Faculty of Engineering

DEFORMATION OF WOOD IN COMPRESSION DUE TO MOISTURE CONTENT CHANGES

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Bachelor of Engineering with Honours
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Deformation of Wood in Compression Due to Moisture Content Changes

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This project is submitted in partial fulfillment of
the requirements for the degree of Bachelor of Engineering with Honours
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Dedicated to my beloved family

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Abstract

This work presents the phenomenon of mechano-sorptive strain in the deformation of wood during moisture content changes. A series of experiments are designed to demonstrate the greatly enhanced deformation due to the mechano-sorptive effect. The purpose of this work is to show the magnitude of mechano-sorptive creep compared to the ordinary viscoelastic creep when applied compressive load. In order to do this, several conditions are induced. They are the moisture movement with moisture content (MC) change, moisture movement without MC change and conditions without moisture movement. This work observes the unique patterns of strains as well as the relative strains of various conditions that are induced in the experiments. The characteristics shown in the results are evaluated logically and compared to existing theories to confirm their validity. Any anomalies are paid special attention to and studied to see whether they are sensible.

Several methods are used to produce the desired conditions. Several apparatus are assembled together in order to be functional. Special care is taken to make sure that the compressive load relatively small and is within elastic limit.

The results have shown that with the presence of mechano-sorptive, the maximum strains and relative strains of Jelutong wood specimens loaded at a constant 200N are 0.433×10^{-3} and 2.87. The results show that the severest deformation is caused by the decreasing MC in the wood specimen, attributed to the mechano-sorptive effect.

Abstrak

Kerja ini menunjukkan fenomena *mechano-sorptive* yang mengakibatkan spesimen kayu Jelutong menjadi teramat lemah apabila daya beban mampatan dikenakan. Ini terjadi semasa pergerakan cecair serta pengurangan kandungan air di dalam struktur kayu. Pelbagai kaedah disediakan bagi menghasilkan beberapa keadaan bagi membezakan kesan mechano-sorptive berbanding keadaan viscoelastic creep. Keadaan-keadaan ini ialah perbezaan kandungan air serta pergerakan air, pergerakan air tanpa perbezaan kandungan air dan keadaan tanpa perbezaan kandungan air. Corak-corak unik serta sifat-sifat tersendiri dalam *strain* dan *relative strain* diperhati dan dikaitkan dengan teori yang sedia ada.

Beberapa cara kerja eksperimen dirancang bagi menghasilkan situasi tertentu. Pelbagai radas digabungkan bagi memenuhi keperluan menjalankan eksperimen-eksperimen ini. Daya beban yang dikenakan dipastikan berada di dalam lingkungan had kenyal spesimen kayu.

Keputusan memnunjukkan strain dan *strain* relatif yang maksima sebanyak 0.433×10^{-3} and 2.87 apabila specimen dikenakan daya beban mampatan sebanyak 200N. Keputusan ini diperhatikan dalam keadaan di mana specimen kayu mengalami pengurangan kandungan air, dikaitkan dengan kesan *mechano-sorptive*.

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Nomenclatures

MS	-	Mechano-sorptive
MC	-	Moisture Content
FSP	-	Fibre Saturation Point
RH	-	Relative Humidity
RS	-	Relative Strain
EMC	-	Equilibrium Moisture Content
ε	-	Strain
MOE	-	Modulus of Elasticity

CHAPTER 1

Introduction

Wood has been used since ancient times and it is still being used increasingly worldwide. Wood has become a very important industry especially throughout the USA, Canada, Japan and many tropical regions including Malaysia. Nowadays, trees are even grown and tended carefully to yield wood of the highest quality and optimum characteristics. The unique characteristics of wood have made it a natural material for homes, furniture, tools, boats and decorative objects. Wood has a high ratio of strength to weight and thus makes it a very suitable structural material. Dry wood has good insulating properties against heat, sound, and electricity. Wood is able to absorb and dissipate vibrations and becomes ideal to make various musical instruments as the violin and piano. The physical appearance of wood is pleasing to create an atmosphere of natural environment. In addition to that, wood is easily shaped with tools and fastened with adhesives, nails, screws, bolts, and dowels. This makes wood highly sought after for crafting purposes. Wood is readily available in many species and possesses a wide range of characteristics. This allows high flexibility and versatility when different species are used together to complement one another.

