an ester, a dihydric alcohol and a terephthalic acid, formed by the esterification condensation of polyfunctional alcohols and acids (Sudirman et al., 2012).

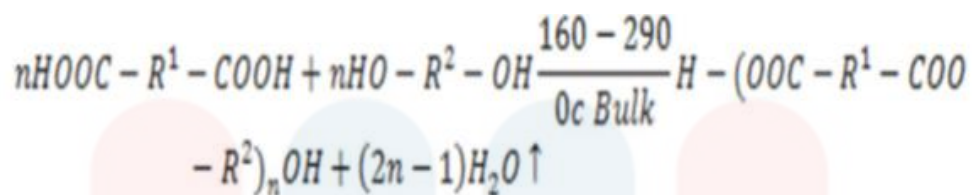


Figure 2.7: Synthesis Formula of Polyester

The nature aliphatic or aromatic of the bivalent- R^1 and R^2 radicals in polyester chains exerts a profound influence on the properties of polyesters and define four main classes of linear polyesters. Alipatic polyesters are low melting (40 - 80°C) semicrystalline polymers or viscous fluids and present inferior mechanical properties. Notable exceptions are poly (alpha-hydroxyacids) and poly (beta-hydroxyacids). Meanwhile, aromatic-aliphatic polyesters, in which R^1 or R^2 is aromatic, are generally high melting (150-270°C) semicrystalline materials that find applications as engineering thermoplastics, films or fibres. Wholly aromatic polyesters in which both R^1 and R^2 are aromatic, are either high Tg amorphous polymers or very high melting semicrystalline polymers that often exhibit liquid crystalline properties. Polyester thermoplastics elastomers which are obtain by replacing a part of ther R^2 diol by dihydroxy polyether macro monomer, present biphasic morphology and rubberlike properties (Roger, 2003).

There are different methods for preparing a thermally stable polyester such as flame retardant polyester, polyester with alkyl group in the addition chain, polyester with quinoxaline ring in the main chain, polyester-imide, unsaturated polyester, aromatic polyester-imide, polyester with sulfur in the main chain, polyester with aryl-ether group aromatic fluoro polyester and aliphatic polyester with high molecular weight (Hossein Mighani, 2012).

2.3.3 Properties of Polyester

Plastics are utilized in almost every industry ranging from automobile to food and medicine and have acquired significance since 1940s due to their properties. The materials have molecular weight ranging from 50-10 kDa, can be chemically modified to various strength and shapes, and resistant to environmental stress (Madison and Huisman, 1999).

Polyester are a class of polymer that can be formulate to be hard or soft, brittle or flexible depending on the structure and can therefore be used in various applications. Unsaturated polyester resins (USP) are widely used as a matrix because of relatively low price than other resins, ease of handling and possess a good balance of mechanical, electrical and chemical properties. Polyester are hydrophilic and become hydrophobic when it reinforced with fibres (Florence Smith et al., 2012).

Polyester fibers are composed of hydrocarbon made of esters and terephthalic acids. A common polyester compound is polyethylene terephthalate, although polyethylene naphthalate withstands more heat and is often used in glass jars. Most polyester fiber can withstand weak mineral acids, but can usually be damaged by bases. It has a bright appearance and resists fading and shrinkage, making it useful for colorful clothing, microfibre and silks. Because polyester is strong, it is often used to make shatterproof plastics.

Polyester is durable, and it stretches making it hard to tear, it does not shrink or crease easily. On the other hand, the material tends to be shiny. Polyester is often referred to as fibreglass which is technically accurate. Polyester offers ease of handling, low cost, dimensional stability, as well as good mechanical, chemical resistance and electrical properties. Polyester are the least expensive of the resin options, providing the most economical way to incorporate resin, filler and reinforcement. Polyester are thermoset polymer (Ugochukwu Chuka Okonkwo et al., 2015).

Thermosetting plastic system generally consists of liquid mixtures of relatively low molar mass reactants, such as monomers and or prepolymers, which polymerise upon heating to form highly-crosslinked, network polymers (M.Davallo et al., 2010). Polyester include naturally occurring chemical, such as in the cutin of plant cuticles as well as synthetics through step-growth polymerization such as polybutyrate. Natural polyesters and a few synthetic ones are biodegradable but most synthetic polyesters are not (Rosato et al., 2004).

Polyester resins without reinforcement are relatively brittle polymers and the fracture toughness, K_{Ic} and fracture energy, G_{Ic} obtained for the polyester resins lie between the typical values of K_{Ic} and G_{Ic} reported for epoxy resins and polystyrene (M.Davallo et al., 2010).

Polyester do however have poor adhesion, high cure shrinkage and inhibition of the curing reaction by air and certain fillers, as well as poor resistance to hydrolysis by water. Polyester as thermoplastics may change shape after the application of heat. While combustible at high temperatures, polyesters tend to shrink away from flames and self-extinguish upon ignition. Polyester has high tenacity and E-modulus as well as low water absorption and minimal shrinkage in comparison with other industrial fibers (Rosato et al., 2004).

2.3.4 The Applications of Polyester

The current increase in the utilization of polyester in marine and transportation industries that widely used as reinforced plastics.. Various application can be used due to it properties and these applications include fibres, coatings, plasticizers, adhesives, polyurethane based resins, films, laminates, industrial construction, insulation, molding compounds and many mores.

Due to the properties of polyester stated above, rigid and flexible plastics that polyester have make it suitable not just for the most assessed medical applications but also considered for application including packaging, moulded goods, paper coating, non-woven fabrics, adhesives, films and performance additives (Mohd Hafiz Zamri et al., 2015).

Despite the fact that polyester is extremely hydrophobic means it has low moisture regain, it has a bright future, particularly in the fashion industry, as consumers increasingly are attracted by its easy care properties. Thus, polyester is a growing fibre for textile applications, particularly in the fashion industry (Florence Smith et.al, 2012).

2.3.5 Current Research of Polyester

Current research regarding to this polyester is related in reinforced using fibres and mostly in nanoparticle or nanocomposite materials. Polyester using unsaturated polyester resin (UPR) reinforced using nano-sized silica particle is being developed recently. This unsaturated resin (UPR) and silica nanocomposite prepared by mechanical process is the one of the promising composite materials (Sudirman et al., 2012).

Recently biodegradable polyester elastomers have been of interest for pharmaceutical and medical applications because of their biocompatibility, mechanical and chemical properties.

Two types of biodegradable elastomers include thermosets and thermoplastics. The crystallized hard regions which can be found in thermoplastics elastomers slow their biodegradation and often cause a nonlinear loss of mechanical properties during degradation process (Sylwia Dworakowska et al., 2011).

2.4 Composite Materials

Composite can be defined as materials consisting of two or more physically distinct phases, suitably arranged or distributed. The continuous phases are referred to as the matrix, while the distributed phases are called the fillers or reinforcement. Three things can determine the characteristics of a composite which are types of matrix, types of fillers and the interface between them. Composite are materials that comprises of strong load carrying materials known as reinforcement embedded in weaker material known as matrix. This reinforcement provides strength and rigidity, helping to support structural load meanwhile the polymer matrices maintain the fibres alignment such as position and orientation and protect them against the environment and damage (Begum and Islam, 2013).

There are many types of composite materials and several methods of classifying them. One method is based on the matrix materials which include polymers, metals and ceramics. The other method is based on the reinforcement phase which has the shape of fibre, particulate and whiskers. Whiskers are like fibres but their length is shorter. The most popular type of composite material is the fibre-reinforced polyester composites, in which continuous thin fibres of one material such as natural fibre are embedded in a polyester matrix.

