STUDY THE IMPACT OF COUPLING AGENT AND FIBER LENGTH ON WOOD PLASTIC COMPOSITE

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ABSTRACT

In the past decades, composite industries are seeking more environmental friendly materials for their products. Because of an increasing interest in biodegradable renewable composites reinforced with plant fiber, wood plastic composite (WPC) come out with characteristic as a green composite which is biodegradable. WPC is made of wood fiber, recycle polypropylene and coupling agent. For optimizing the impact of mechanical and physical properties on WPC, three most important variables including fiber length, coupling agent, orientation of fiber were investigated. Extrusion and hot press plate are the processes involve in this experiment to produce WPC. Then, WPC will go through four testing which are Differential scanning calorimetry (DSC), Thermogravimetry Analysis (TGA), Tensile and Flexural testing. Based on the result obtained, the relation of fiber length is directly proportional to tensile strength and stress transfer. Furthermore, the parallel orientation is the best of fiber orientation that will increase the mechanical properties besides coupling agent at 4% will achieve optimum level to increase the strength bonding between wood fibers and polypropylene. Therefore, wood plastic composite (WPC) can give good impact to our economy due to their advantages to environment and human.

ABSTRAK

Dekad yang lalu, industri komposit mencari bahan-bahan yang lebih mesra alam sekitar bagi produk mereka. Kerana minat yang semakin meningkat dalam rencam terbiodegradasikan yang boleh diperbaharui diperkukuhkan lagi dengan serat tumbuhan, komposit plastik kayu (WPC) muncul dengan ciri-ciri sebagai komposit hijau yang boleh terurai semulajadi.WPC diperbuat daripada serat kayu, polipropilin kitar semula dan agen gandingan. Untuk mengoptimumkan kesan sifat mekanikal dan fizikal pada WPC, tiga pembolehubah yang paling penting termasuklah panjang gentian, agen gandingan, dan orientasi gentian telah dikaji. Pengekstrudan dan plat penekan panas adalah proses yang terlibat dalam eksperimen ini untuk menghasilkan WPC. Kemudian, WPC akan melalui empat ujian iaitu Kalorimeter Pengimbasan Pembezaan (DSC), Analisis Termogravimetri (TGA), ujian tegangan dan lenturan. Berdasarkan keputusan yang diperolehi, hubungan panjang gentian adalah berkadar terus dengan kekuatan tegangan dan pemindahan tekanan. Tambahan pula, orientasi selari merupakan orientasi gentian yang terbaik yang akan meningkatkan sifat-sifat mekanikal di samping agen gandingan pada kadar 4% yang akan mencapai tahap optimum untuk meningkatkan kekuatan ikatan antara gentian kayu dan polipropilin. Oleh itu, komposit plastik kayu (WPC) boleh memberi impak yang baik kepada ekonomi kita kerana kelebihannya kepada alam sekitar dan manusia.

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LIST OF SYMBOLS

ε	Strain
σ	Stress
σ^*_f	Fiber tensile strength
l_c	Critical length
°	Angle
℃	Degree Celsius
%	Percentage
wt%	Weight percent
%w/v	Percent weight over volume
$	Dollar
B	Width
D	Thickness
D	Deflection due to load F applied at the middle of the beam
F	Load (force) at the fracture point
h	Hour
h	Height of the beam
L	Length of the support span
L	Distance between the two outer supports
N	Newton
w	Width and height of the beam

LIST OF ABBREVIATIONS

ASTM	American society for Testing and Materials
ATR	Attenuated total reflectance
DSC	Differential scanning calorimetry
FTIR	Fourier Transform Infrared Spectroscopy
H_2O_2	Hydrogen peroxide
IB	Internal bonding
L/D	Length to diameter
MAPP	Maleic anhydride grafted polypropylene
MPa	Megapascal
NaOH	Sodium hydroxide
PE	Polyethylene
PP	Polypropylene
TGA	Thermogravimetry Analysis
UV	Ultraviolet
WPC	Wood Plastic Composite

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In the recent years, composites are widely developed due to the increased environmental consciousness. The tremendous increase of production and use plastics in our life causes abundant of plastic wastes. According to municipal solid waste (MSW) in Malaysia, due to growing population and increasing consumption, the amount of solid waste generated in Peninsular Malaysia went up from 17,000 tons per day in 2002 to 19,100 tons in 2005, an average of 0.8 kilogram per capita per day which plastic waste consume 24%. The generation of solid waste is expected to reach 30,000 tons per day in 2020. Since plastics are known as non-biodegradable material which cause disposal problem, this lead to the scientific research toward eco-composite materials. Combination of wood pallet and thermoplastic called compounding which formed wood plastic composite (WPC). This can be done by using certain processes such as extrusion and injection molding. WPC was born as a modern concept in Italy in the 1970s, and popularized in North America in the early 1990s. By the start of the 21st century it was spreading to India, Singapore, Malaysia, Japan and China (Pritchard, 2004).