However, wood inherently possess several limitations and can cause problems when not used carefully. The mechanical and physical properties of all wood are highly dependent on its moisture content (MC) and the temperature where it is used. This is particularly significant because the dynamic change in weather conditions can drastically alter the MC of ambient air especially in seasonal countries. Even in tropical regions, wood is susceptible to be exposed to direct contact with water due to heavy rains.

This can adversely affect the properties of wood. More seriously, it can also cause deformation in wood and ultimately affects the dimensional stability and even shift wood members from its original position. The magnitude of deformation depends on several factors including wood species, original dimensions and the condition where the wood member is being used. While the concern is not so great on visual appearance defects, it is crucial when structural integrity is considered. This is because wood used as structural members for buildings to support load require very high accuracy and dimensional stability. Deformations can cause the joints to become detached and weaken. Moreover, excessive deformations can cause loads on certain wood members to exceed its design intent. For example, deformations on several wood members will cause a shift in the load balance to the remainder of other wood members and this can potentially cause some wood members to incur loads above its safety limit and eventually collapse. These deformations can also cause major problems where accuracy is concerned. This is especially true in wooden boats where excessive deformations can cause a piece of wood plank to become detached from its plank to form a gap that allows water to enter the boat. These deformations must be taken into account by engineers when designing and conducting any engineering projects.

Deformations in wood due to moisture changes have been a major problem and concern in the wood industry. Although many innovations are developed to tackle this issue, the problems have not been solved entirely. Therefore, the purpose of this work is to conduct a series of experiments in order to better understand this phenomenon. From this work, the deformation in wood can be broken down into several components, namely the viscoelastic, swelling or shrinkage and the MS. Thus, deformation due to the MS effect can be evaluated. The quantitative effect of MS on deformation of wood will be assessed to determine whether or not and also to what extend it is significant.

The following chapters will discuss more on the effect of moisture changes, namely the MS effect. Chapter 2 (Literature Review) will describe in detail the wood structure, its MC as well as the fibre saturation point (FSP). Moisture movement mechanism and the swelling and shrinkage of wood will also be discussed. The distinction between viscoelastic creep and MS creep will be focused. Other contents include the thermal effect, deformation mechanism and other factors that affect the properties of wood.

Chapter 3 (Methodology) will describe the experiment that is conducted. This chapter includes the experiment procedures, apparatus setup as well as other logical approaches to overcome the problems and limitations.

Chapter 4 (Results, Analysis and Discussions) will present the results obtained in the experiment and relate them to several theories. Detailed analysis of the results will also be covered. In the discussion section, the characteristics and trends of the results will be discussed and justified whether they are consistent with existing theories.

Finally, in Chapter 5 (Conclusions and Recommendations), the constraints and limitations of the existing experiment is discussed together with the conclusions. Also presented here are the recommendations for improvisation on the integrity and reliability of the current experiment.

CHAPTER 2

Literature Review

2.1 Introduction

In conducting this experiment, there are several elements that are significant and can affect the final outcome. In order to analyze the movement of moisture in wood, it is first required to understand the structure of wood. The structure will determine the response of a certain wood specimen in this experiment. MC and its relations is the core and are directly involved in the experiment set-up and therefore thorough knowledge and understanding is required to create the required moisture parameters. Moisture movement mechanism is also studied to comprehend the characteristics of shrinkage and swelling in wood. The anisotropic behaviour of shrinkage and swelling in wood will be discussed. The effect of FSP is introduced. The thermal expansion coefficient is studied to determine its significance to this experiment, to what extend it will affect the results and whether the accuracy is compromised when thermal effects are ignored. The modulus of elasticity or the stiffness of the wood species is directly related to the stress and strain induced upon the wood specimen. The stiffness may deviate from the standard specification. Factors that affect the stiffness of wood are briefly discussed. The modes of deformation in wood are also discussed in detail. Ideally, the experiment should be conducted within the elastic region. The deformation of wood in this experiment is the result of creep and MC changes. It is therefore crucial to understand creep and its parameters. It is also important to note the difference between viscoelastic creep and MS creep.

2.2 Wood Structure

Wood can best be understood as a fiber-reinforced composite material (Schniewind, Berndt, 1999). Composite interactions can occur on several levels of physical structure. At the cell wall layer, composite action takes place between oriented, fibrous, framework material and amorphous matrix material. Composite interaction can also happen between growth zones during different stages of tree growth.