Fillers are utilized to enhance the mechanical and physical properties of the composite and to make the final product more economical. Fillers are capable of improving the fibre reinforced polymer strength and toughness, thus enhancing fatigue, shrinkage, creep and also the chemical resistance of the matrixes. Fillers of natural fibres, ceramics and alloys are used with main reinforcing material (Arpitha et al., 2014).

2.4.1 Properties of Composite

Composite materials properties are found such as it does not yield, very fatigue resistant, composite materials are subject to humidity, sensitive to the common chemical use, have medium to low level impact resistance which is inferior to that of metallic materials, have excellent fire resistance and mostly composite materials do not corrode (Daniel et al., 2013).

CHAPTER 3

MATERIALS AND METHOD

3.1 Materials

The raw materials that been used in this study are polyester resins that been purchase from Multifilla (M) Sdn. Bhd, Selangor and coir fibre that been collected around Rantau Panjang, Kelantan.

3.2 Method

3.2.1 Fibre Preparation of Coconut Coir

The coir fibre are soak in water for 30 minutes and been filtrated to remove unwanted materials such as sand, soil and woody tissues. The fibre had been put into oven at 105⁰C for drying about 24 hours. The fibre were taken out for further composite preparation process.

3.2.2 Chemical Treatment of Coconut Coir Fibre

The alkaline treatment been done to treated the coconut coir using sodium hydroxide (NaOH) to reduce lignin content and to disruct cell wall components of the lignocellulosic biomass. In the pre-treatment, 4 g of 1000 ml sodium hydroxide (NaOH) are added into 20 g of coir fibres and been heated at 80⁰C for 20 minutes with constant stirring. Coir fibre were then left cooled after 20 minutes heating. The coir fibres were then neutralized using water bath and dried in the oven at 80⁰C for 24 hours.

3.2.3 Composite Preparation

Composite were prepared by varied the fibres weight content from 10% to 30% and fibres condition which are treated fibres and untreated fibres. In this research, polyester resins with density of 1.09 g/cm^3 was used. The first step in composite preparation is by putting the coir fibres that been weighed into the mould and been pressed by the compression moulding for an hours to make the coir fibres fit into the moulding. After an hour of compression, the coir is been taken out from the moulding.

The moulding was then coated with mould release reagent and left dried for 10 second before laying the dried coir fibre that been compact by compression moulding into the mould. The polyester with catalyst is then poured into the moulding that has coir fibre layer by layer until all the polyester with catalyst spread well with coir fibre in the mould. The moulding is then been put into the compressing molding for curing and further pressed for 24 hours. When the composite fully cured it will removed from the mould.

3.2.4 Mould Dimension and Composite Composition

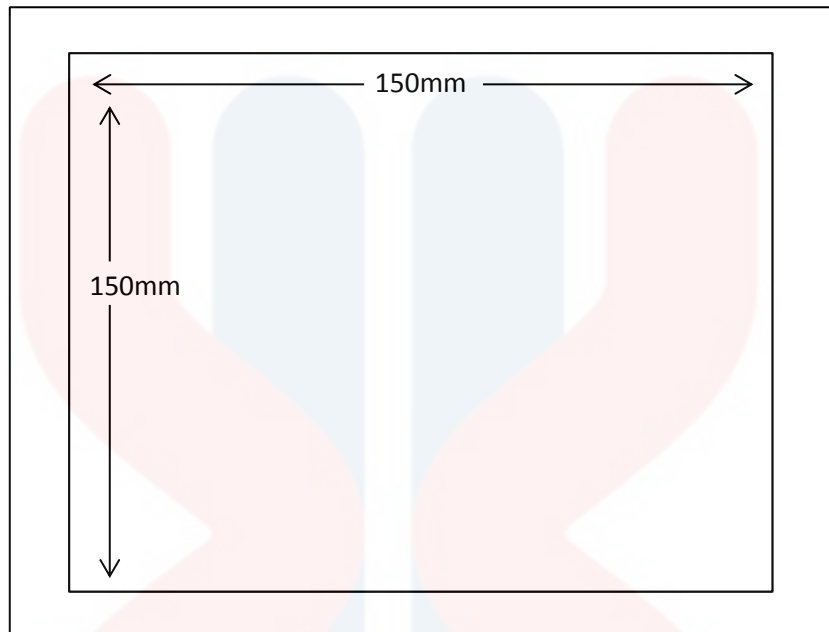


Figure 3.1 : Mould Dimension with Thickness of 1mm

Table 3.1: Composite Weight Fraction

Fibres Condition	Polyester Content (%)	Coir Fibres Content (%)
	100	-
Treated	90	10
	80	20
	70	30
Untreated	90	10
	80	20
	70	30

3.2.5 Analysis

3.2.5.1 Mechanical Analysis of Sample

Mechanical analysis is also used to investigate the behavior of the composites. The dimension for this sample is 150 mm x 25 mm for flexural test and 15 mm x 75 mm for tensile test. Tensile test and flexural test is test base on American Standard Testing Method (ASTM). The ASTM that been used are D4476 and D3039. Tensile test is the most common mechanical testing for determining the physical properties of materials such as strength, ductility, toughness, elastic modulus and strain hardening. The test consists of applying a constant of applying a constant strain on the fibres with load 5 Kn. Universal testing machine was used with strain speed of 1mm/min.

The distance between clips was defined of 10mm.flexural analysis were carried out at room temperature through three-point bend testing using universal testing machine (Testometric Rochdate, England). The speed of the crosshead was 1mm/min. The test is done until failure occurred.

3.2.5.2 Percentage of Thickness Swelling

The thickness swelling of composite sample will be measured using Vernier caliper and the sample will be cut into 20mm x 20mm x 10mm in size according to the ASTM D570. The thickness of the sample before and after soaking in the distilled water will be measured as W_0 and W_1 .

Respectively, the calculation of percentage of thickness swelling is given in eq 3.1:

$$\text{Percentage of thickness swelling (\%)} = \frac{W_0 - W_1}{W_0} \times 100\% \quad \text{e.q 3.1}$$

Where W_0 is the initial thickness of sample before immersion in distilled water and W_1 is the thickness of sample after immersion in distilled water (mm).

3.2.5.3 Percentage of Water Absorption

The percentage of water absorption will be measured after soaking the sample in distilled water for a day. The composite sample will be cut into dimension of 20mm x 20mm x 10mm in size according to ASTM D570. Then the sample will be weighed. Respectively, the calculation of percentage of water absorption is given in eq 3.2:

$$\text{Percentage of water absorption (\%)} = \frac{W_0 - W_1}{W_0} \times 100\% \quad \text{e.q 3.2}$$

Where W_0 is the initial weight of sample before immersion in distilled water and W_1 is the weight of sample after immersion in distilled water (mm).

3.2.5.4 Percentage of Moisture Content

The composite will be cut into dimension of 20mm x 20mm x 10mm according to the ASTM D570. The sample will be heated in oven for 24 hours at 105⁰C. Then the sample will be weighed.

Respectively, the calculation of percentage of water absorption is given in eq 3.3:

$$\text{Percentage of moisture content (\%)} = \frac{W_0 - W_1}{W_0} \times 100\% \quad \text{e.q 3.3}$$

Where W_0 is the initial weight of sample before heating in oven and W_1 is the weight of sample after heating in the oven (mm).