North American WPC markets have reached almost $1 billion in sales between 2001 and 2006. WPCs may be one of the most dynamic sectors of today's plastic industry with an average annual growth rate of approximately 18% in Northern America and 14% in Europe (Gupta et al., 2007). WPC widely used as benches, playground equipment, decking, and automotive industry. This mainly due to wood plastic composite are renewable, less abrasive to processing equipment, environmental friendly, low maintenance and similar as wood feature (H'ng Pak San et al., 2008).

However, not much attention has been paid to the effect of chemical composition of wood on the mechanical and physical properties (Ashori, and Nourbakhshsh, 2009). This is due to different characteristics between wood and thermoplastics. Wood is hydrophilic which absorb moisture easily because its surface contains hydroxyl group (-OH) while thermoplastic is hydrophobic, having lack of affinity for water and non reactive. Therefore, the two antagonist materials need some additives to improve interfacial adhesion between the polymer matrix and fiber. Chemical coupling is one of the most important topics in WPC. Kokta and co-workers are reported that coupling agents improve interfacial bonding at low concentration, but they were detrimental to graft copolymerization and interfacial bonding strength at high concentration (Maldas et al., 1989; Maldas and Kokta, 1991). On the other hand, an effective way to increase product stiffness is by adding wood filler even strength commonly suffers (Wolcott et al., 2003, Wolcott et al., 1999). The commercial WPC produced from wood flour have a low length-to diameter (L/D) ratio. Therefore, if adhesion between wood fibers and the plastic matrix is good; fibers are uniformly dispersed in the matrix; and fibers are adequately oriented (Wolcott et al., 1999; Gamstedt et al., 2007), both strength and stiffness increases can be realized with increasing fiber length.

Last but not least, fundamental research is still needed to further advance our understanding the impact of coupling agents and fiber length.

1.2 Problem Statement

Although the productions of WPC increase year by year, there have a major problem which is the chemical incompatibility between the hydrophilic fiber and the hydrophobic polymer that need to be solved and improved (Selke SE and Wichman I., 2004). Furthermore, lack of proper information about the fiber length, orientation of fiber, and coupling agent besides abundant of wood flour and plastic waste which can be recycle to make useable product such as wood plastic composite (WPC).

1.3 Research Objectives

1.3.1 To study the impact of fiber orientation on the mechanical properties of WPC.
1.3.2 To investigate the impact of coupling agent on the physical and mechanical properties of WPC.
1.3.3 To determine the impact of fiber length.

1.4 Scope of Study

This study focus on the testing involves investigating the impact of coupling agents, fiber length, orientation of fiber and tensile strength. For instance, Internal Bonding (IB), Fourier Transform Infrared Spectroscopy (FTIR), Differential scanning calorimetry (DSC), Thermogravimetry Analysis (TGA), Tensile testing and weathering testing.

1.5 Significance of Study

Wood plastic composite comes from waste material. One of the advantages of WPC is environmental friendly. Hence, we should preserve the earth from contaminated and recycled the waste. Furthermore, the quality, strength, mechanical and physical properties of WPC need to be improved since not much pay attention about that and the research still in progress.

CHAPTER 2

LITERATURE REVIEW

2.1 Wood plastic composite (WPC)

The most widely known and used natural-organic fillers are wood flour and fibers. Wood flour can be easily and cheaply obtained from sawmill wastes and it is usually used after proper sieving. While plastic is a type of the polymer such as polypropylene, polyethylene and polyamide. Plastics waste is easily can be found at everywhere due to widely used as a shopping bag, bottles, packaging and others. Combination of both materials will become wood plastic composite (WPC).

