Study on Relationship between Basic Density and Various Group Age of *Gigantochloa scortechinii*

by

NURUL NAJWA BINTI ZUBAIDI

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DECLARATION

I declared that this thesis entitled "Study on Relationship between Basic Density and Various Group Age of *Gigantochloa scortechinii*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________

Name : ______________________

Date : ______________________

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ASTM	American Standard Testing Method
FRIM	Forest Research Institute Malaysia
MDF	Medium Density Fibreboard
PB	Particle Board

LIST OF SYMBOLS

cm^3	centimetre cubic
g	gram
mm	millimetre
m	mass
v	volume
±	plus/ minus
°C	degree Celcius
%	percent

Study On Relationship Between Basic Density And Various Group Age Of *Gigantochloa Scortechinii*

ABSTRACT

This research is to study on between physical properties which is basic density of bamboo species *Gigantochloa scortechinii* with various group ages. The bamboo sample has been harvested at FRIM Kelantan (Jeli). The group of ages that has been choose in this research are from age 1, 2, 3, 4 and 5. The basic density test was carried out by selecting sample in even number of internode starting from culm 2 until culm 26 with 3 replications of sample in each internode. This research was conducted by using the denisty meter to get the basic density. The average for the overall basic density has been recorded that bamboo was 5 years old have a higher basic density than the other bamboo from 1, 2, 3 and 4 years old. From this study, the basic density of bamboo at the bottom shows an increase, while in the central part of bamboo internode the basic density flactuate and decrease in basic density readings at the top of the bamboo through various stages of life. Through the reading of correlation that were calculated, there are only two different bamboos which value is significant, 2 and 5 year-old with the r-value 0.620 (p=0.024) and r-value is 0.809 (p=0.001) respectively. In conclusion, bamboo was 5 years old have a higher level of basic density and the coefficient of correlation is very significant and it was suitable to be harvested for use as a raw material in any product.

Kajian Mengenai Hubungan Di Antara Ketumpatan Asas Dengan Pelbagai Kumpulan Umur *Gigantochloa Scortechinii*

ABSTRAK

Kajian ini adalah menyiasat hubungan sifat fizikal iaitu ketumpatan asas buluh dari spesis *Gigantochloa scortechinii* yang diambil dari kawasan FRIM Kelantan (Jeli) dengan pelbagai kumpulan umur. Buluh yang dipilih di dalam kajian ini adalah daripada buluh yang berumur 1, 2, 3, 4 dan 5. Ujian ini dijalankan dengan memilih sampel mengikut nombor genap ruas iaitu bermula daripada ruas 2 sehingga ke ruas 26 dan sampel diambil dengan 3 kali pengulangan sampel di setiap ruas. Ujian ketumpatan buluh ini dijalankan dengan menggunakan alat meter ketumpatan. Purata bagi ketumpatan asas secara keseluruhan mendapati bahawa buluh yang berumur 5 tahun mempunyai ketumpatan asas yang tinggi berbanding buluh yang berumur 1, 2, 3 dan 4 tahun. Daripada kajian ini, ketumpatan asas buluh di bahagian bawah menunjukkan peningkatan, manakala di bahagian tengah buluh ketumpatan asas buluh berubah-ubah dan penurunan bacaan ketumpatan asas di bahagian atas buluh melalui pelbagai tahap umur. Melalui bacaan pekali korelasi yang telah dikira, terdapat dua buluh berbeza tahun yang mempunyai nilai yang ketara iaitu buluh berumur 2 dan 5 tahun dengan r-nilai 0,620 ($p = 0.024$) dan 0.809 ($p = 0.001$) masing-masing. Secara konklusinya, buluh yang berumur 5 tahun mempunyai tahap ketumpatan asas yang tinggi dan pekali korelasi yang sangat ketara dan ianya telah sesuai untuk dituai untuk digunakan sebagai bahan mentah di dalam mana-mana produk.

CHAPTER 1

INTRODUCTION

1.0 Background of Study

Bamboo is a plant that categorized under the monocotyledonous plant and it has been classified as non-wood species in wood industrial. Bamboo is a universal plant which it can be easily accessible worldwide. There are about 70 genera and over 1,200 to 1,500 species of bamboo has been found from all around the world (Rogerson *et al.*, 2014). In Malaysia, there are approximately 70 species of bamboo which is 50 from Peninsular Malaysia, 30 species found in Sabah area and 20 species in Sarawak (Tran, 2010).