CHAPTER 4

RESULTS AND DISCUSSION

This chapter deals with the analysis of the mechanical and physical properties of the composite samples. The samples were tested for tensile, flexural, thickness swelling, water absorption, moisture content and density. The results of different test conducted are represented along with comparison of the values of composites prepared. The composite are prepared with different fibre loading percentage.

4.1 Physical Properties

4.1.1 Moisture Content

Table 4.1: Results of Moisture Content

Fibre Condition	Polyester,P (%) / Coir,C (%)	Moisture Content (%)
	100P	0.01
Treated	90P10C	0.38
	80P20C	2.16
	70P30C	4.11
Untreated	90P10C	1.72
	80P20C	2.58
	70P30C	4.08

Moisture content is the quantity of water contained in a material. Table 4.1, stated the percentage of moisture content and water loss after the composite samples have been dried in oven for 24 hours at 105⁰C.

From Table 4.1, 100P sample shows moisture content of 0.01 which it contain a small amount of water due to the structure of polyester that it have relatively high

hydrophobic structure with very small amount of hydrophilic structure. This moisture regain means polyester is extremely hydrophobic (Florence Smith et al., 2012). Both treated and untreated coir fibre composites shows that the higher coir fibre loading percentage, the higher moisture content in the sample.

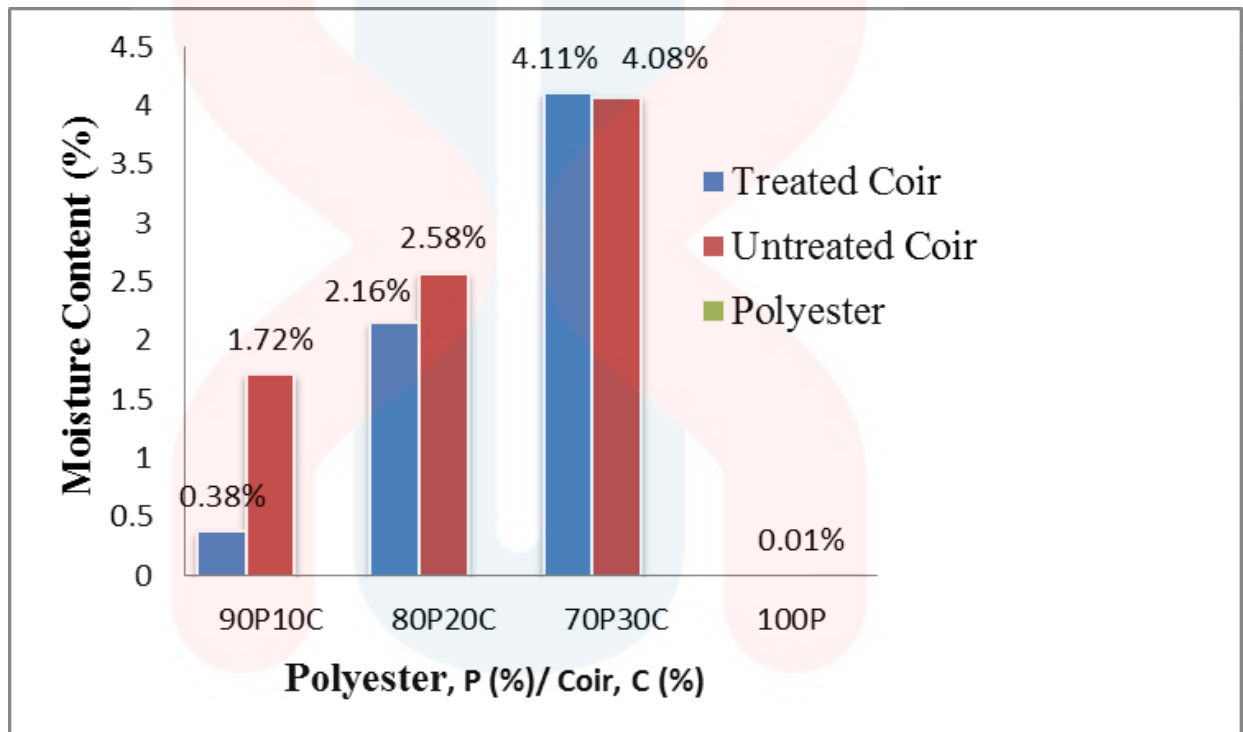


Figure 4.1: Percentage of Moisture Content

As for treated coir composite, sample of 70P30C have highest percentage of moisture content compared to the sample of 90P10C and 80P20C. The sample of 70P30C have 4.11% of moisture content which are 90.75% and 47.45% higher moisture content than sample of 90P10C and 80P20C.

Moisture may be present as adsorbed moisture at internal surface and act as capillary condensed water in small pores. Samples of treated coir fibre composite shows low moisture content compared to untreated coir fibre composite. This is due to the

alkaline treatment that minimized the water absorption in composite sample and the water content in coir fibre are reduced when the fibre undergoes pre-treatment process where it disrupts the water uptakes from the fibres.

From Table 4.1, it shows that for untreated coir composite sample of 70P30C also shows the highest percentage of moisture content compared to sample of 90P10C and 80P20C. Sample of 70P30C have 4.08% of moisture content which are 57.84% and 36.76% higher moisture content than sample of 90P10C and 80P20C.

High water content in untreated coir fibre composite sample may be due to non-disrupted lignocellulosic of the fibres and may be due to the voids, pores between fibre and matrix that can make water molecule dispersed into the composite.

Generally, moisture diffusion in a composite depends on factors such as volume fraction of fibres, fibre orientation, fibre types, area of exposure surface, surface voids, viscosity of the matrix, humidity and temperature (Pradeep K.Kushwaka and Rakesh Kumar, 2016).

4.1.2 Thickness Swelling

Thickness swelling is the enlargement of sample when it is soak in water. For thickness swelling test, the samples had been soaked in water for 24 hours.

Table 4.2: Results of Thickness Swelling

Fibre Condition	Polyester,P (%) / Coir,C (%)	Thickness Swelling (%)
	100P	0.09
Treated	90P10C	0.41
	80P20C	0.60
	70P30C	1.06
Untreated	90P10C	0.62
	80P20C	1.06
	70P30C	2.91