2.1.1 Chemical and Physical properties

Wood fibers are produced by thermo mechanical processes on wood waste (LA Mantia et al., 2011). For examples, kenaf, jute, starch, and sisal. Wood is a natural and complex polymer which contains cellulose, hemicelluloses, lignin, and extractives (Ashori et al., 2009). Indeed wood or lignocellulosic fibres have good mechanical properties. Figure 2.1 show the structure of cellulose in plant cell.

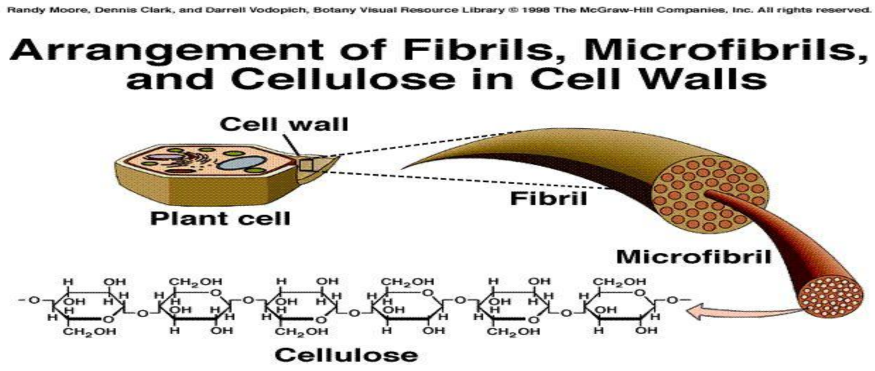

Figure 2.1: Structure of cellulose in plant cell. (Randy Moore, Dennis Clark, and Darrell Vodopich, Botany Visual Resources Library © 1998 The McGraw-Hill Companies, Inc. All rights reserved.)

Their ecological character, biodegradability, low costs, nonabrasive nature, safe fiber handling, high possible filling levels, low energy consumption, high specific properties, low density and wide variety of fiber types are very important factors for their acceptance in large volume markets, such as the automotive and construction industry. Furthermore, the public generally regards products made from renewable raw materials as environmentally friendly (Lundquist et al., 2003; Kim et al., 2006; Bismarck et al., 2006).

Polypropylene have resistant to heat distortion, excellent electrical properties and fatigue strength, chemically inert, relatively inexpensive and poor resistance to UV light (Callister et al., 2008).

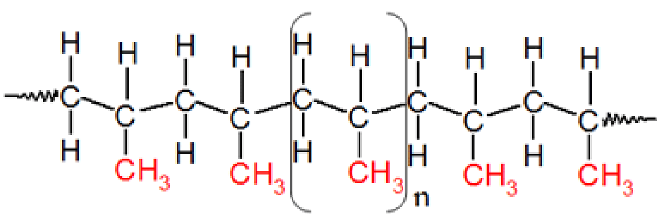

Figure 2.2: Structure of polypropylene. (Source: HMC Polymers Thailand, 2008)

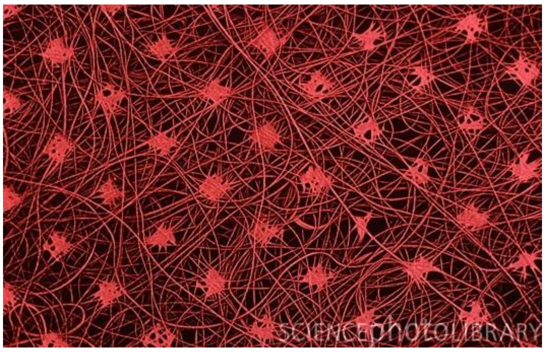

Figure 2.3: False-colour scanning electron micrograph (SEM) of the detailed structure of polypropylene (polypropene) filaments

When these two material are combined (Figure 2.4), there are a problem occur in their properties. Since wood fiber is hydrophilic against to polypropylene which is in hydrophobic behavior. This is shown in the structure compound (Figure 2.5) have a gap between them and not mix well.

Figure 2.4: Combination of wood flour and plastic granule to form wood plastic composite.

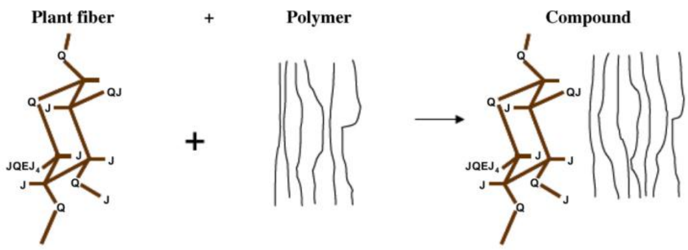

Figure 2.5: Structure compound of wood plastic composite.