Most of the bamboo species in Malaysia can be found at logged-over areas, hill slopes, and river cliffs, and also open space land with an altitude from sea level to 1,000 metres (Razak *et al.,* 2013; Kamaruddin, 2009). Bamboo's habitat is actually placed that has been abandoned and far from human activities. Basic requirements for bamboo's habitat are good soil, water, light, and a climate that is not too severe (Ted, 2010). Bamboo also can be planted as garden decorations or house decorations. However, not all species suitable to be used as plant decorations. This is because only several bamboos that are adaptable for growing in the ground and in containers. Examples of bamboo that can be planted at home such as *Thamnocalamus*, *Sasa* and *Fargesia robust* (Ted, 2010).

Bamboo has a lot of unique characteristics that not widely discover. It has a very fast growth rate due to its unique rhizome-dependent system. Some bamboo species can grow to a certain height per day, which are about 15 to 18 centimetres (Rogerson *et al.*, 2014). This is because bamboo came from grass family which has an ability to grow faster than other plants. Bamboo can grow wild in any conditions like hot temperature and rain seasons in the forest as they do not require any intensive care (Razak *et al.*, 2013). It also has a short time to mature. Due to its fast-growing ability, the bamboo can be harvested in the short time that is within three to five years before it can be converted to suitable products (Razak *et al.,* 2010).

Due to the high-technologies, bamboo has been studied and gives a lot potential in many industries. Since the 20th century, many industrial applications have been using bamboo as a raw material in wood-based composites because of its density which is higher in strength. It can be one of potential material in wood-based industries to be used in many ways as it can produce good and structural products, and also lighter than steel. Meanwhile, bamboo culms have a great potential in the wood-based composite that is widely used in modern constructions and products. These potential in the same time can help in replacing or reducing the using of timber which depletes from day to day. The end-product of bamboo has been verified well, then the wooden boards due to its rigidity and durability (Chaowana, 2013).

Nowadays, the demand for timber is increasing in the world's market. The timber supply plantation also could not cope with the growing demand for timbers (Razak *et al.*, 2012) and it is one of the causes for many illegal logging being reported. This illegal logging will cause serious damaged if it is not controllable and thus will resulting to global warming. Global warming nowadays becomes a serious issue globally. In order to save the world to our future needs, it needs the changes in every single step that can cause little-to-more pollution such as environmentally friendly products. The used of bamboo as a potential material replacement of wood can help in decreasing in global warming, especially in manufacturing, design and construction material (Nelli, 2012).

The significance of this study are to have a variety ideas of bamboo usage and its importance from the bamboo life in sustainable development and it also can help in making our life more sustain than before as it can replace or can be manage well than the product-based material like wood, metals and plastics which can conclude to global warming. People should know the potential of bamboo which gives a lot of benefits to Earth and also to human well-being. Bamboo can help in many ways to save the world to our future needs. For example, bamboo can help in deforestation which is mainly due to timber logging where the plantation of bamboo can reduce the using of timber (INBAR, 2014).

This research is focusing on how bamboo can help in wood-based industries and globally such in giving the information related to basic density based on the age of the bamboo. The age of bamboo will be selected from a young age to matured age which are 1, 2, 3, 4 and 5-year old of *Gigantochloa scortechinii*. This information is very important in order to know the physical properties of the bamboo and either it suitable age to be a harvest to be used as to make a certain product. This study will help in reducing bamboo harvest at an early age and producing a good product based on the strength of the bamboo. Bamboo has been in increasing attention for industrial applications especially in wood-based industries since 20th century (Chaowana, 2013).

1.1 Problem Statement

The utilization of bamboo in industrial sectors can replace the use of certain wood species and steel, due to its potential strength and thus, will save the environment from deforestation and environmental changes. Deforestation in worldwide is becoming a hot issue which it is caused by human activities and it can affect human's life and also the environment and ecosystems as well as it can cause global warming, species extinction and also soil erosion (Chakravarty *et al*., 2012).

The strength and durability of bamboo are the main characters to clarify the appropriateness of the structural application. In terms of its structural properties, bamboo has an extremely strong fibre to compare with concrete and roughly have a same strength-to-weight ratio of steel in tension. Thus, the bamboo has long spans same as the concrete (Gutu, 2013). Its strength also being reported by Khairun (2003), which has higher in strength than steel, cement, woods and plastics.

Bamboo has a short period of time to mature, which about two to five years of planting depends on its final products. Local community or villagers, however, tend to cut the bamboo at early age of bamboo and lead to limited information on their finishing properties. Studying on the physical properties especially basic density property of various age groups of *Gigantochloa scortechinii* can help in providing the information in order to improve the utilization of its end-product. This study also benefits immensely in terms of avoiding the harvesting bamboo in early mature aging.