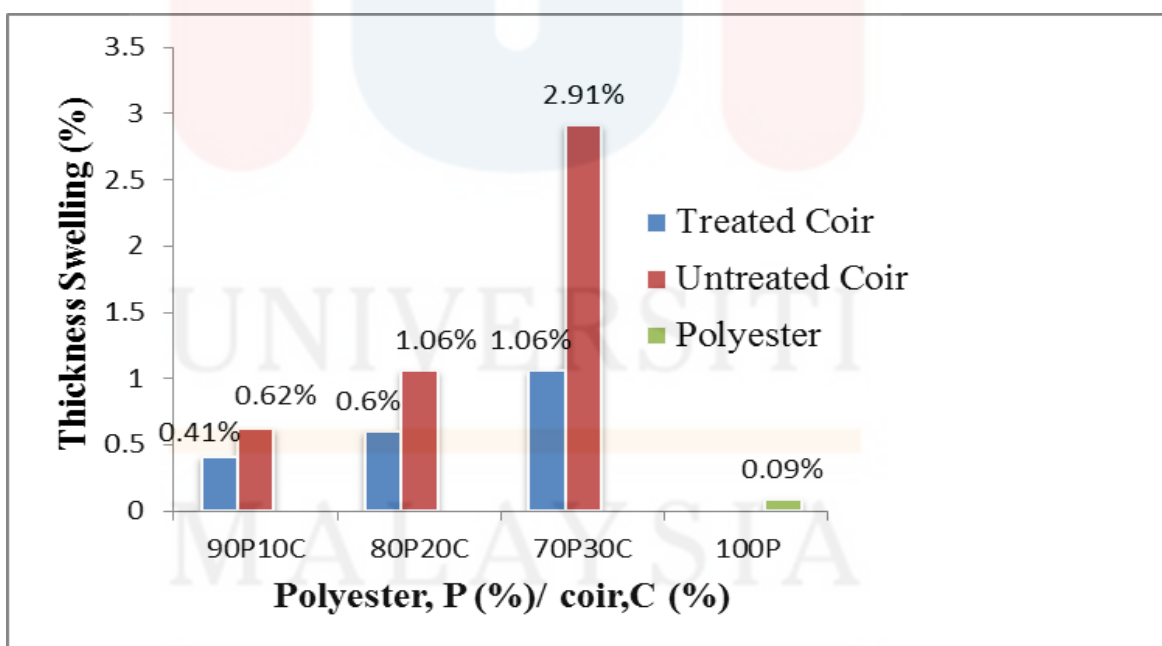


Figure 4.2: Percentage of Thickness Swelling

Figure 4.2 shows that both treated and untreated coir fibre composite samples increased in percentage of thickness swelling as the coir fibre loading percentage increased.

For treated coir fibre composite, sample of 70P30C shows higher thickness swelling compared to sample of 90P10C and 80P20C. The thickness swelling for sample 70P30C is 1.06% which are 61.32% and 43.40% higher thickness swelling compared to 90P10C and 80P20C.

The exposure of the lignocellulosic of fibres on the surface of the composite sample causing contradiction of water absorption and thickness swelling. Through Figure 4.2, we can see that high fibre loading of composite will increase the fibre-matrix interfacial adhesion and thus will increase the thickness swelling.

Thickness swelling occurred as the water molecules penetrate in the coir fibre reinforced composite. The water penetrations occur through micro-crack and it reduce the interfacial adhesion of the coir fibre within the polyester matrix (R.Yahaya et al., 2016).

In Figure 4.2, treated coir fibre composite shows lesser thickness swelling than the untreated coir fibre composite along with 100P due to the lesser water absorption.

The treated coir fibre composite shows lesser thickness swelling due to the alkaline treatment that acted on the coir fibre causing minimum water absorption of treated coir fibre composite. Treating coir fibre with alkaline treatment will remove amount of lignin, oil and wax from the internal layer of fibre cell. It also decomposes cellulose into small segment and are expose to short length crystallinities that definitely interrupt the hydrophilic properties of lignocellulose materials and their capillary action which may lead to minimum absorption of water and thickness swelling (Tamer Hamouda et.al, 2015).

As for untreated coir fibre composite, sample of 70P30C shows larger thickness swelling compared to sample of 90P10C and 80P20C. The different thickness swelling between this two composite are 78.70% (90P10C) and 63.57% (80P20C) less thickness swelling compared to sample of 70P30C coir fibre composite.

The thickness swelling of untreated coir fibre composite is higher compared to treated coir fibre composites. This is because hydrophilic properties of lignocellulose material with their capillary action cause the water intake in the samples when the samples were soaked in water causing increasing in dimension of the composite.

In untreated coir fibre composite, the water molecules attract the hydrophilic groups of coir fibre and react with the hydrogen group of the cellulose molecule to form hydrogen bond (Ray D and Rout J, 2005).

4.1.3 Water Absorption

Water absorption is the water intake from the composite when it is immersed in water. In this test, composite sample are soaked in water for 24 hours.

Table 4.3: Results of Water Absorption

Fibre Condition	Polyester,P (%), Coir,C (%)	Water Absorption (%)
	100P	1.18
Treated	90P10C	4.53
	80P20C	10.46
	70P30C	19.23
Untreated	90P10C	9.49
	80P20C	17.81
	70P30C	28.60

From Table 4.3, percentage of water absorption increased as increased fibre loading percentage. Table 4.3 show that sample of 100P have 1.18% of water absorption this is because it is stated that polyester are hydrophilic and become hydrophobic when it reinforced with fibres (Florence Smith et al., 2012).

For treated coir fibre composite sample, it is stated that sample of 70P30C have higher water absorption compared to sample of 90P10C and 80P20C. Sample of 70P30C have 19.23% water absorption and it shows that 70P30C have 76.44% and 45.61% higher water absorption compared to sample of 90P10C and 80P20C.

Meanwhile for untreated coir fibre composite, sample of 70P30C have water absorption of 28.60% which are higher compared to the other two samples of different fibre loading. The 70P30C sample had 66.82% higher water absorption than sample of 90P10C and 37.73% higher than sample of 80P20C.

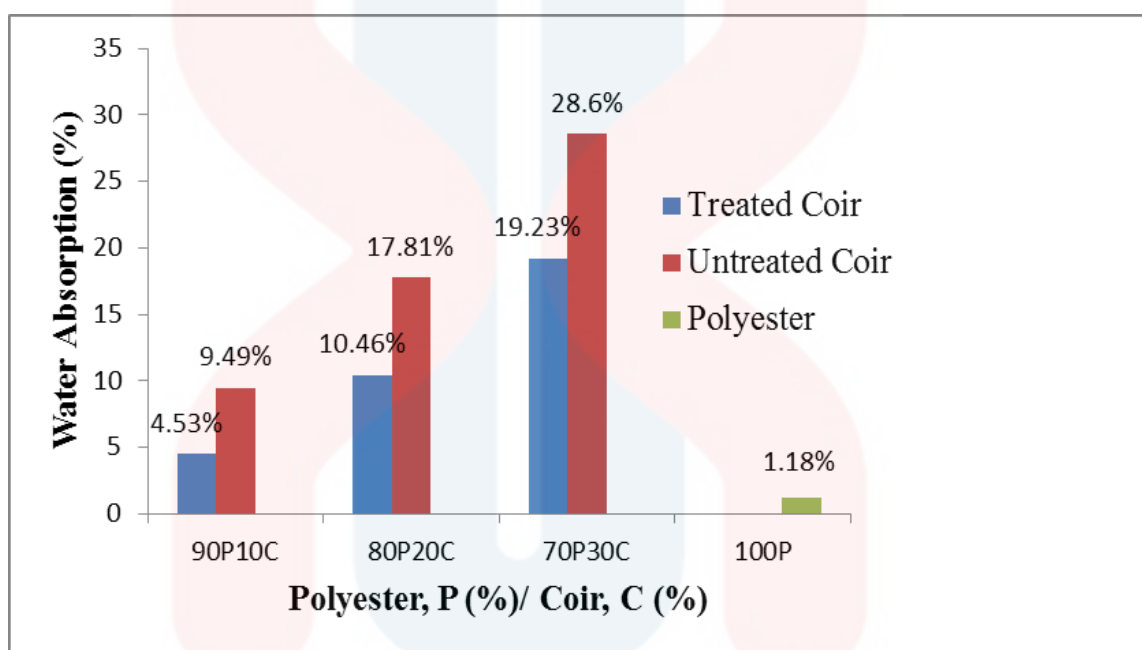


Figure 4.3: Percentage of Water Absorption

From the Figure 4.3, we can conclude that the percentage of water absorption for untreated coir fibre composite sample is higher than the treated coir fibre composite sample.