2.1.2 Interfacial adhesion

Poor interaction between the polymer and fiber decrease the adhesion and a reduction in the ability of the matrix to transfer stress to the fibers. The mechanisms of adhesion involve various forces of bonding such as mechanical, electronic, diffusion that occur at the interface. Wetting of WPC and surface analysis will provide good information on their ability to bond.

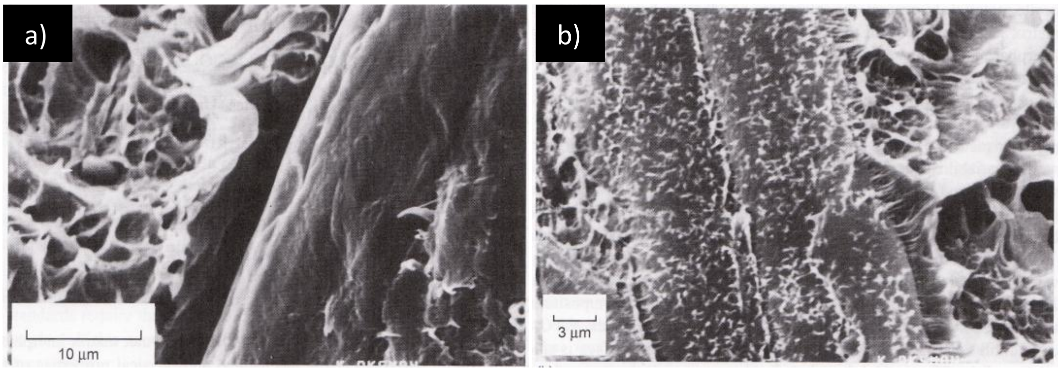

Figure 2.6 Example of (a) poor and (b) good adhesion between the wood and PE matrix (Oksman and Bengtsson, 2007).

2.1.3 Advantages and Disadvantages

Environmental friendly is the greatest advantage of wood plastic composite due to it come from waste and recycles material. Compared to the solid wood, WPC have low maintenance. Most of the research in many countries is focus on the durability and extended service life of WPC due to large interest in its outdoor use (Hiziroglu, 2009). A low-life cycle cost is the main reason why the WPC growth fast since the last two decade. In addition, it is decay resistance against fungi or microbial attack. However, WPC have several disadvantages such as thermal expansion, creep, high density and difficult application of paint.

Recent advances in catalyst technologies for polymerization of polyolefin resins and process engineering have made WPC a material of choice for different application as shown in Figure 2.7 (Niska and Sain, 2008).

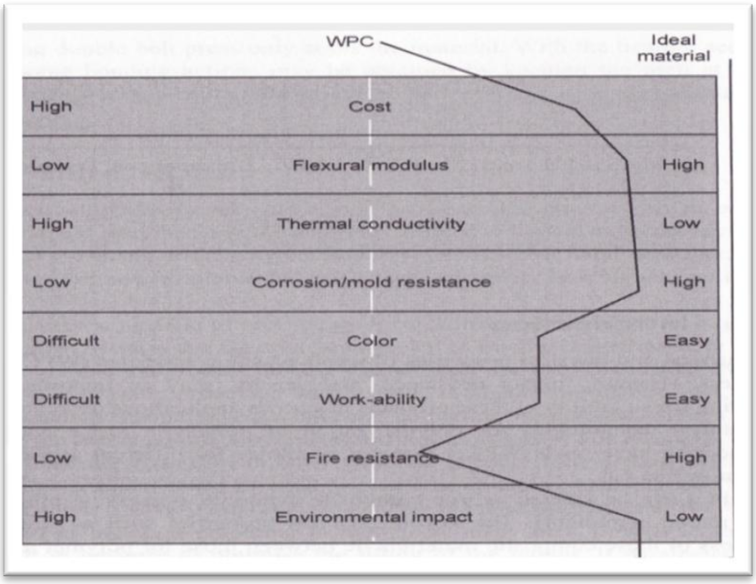

Figure 2.7: Combining the best feature of wood and plastic, WPC functional properties are ideal for many applications (Principia Partners, 2006)

2.1.4 Applications

Table 2.1 Applications of WPC

Construction	Lightweight board, embankment support, shuttering and other applications.
Automotive	Panels and trim.
Building	Exterior building (Decking, soffits, facias and bargeboards) Interior building (doors, skirting board)
Furniture	Outdoor furniture (picnic tables and benches) and indoor furniture, bathroom and kitchen cabinets.
Infrastructure	Landscaping timber, garden structures (gazebos), playground equipment, and signage.