1.2 Objectives

1. To evaluate the basic density at different internodes of *Gigantochloa scortechinii.*

2. To study on the basic density of various age groups of *Gigantochloa scortechinii*.

3. To identify the relationship between basic density of *Gigantochloa scortechinii* and age groups.

CHAPTER 2

LITERATURE REVIEW

2.1 Bamboo

Bamboo is also known as *Bambusa* has seven to ten sub-families of genres. There are approximately about 75 genera and they are from native to Africa, the Americas, Asia and Oceania and have been introduced into Europe (Benton, 2015). It includes in the grass family, Gramineae member which same as weeds, corn, and paddy (Kamaruddin, 2009). Bamboo is a unique group of giant arborescent grasses where its culms arise from its unique dependent-rhizome (Khairun, 2003). Grass actually can grow taller in the short range time and can live wildly without special care. It is from the sub-family of Bambusoidae and super-tribe is Bambusodae (Naszroul, 2012).

Bamboo can be accessible through globally. There are over 1,600 species all over the world that can be found in diverse climates from cold mountains to hot tropical regions (Rogerson *et al.*, 2014). From 59 totals of bamboo species, there are only 14 species that are commercially utilized because of lack of knowledge on the properties and potential usage. Bamboos are usually utilized as to make furniture, daily instrument tools, and crafts. The rest species are left idle in the forest or habitat (Khairun, 2003).

Bamboo can be easily found in Southeast Asia which includes 64 percent from worldwide. Next is 33 percent which is from South America and the rest of 3 percent can be found Africa and Oceania (Jawaid, 2012). By looking at the distribution of the bamboo, most of them located in Asian countries because Asian countries do have medium-dry climates and has a moderate rainfall on average. This climate is very suitable for bamboo to live and distribute wildly. This is because bamboo can live wildly in the forest with the contact of soils and damp conditions (Lasius, 2005).

Bamboo can adapt well in temperature around 8.8ºC up to 36 º C maximum temperatures and annual precipitation of 1,020 to 6,350 mm (Tran, 2010), which is very suitable for the tropical and subtropical regions of the world (Rogerson *et al.*, 2014). This is shown that Asian has a good climate for the bamboo growth as most of the Asian country has tropical climate over the year. It is a great place for bamboo to grow abundantly and widely distributed. Malaysia is known as a tropical rain forest. Malaysian forest always receives 2,000 mm of rainfall are every year which is good for the bamboos distribution (Galvin, 2009).

In Malaysia, there are approximately 70 species of bamboo where there are 50 species in Peninsular Malaysia, 30 species from Sabah area and 20 species in Sarawak. Most of them are widely distributed wild at the edge of forests, logged area forests and along the river banks (Razak *et al.*, 2013). Based on Kamaruddin (2009), Kelantan has the highest density of bamboo which covers about one hundred fifty-five (155) hectares and followed by Pahang, covers about one hundred twenty-two (122) hectares. Table 2.1 show the density of bamboos forest district in Peninsular Malaysia where Kelantan has the highest density of bamboo forests of *Gigantochloa scortechinii* which species that will be focussed on this research (Lockman et al., 1992).

Table 2.1: Density of bamboos by forest district in Peninsular Malaysia

State	Compartment areas		Stock		Species
	Hectares	(%)	No. of culms	(%)	
Johor	31 615.51	100	3 881 600	100	*B. heterostachya, S. zollingeri*
Kedah	20 902.55	100	6 405 900	100	*D. asper, G. scortechinii, S. grande*
Kelantan	90 747.00	100	31 035 750	100	*G. scortechinii, S. grande, G. species, D. pendulus*
Melaka	563.37	100	249 750	100	*D. asper*
Negeri Sembilan	24 284.22	100	7 \415 460	100	*D. sinuatus, S. zollingeri*
Pahang	120 367.63	100	23 480 760	100	*S. brachycladum, S. gracile, B. vulgaris, D. asper, B. ridleyi*
Perak	67 680.49	100	20 174 160	100	*B. vulgaris, S. zollingeri, G. wrayi, D. scandens, S. grande, G. scortechinii.*
Perlis	0.00	0	0	0	
Pulau Pinang	2 739.00	100	1 096 950	100	*S. zollingeri, B. arundinacea*
Selangor	39 641.36	100	12 397 410	100	*G. scortechinii, D. asper B. vulgaris*
Terengganu	22 976.00	100	3 446 400	100	*G. scortechinii, D. asper D. sinuatus*
Wilayah Persekutuan	0.00	0.00	0	0.090	
P. Malaysia	421 722.38	100	110 584 140	100	

Source: (Lockman *et al.*, 1992)

Bamboo has a lot of specialities and it is very unique than other plants. The uniqueness of bamboo is not classified as a tree but it can grow taller as well as tree. It can grow about to 20 metres tall depends on its species (Khairun, 2003). It can grow up until it will be fully matured after three years old to five years old and stop growing. Bamboo have more strength to weight ratio compared to woods which it can be facilitates when it harvests, transport and manufacture the products. It has fast growth rate where it can grow about 15 to 18 centimetres in a day depends on its species and it also can be replenish itself after harvesting (Rogerson *et al.*, 2014).