The water absorption test was used to determine the amount of water absorption by composite that are treated and untreated coir fibre along with different fibre loading.

Figure 4.3 shows untreated coir fibre composite has higher water absorption compared to treated coir fibre composite. Rate of water absorption is greatly affected by the composite density and void content.

High fibre loading will increase the water absorption as the rate of water absorption increasing steadily with increasing fibre content. This is due to the coir fibre contain more polar hydroxide groups which results in a high moisture absorption level of natural fibre based polymer composite.

Basically, all sample had a sharp linear starting and increase in moisture absorption until they reach their saturation state with maximum moisture content. In all composite sample, after 24 hours of water immersion, the treated coir fibre composite absorbed lesser water contain compared to untreated coir fibre composite. Similar in thickness swelling, water absorption was also influenced by the void content of the coir fibre composite. The weight of composite will increase by trapping the water inside the voids (R.Yahaya et al., 2016).

4.1.4 Density of Composite

The moulding used is 150 mm x 150 mm x 1 mm which is the volume of mould is 225cm³. The volume of polyester resin required to make 100% polyester sample is 225L which is 225.6g. The density of the polymer resins 1.09gcm⁻³ and the density of coir fibre is 1.2gcm⁻³.

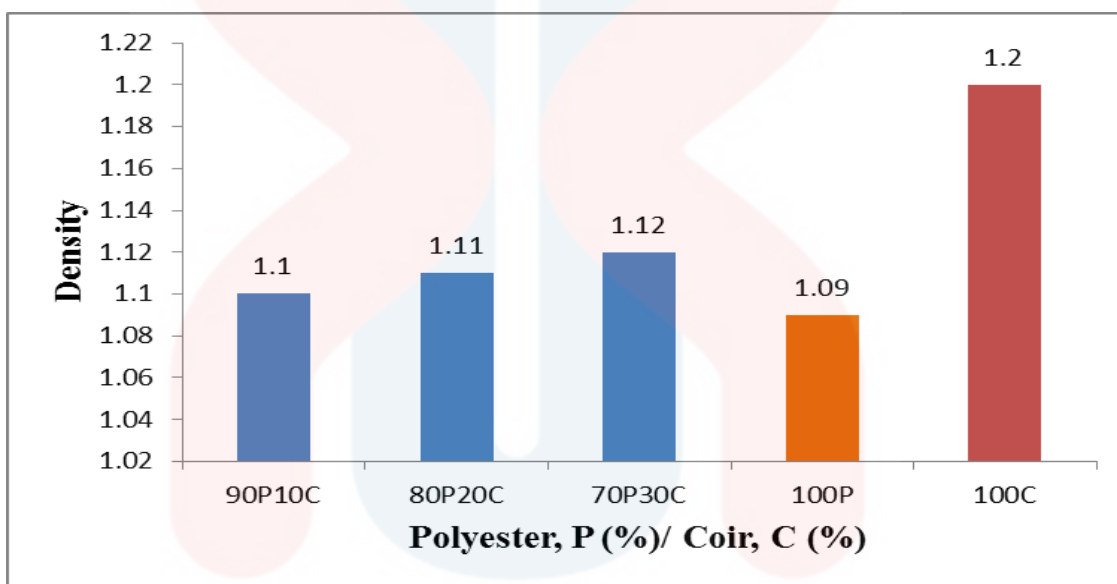


Figure 4.4 : Density of Composite (gcm⁻³)

From the figure 4.4, we can see that the density of coir polyester composite increased by 0.01 gcm⁻³ as the fibre loading percentage increased by 10% in each composite sample.

Density mainly depends on the relative proportion of reinforcement and matrix. The void content of composites is different between experimental density and theoretical density values of composite. In this test we can see that experimental density of polyester is 1.00 gcm⁻³ and their theoretical density is 1.09 to 1.15 gcm⁻³.

It is stated that less fibre loading will decrease density value of composite. There is a present of pore on composite sample which called voids that relate to the incompletely dispersed of polyester resins. Matrix between fibre reinforced. The pores will decrease the density of the composite. The inclusion of the fibres into the composite decreases the packing which lead to the disruption of fibre distribution and resulting in higher voids space. Thus greater voids or pores, yield to low density of composite (Geetanjali Das and Sandhayarani Biswas, 2012).

4.2 Mechanical Properties

4.2.1 Tensile Test

Tensile is which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for application, quality control and to predict how a material will react under other types of forces.

Table 4.4: Results of Tensile Strength (TS), Tensile Modulus (TM) and Strain

Fibre Condition	Polyester,P (%) / Coir,C (%)	Tensile		
		TS (MPa)	TM (GPa)	Strain (%)
	100P	107.5 ± 50.4	7.0 ± 3.7	2.2 ± 1.1
Treated	90P10C	126.0 ± 34.8	3.4 ± 0.5	3.2 ± 1.2
	80P20C	95.1 ± 18.8	6.4 ± 4.2	2.0 ± 0.4
	70P30C	94.7 ± 8.9	5.4 ± 3.8	3.7 ± 2.0
Untreated	90P10C	101.8 ± 11.5	5.7 ± 1.3	2.4 ± 0.1
	80P20C	126.6 ± 19.5	10.7 ± 1.7	2.3 ± 0.2
	70P30C	121.3 ± 9.8	2.7 ± 0.4	4.9 ± 0.9

In Table 4.4, it was found that the polyester resin had a tensile strength of 107.5 MPa and tensile modulus of 7.0 GPa.

It has been observed for treated coir fibre composite in the table that, sample of 90P10C have higher tensile strength compared to 80P20C and 70P30C sample of composite with value of 126.0 MPa. Tensile modulus of 80P20C sample (6.4 GPa) shows highest reading compared to sample of 90P10C (3.4 GPa) and sample of 70P30C (5.4 GPa).

Tensile strength of composite sample decrease as increase fibre loading and for tensile modulus, the modulus increase until the sample reached 20% of fibre loading then decreasing in value at 30% of fibre loading.

Fibre loading of treated coir fibre leads to decreasing tensile strength due to poor adhesion. As discussed previously in moisture content and thickness swelling, this two factors increasing in value as increase fibre loading which also lead from poor wetting phenomenon and poor adhesion. This poor adhesion hinders the increase of tensile strength due to improper dispersion between polyester matrix and fibre (Geetanjali Das and Sandhayarani Biswas, 2012).

Fibre length also influences the strength of composite. As the fibre length increase, the tensile strength increase but will decrease irrespective due to the fact that length of fibre may not be sufficient enough for proper load distribution.

Basically from the treated coir fibre composite results, it has low wetting between the fibre and matrix. A weak interface is created which is lead to a weak bonding. It was found led to the less area of the fibre being bonded by the matrix which can cause weak interface and thus it lead to weak bonding and the composite will become easier to deform and flexible towards increase fibre loading which behave like voids in the continuous phase (I.Z Bujang et al., 2007).