Figure 2.8: Productions from WPC. (a)WPC floor laminated (b) Garbage from WPC, and (c) WPC bench

2.2 Coupling Agent

Applying MAPP on the surface of the wood flour can promote filler polymer interaction, which, in turn, would improve mechanical properties of the composite as well as its water uptake and thermal stability. In all cases, the degradation temperatures shifted to higher values after using MAPP.

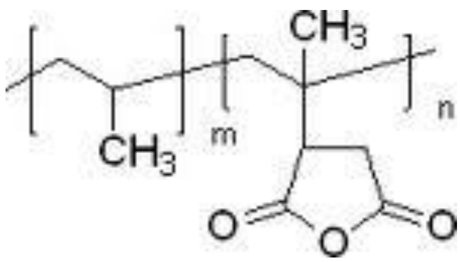

Figure 2.9: Structure of maleic anhydride grafted polypropylene (MAPP).

In order to improve the affinity and adhesion between fibers and thermoplastic matrices in production, chemical ‘‘coupling’’ or ‘‘compatibilizing’’ agents have been employed (Kim et al., 2006). Chemical coupling agents are substances, typically polymers that are used in small quantities to treat a surface so that bonding occurs between it and other surfaces, e.g. wood and thermoplastics. There are changes occur before and after adding the coupling agent into the compound (Figure 2.10)

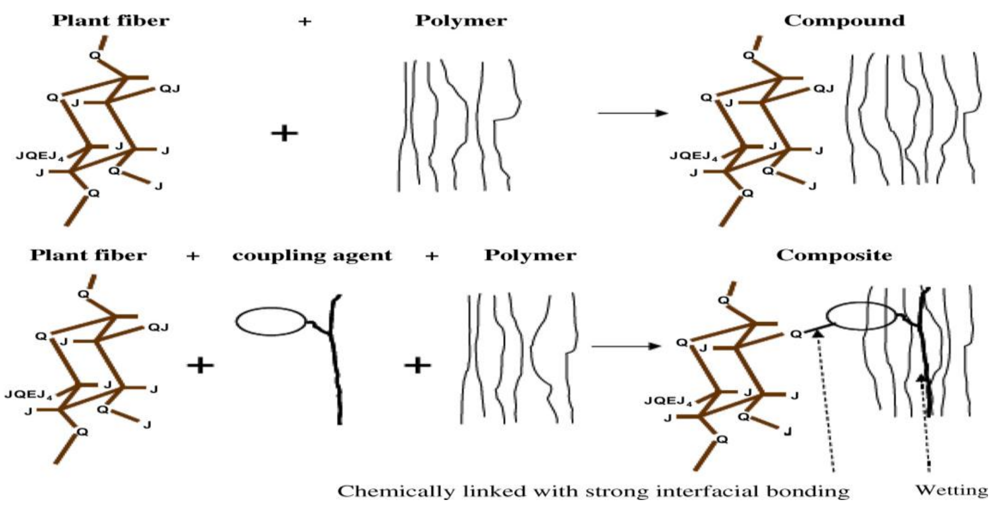

Figure 2.10: Mechanism of coupling agent between hydrophilic fiber and hydrophobicmatrix polymer

2.2.1 Advantages

The coupling agent, maleic anhydride grafted polypropylene appears to be the most widely used. The reasons are the efficiency, the easiness of processing and ease of purchasing this product.

2.3 Mechanical Properties

2.3.1 Tensile Strength

Tensile properties indicate how the material will react to forces being applied in tension. The main product of a tensile test is a load versus elongation curve which is then converted into a stress versus strain curve (Figure 2.11).