Dry wood is primarily composed of cellulose, lignin, hemicelluloses, and minor amounts (5% to 10%) of extraneous materials. Cellulose is the major component, constituting approximately 50% of wood substance by weight. During growth of the tree, the cellulose molecules are arranged into strands called fibrils, Fibril are then organized to make up the cell wall of wood fibers. Most of the cell wall cellulose is crystalline.

Lignin constitutes 23% to 33% of the wood substance in softwoods and 16% to 25% in hardwoods. It is concentrated toward the outside of the cells and between cells. Lignin binds individual cells together.

Hemicelluloses play an important role in fiber-to-fiber bonding. Lignin and hemicelluloses combine to form the matrix in which the cellulose microfibrils are embedded [1]. Their structure inside the wood cell wall is thought to be that of a water-swelling gel [2]. They are soluble in alkali and water.

Extraneous materials are not structural components. Both organic and inorganic extraneous materials are found in wood. The organic component takes the form of extractives, which contribute to such wood properties as color, odor, taste, decay resistance, density, hygroscopicity, and flammability. Extractives include tannins and other polyphenolics, coloring matter, essential oils, fats, resins, waxes, gum starch, and simple metabolic intermediates [4]. This component is termed extractives because it can be removed from wood by extraction with solvents, such as water, alcohol, acetone, benzene, or ether. Extractives may constitute roughly 5% to 30% of the wood substance, depending on such factors as species, growth conditions, and time of year when the tree is cut.

Wood may be described as an orthotropic material; that is, it has unique and independent mechanical properties in the directions of three mutually perpendicular axes: longitudinal, radial, and tangential. The longitudinal axis L is parallel to the fiber (grain); the radial axis R is normal to the growth rings (perpendicular to the grain in the radial direction); and the tangential axis T is perpendicular to the grain but tangent to the growth rings.

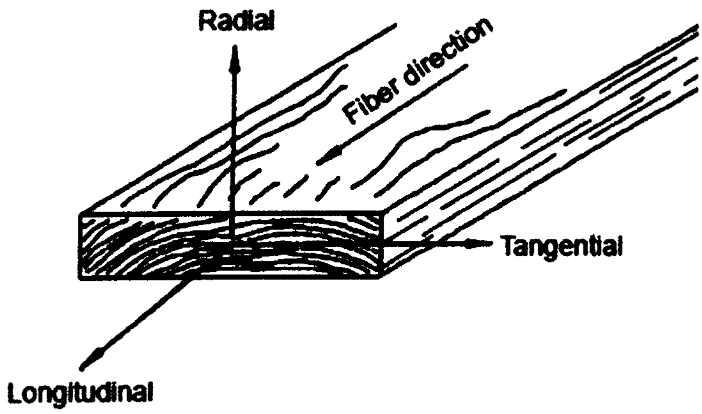

Figure 1 Principal directions of wood

2.3 Wood Specimen

The local Jelutong wood species will be used throughout the entire experiments. The scientific name for Jelutong is Dyera Costulata. The wood is white or straw colored, and there is no differentiation between heartwood and sapwood [4]. The texture is moderately fine and even. The grain is straight and the luster is low. The wood weighs about 465 kg/m^3 (28 lb/ft3) at 12% MC. The wood is very easy to dry with little tendency to split or warp.

2.4 Moisture Content

MC of wood is defined as the weight of water in wood expressed as a fraction, usually a percentage, of the weight of ovendry wood [10]. Weight, shrinkage, strength, and other properties depend upon the MC of wood [12]. In trees, MC can range from about 30% to more than 200% of the weight of wood substance. In softwoods, the MC of sapwood is usually greater than that of heartwood. In hardwoods, the difference in MC between heartwood and sapwood depends on the species. Variability of MC exists even within individual boards cut from the same tree. The equilibrium MC (EMC) of timber is that moisture at which timber neither loses nor gains moisture from the surrounding atmosphere (McNaught, 1987).

2.5 Determining MC

2.5.1 Oven dry method

In the oven-drying method, specimens are taken from representative boards or pieces of a quantity of lumber. Each specimen are weighed immediately, before any drying or reabsorption of moisture has taken place. After weighing, the specimen is placed in an oven heated to 101°C to 105°C and kept there until no appreciable weight change occurs in 4-h weighing intervals. The constant or ovendry weight and the weight of the specimen when cut are used to determine the percentage of MC using the formula

$$\text{Moisture Content (\%)} = \frac{\text{Weight when cut - Ovendry weight}}{\text{Ovendry weight}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots (1)$$