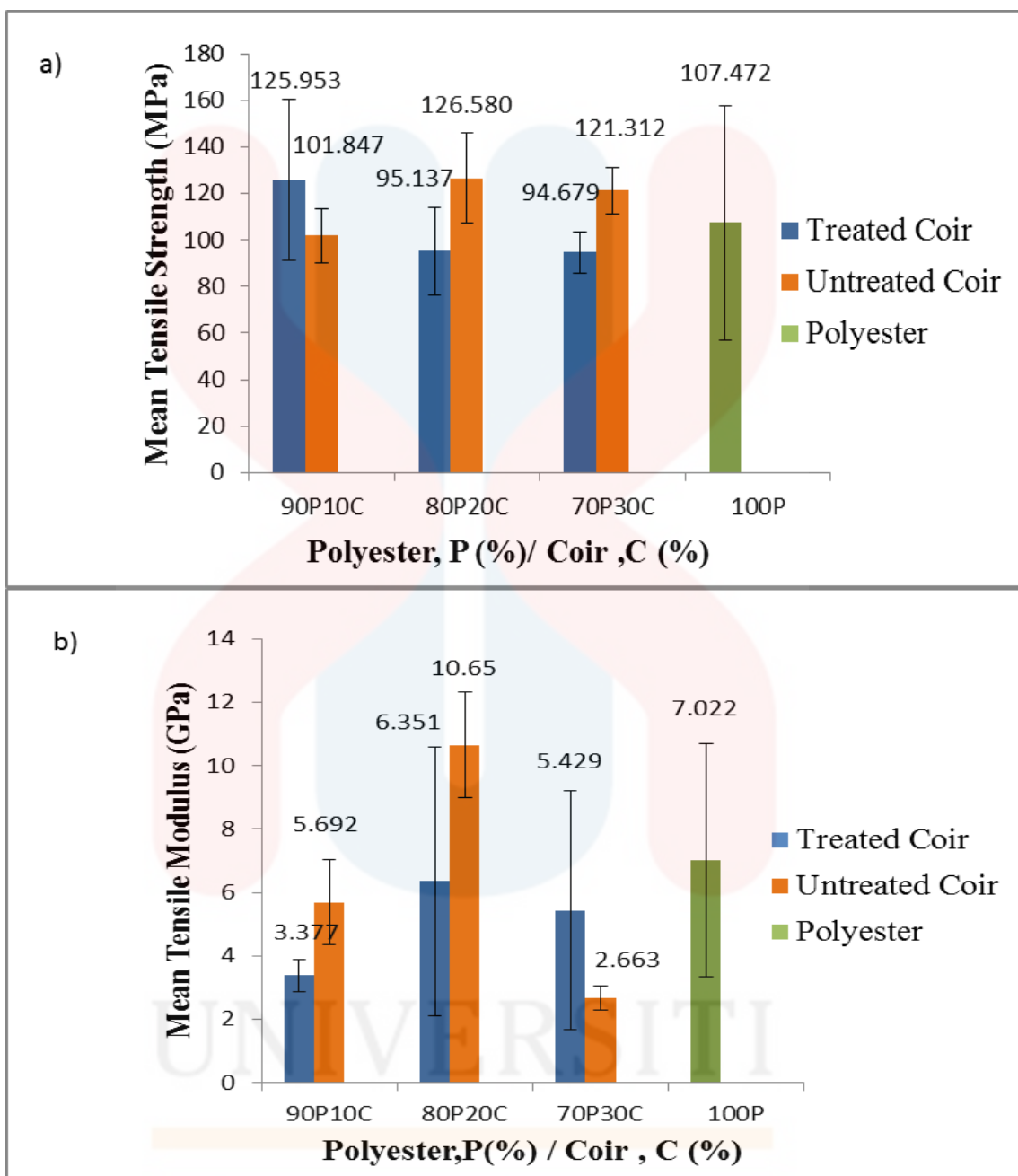


Figure 4.5: Shows a) Tensile strength (MPa) and b) Tensile Modulus (GPa)

Figure 4.5(a), it has been observed for untreated coir fibre composite, sample of 80P20C shows higher tensile strength compared to sample of 90P10C and 70P30C which value of 126.6 MPa. Figure 4.5(b) the tensile modulus of 80P20C sample (10.7GPa) show higher value compared to sample of 90P10C (5.7 GPa) and 70P30C (2.7 GPa).

Figure 4.5(b), tensile strength increase as the fibre content increase and somehow in further increase of fibre content will decrease tensile strength due to poor adhesion that avoid the increase of tensile strength. There is a good wetting between fibre reinforcement and polyester matrix. A strong interface is created which is led to a strong bonding causing tensile strength for sample of 90P10C and 80P20C increasing.

The tensile modulus increase as fibre content increase due to increased brittleness of the composite which is strain and stress curve become steeper.

Figure 4.5(a) and 4.5(b), it is observed that treated coir fibre composite show less strength and modulus value compared to untreated coir fibre composite. Tensile strength and tensile modulus increase with treated coir fibre compared to untreated coir fibre because surface treatment with alkaline removes the lignin and pectin to a certain extent and the new surface displays better adhesive properties with the matrix and hence better mechanical properties. Surface modification take place such that the resulting interfacial bonding with the matrix is stronger hence tensile value are greater.

In both coir fibre condition for 30% coir loading tensile strength and tensile modulus show decreasing value because of degradation of surface is much more and it result in loss of strength of the fibre which cannot be even compensated by the strong interfacial bonding with the matrix. Hence, tensile strength and tensile modulus value lower.

4.2.2 Flexural Test

Flexural strength and modulus of a composite is dependent on the fibre strength and extreme layer of reinforcement plays a vital role.

The crack of the sample always initiates on the tension side of the composite sample and slowly propagates in an upwards direction. Normally the flexural modulus is very sensitive to the matrix properties and fibre matrix interfacial bonding.

Table 4.5: Results of Flexural Strength (FS) and Flexural Modulus (FM)

Fibre Condition	Polyester,P (%) / Coir,C (%)	Flexural	
		FS (MPa)	FM (GPa)
	100P	308.0 ± 120.9	14.9 ± 4.5
Treated	90P10C	217.7 ± 57.8	14.3 ± 1.0
	80P20C	231.6 ± 44.8	14.7 ± 2.69
	70P30C	255.2 ± 32.8	11.4 ± 3.4
Untreated	90P10C	183.6 ± 46.1	7.4 ± 1.0
	80P20C	214.3 ± 17.1	14.2 ± 1.3
	70P30C	274.4 ± 41.8	9.4 ± 0.4