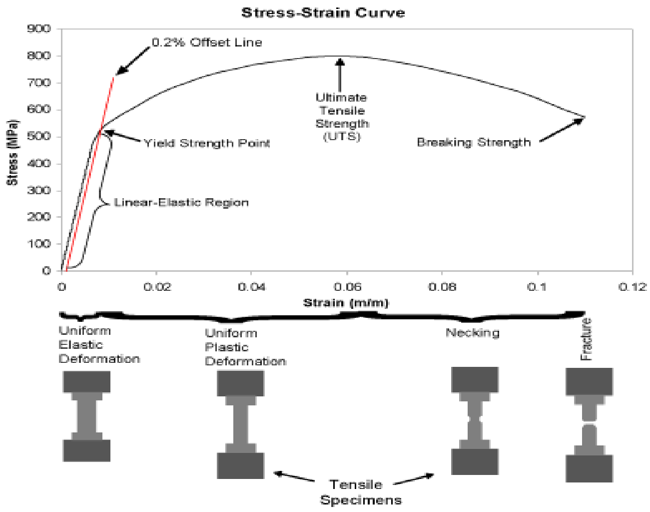

Figure 2.11: Schematic tensile stress-strain curve for a polymer.

The result published by Kamarkar et al. (2007) who studied the properties of wood-fiber reinforced polypropylene composites showed that the tensile strength of PP/wood fiber composites increase with increasing fiber length.

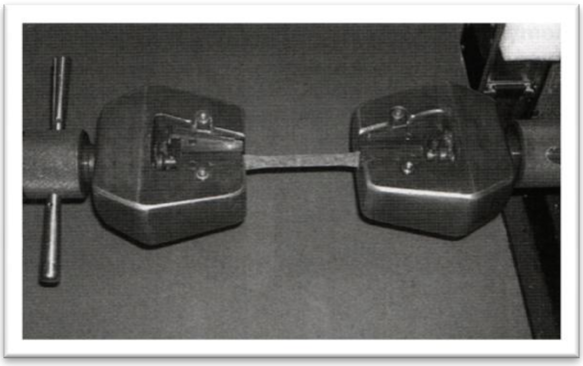

Figure 2.12: Test assemblies for tensile testing of WPC

2.3.2 Flexural properties

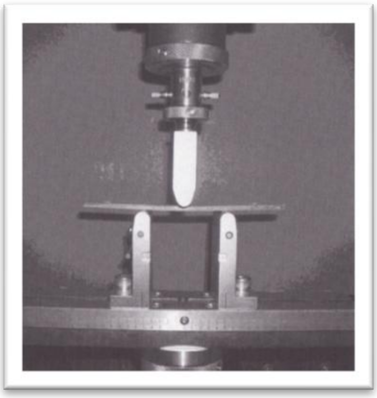

Figure 2.13: Test assemblies for static bending of WPC

2.3.2.1 Flexural Strength (MOR)

Flexural strength is a mechanical parameter for brittle material, also known as modulus of rupture, bend strength, or fracture strength besides defined as a material's ability to resist deformation under load. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress, here given the symbol σ.

For a rectangular sample under a load in a three-point bending setup (Figure 2.14);

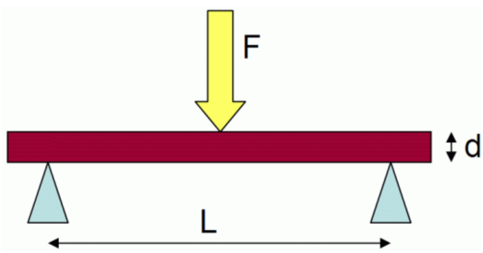

Figure 2.14: Beam under three point bending

$$\sigma = \frac{3FL}{2bd^2}$$

F is the load (force) at the fracture point
L is the length of the support span
b is width
d is thickness

2.3.2.2 Flexural Modulus (MOE)

In mechanics, the flexural modulus is the ratio of stress to strain in flexural deformation, or the tendency for a material to bend. It is determined from the slope of a stress-strain curve produced by a flexural test (such as the ASTM D 790), and uses units of force per area.

For a 3-point deflection test of a beam;

$$E(bend) = \frac{L^3F}{4wh^3d}$$

w is the width and height of the beam
h is and height of the beam
L is the distance between the two outer supports
d is the deflection due to load *F* applied at the middle of the beam.
F is the load (force).

2.3.3 Fiber length

Most important parameter that controlling the mechanical properties is fiber length or more specifically is aspect ratio (Ashori and Amir, 2010). Stark and Rowlands (2003) reported that aspect ratio, rather than particle size, has greatest effect on strength and stiffness. Figure 2.16 show that stress position profile of fiber length.