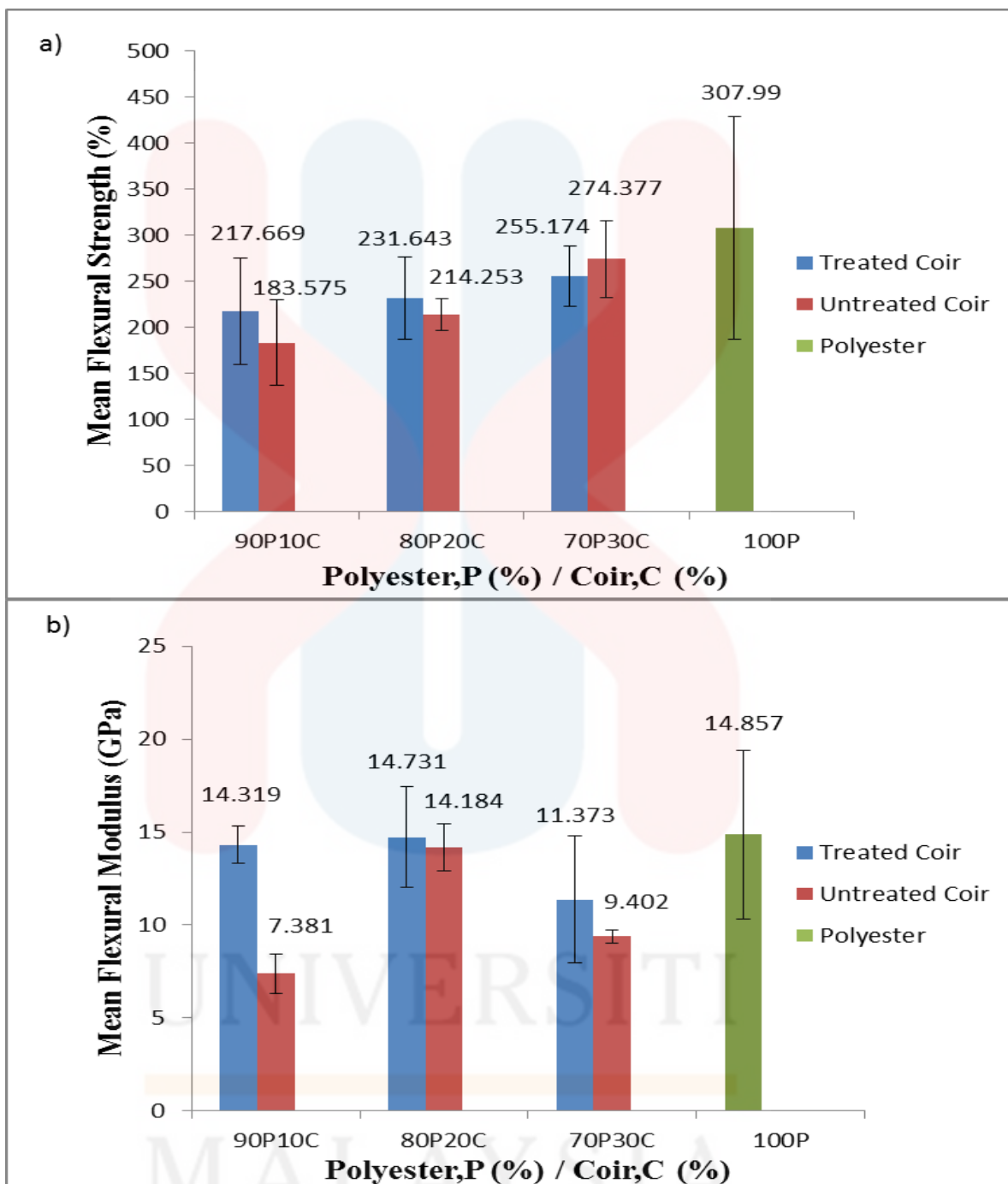


Figure 4.6: Show a) Flexural Strength (MPa) and b) Flexural Modulus (GPa)

It has been observed from Table 4.5, polyester resins had flexural strength and flexural modulus of 308 MPa and 14.9 GPa. Figure 4.6, indicated that flexural strength and flexural modulus is directly proportional to fibre content of coir composite.

Treated coir fibre composite show flexural strength and modulus increased with fibre loading percentage. Sample of 70P30C show higher flexural strength compared to sample of 90P10C and 80P20C. The flexural strength of 70P30C is 225.2 MPa which is 14.70% and 9.22% higher than sample of 90P10C and 80P20C.

Treatment of coir fibre can attribute to the fibre becoming rigid and somewhat brittle afterwards as treatment progresses and developing more crystallinity causing increase strength and lower extensibility.

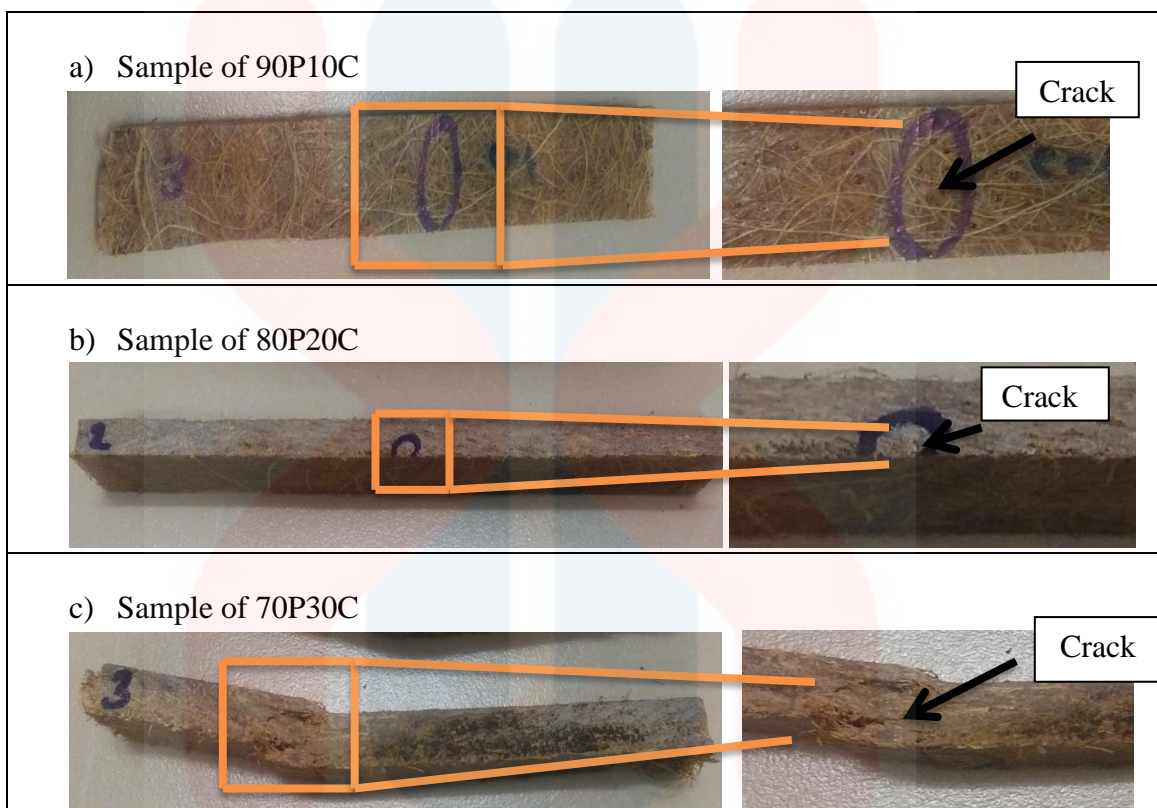
When bending stress is applied, these fibres tend to break due to increased brittleness and could not conduct effective stress transfer effectively which considerably reduce the strength of the composite.

From Figure 4.6, the untreated coir fibre composite increase their flexural strength and flexural modulus as increasing fibre loading. The higher flexural strength is 274.4 MPa at sample of 70P30C as compared to sample of 90P10C (183.6 MPa) and sample of 80P20C (214.3 MPa).

Flexural strength values of the untreated fibre coir composite are considerably lower than that of the treated coir fibre composite due to the removal of impurities from the fibre surface after treatment which leads to better adhesion of the fibre reinforced with polymer matrix.

From the Figure 4.6(b) of flexural modulus, the higher flexural modulus for treated coir composite at sample of 70P30C which is 11.4 GPa and for untreated coir fibre composite at sample of 80P20C which is 14.2 GPa. Overall, the modulus decrease as the fibre loading increase. The reasons for the lower flexural properties at high fibre content are probably due to the weak fibre to fibre interaction, voids and poor adhesion of fibre in matrix.

Table 4.6: Bending of Treated Coir Fibre



The Table of 4.6 is related to the bar graph shown in Figure 4.6(a) and 4.6(b). As increasing fibre loading, the flexural strength increase and flexural modulus increase for sample up to 20% fibre loading. This is because this composite of 90P10C and 80P20C followed the theory when increasing fibre loading, the composite tend to be low brittleness and increase in ductility which shown in the Table 4.6(a) and 4.6(b). However for composition of 70P30C of 30% fibre loading the value decreasing this is because as we can see from table 4.6(c), the sample of 70P30 tend to increase in brittleness and decrease in ductility.

Table 4.7: Bending of Untreated Coir Fibre

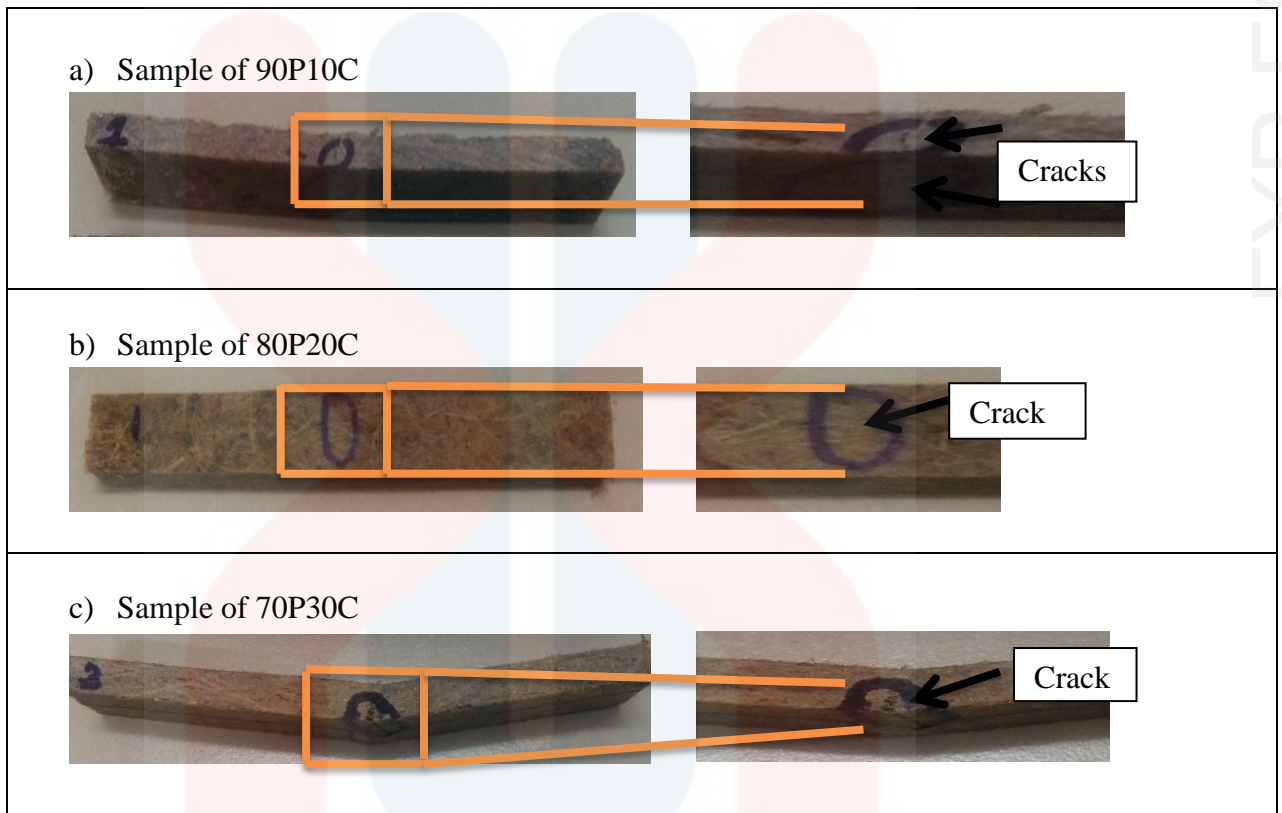


Table 4.7 is related to the bar graph shown in Figure 4.6(a) and 4.6(b). This untreated coir fibre composites, the results trend show same as the trend of treated coir fibre composites which is as increasing fibre loading, the flexural strength increase and flexural modulus increase up to 20% fibre loading then decreasing at 30% coir fibre composition. This is because this composite of 90P10C and 80P20C following the theory of increasing fibre loading, the composite tend to be high brittleness and low in ductility which shown in the Table 4.7(a) and 4.7(b) where it crack increasing and the bend is low. Meanwhile, from table 4.7c the composite shows low crack with high bend this is due to up to 20% of fibre loading, the sample tend to be decrease in brittleness and increase in ductility.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this investigation, the effect of treatment and fibre loading of coir fibre with polyester composite on physical and mechanical properties was studied. It should be noted that this study research are to determine the effect of utilizing different coconut coir composition as reinforcement in polyester biocomposite and to determine the effect of fibre pre-treatment on the coconut coir reinforced in polyester biocomposite.

The conclusions derived from this study are as increase fibre loading, the mechanical properties will increase until they reached maximum value of their strength. Fibre condition will effects mechanical properties and highly effects the physical properties of the composites.

Then, alkaline treatment of natural fibre improved the physical and mechanical properties and results in low brittleness and high ductility of composite. Alkaline treatment results in decrease of water absorption, thickness swelling and moisture content by the composite and increased in mechanical properties.

The optimum composite for treated coir fibre composite is at 90P10C which it contains lower percentage of moisture content, thickness swelling and water absorption. This composite have tensile strength of 126 MPa and tensile modulus of 3.2 GPa. The formulation of 90P10C also has flexural strength of 217.7 MPa and flexural modulus of 14.3 GPa. This composite are the most ductile compared to other formulation.

The optimum composite formulation for untreated coir fibre composite is 80P20C which have thickness swelling of 1.06%, moisture content of 2.58%, water absorption of 17.81%, tensile strength and modulus of 126.6 MPa and 10.7 GPa, flexural strength and modulus of 214.3 MPa and 14.2 GPa. Thus it contains optimum physical and mechanical properties.

Basically, the most important factors for obtaining good fibre reinforcement in the composite are the bonding strength between natural fibres and polymer matrix.

5.2 Recommendation

Highly recommended for this research study are by increasing alkaline treatment concentration and increasing time of pre-treatment can improve the interfacial bonding and adhesion between fibre and matrix. Interfacial bonding between fibre and matrix will be improved by alkaline treatment. Alkaline treatment results in decrease of water absorption, thickness swelling and moisture content by the composite and increased in mechanical properties.

Then, physical properties in a composite depends on factors such as volume fraction of fibres, fibre orientation, fibre types, area of exposure surface, surface voids, viscosity of the matrix, humidity and temperature. Thus by improving these factors, will produce high ductility of composite with low brittleness.

Testing the coir fibre composite for their thermal properties by using thermogravimetric analysis (TGA) to determine the chemical properties (decomposition, dehydration, oxidation or reduction) of materials and their physical phenomena (phase transition, vaporization, absorption, adsorption and desorption) information with constant heating rate and with constant temperature or mass loss.

Next, this research must be studied further in testing the coir fibre composite for their morphological properties by using scanning electron microscope (SEM) and transmission electron microscopy (TEM) to determine the composite micro structure.