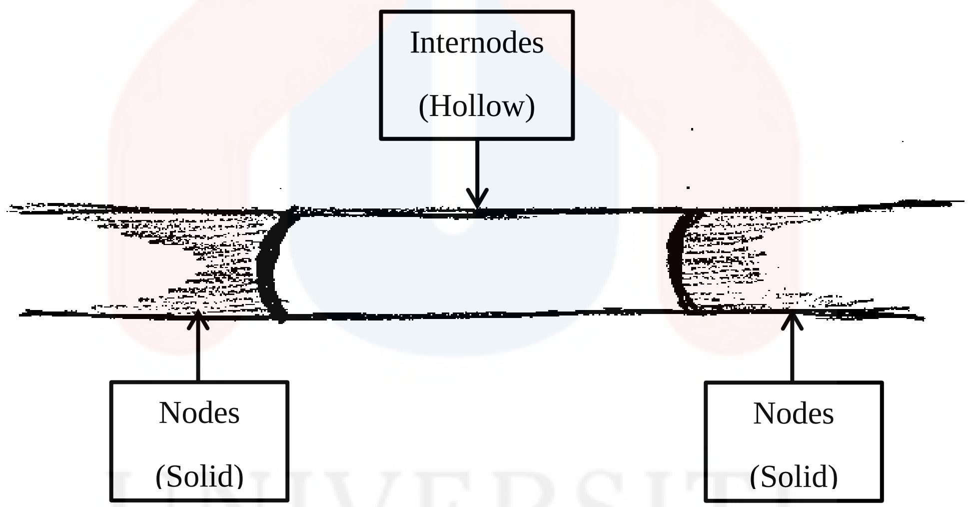

Figure 2.1: The nodes and internodes of bamboo

Source: (Huang *et al.*, 2015)

Bamboo can grow to its full height, unlike trees. It also girths in a single growing season. The height of growth bamboo culm is depending on the internodes growth. In the Figure 2.1 shown is the node and the internode of a bamboo. The length of internode can be longer on the upper culm rather than the lower culm. This is because the upper culm is the first culm to grow and it will grow until it reaches its maturity. The speed of the bamboo growth is varies between the internodes (Chaowana, 2013).

The bamboo strength, elasticity and lightness also cannot be compared with steel, cements and plastics (Suhaily *et al.*, 2013). It may look likes unbelievable but steel, cement does have limits until several time to be used as it not naturally made and also not eco-friendly. It may affect the human well-being and environment in future. Compared to bamboo product, like bamboo woven house, it can be used for a long time and it not lead to environmental pollution even when it being abolished because of damaged (Janssen, 2000).

As bamboo is another level compared to steel, cements, woods, and plastics, it can be a great potential for bamboo to be used as based-material in construction or industries. Bamboo is eco-friendly, easy access and also have short time to mature. It does not have to wait for 15 years or more like teak plantation to achieve mature age and be able to harvest to produce a product and teak timber is much higher than bamboo (Agus *et al.*, 2011).

2.1.1 *Gigantochloa scortechinii*

Gigantochloa scortechinii also known as Buluh Rayah, Buluh Gala, Buluh Paao, Buluh Seremai or Buluh Telur in the local community in Malaysia. Most of them called *Gigantochloa scortechinii* as Semantan bamboo and it the most widespread or the most useful species in Peninsular Malaysia (Khairun, 2003). Figure 2.2 shows a clump of *Gigantochloa scortechinii* which are the most useful bamboo and grow widely in Kelantan. It is *Gigantochloa scortechinii* also be the most popular tropical bamboo species for plantation (Razak *et al.*, 2012).

Figure 2.2: A clump of *Gigantochloa scortechinii* bamboo

Source: (Ismail, 2011)

In Peninsular Malaysia, there are 13 species of *Gigantochloa*. There are *Gigantochloa albopilosa, Gigantochloa rideleyi, Gigantochloa hasskarliana, Gigantochloa latifolia, Gigantochloa ligulata, Gigantochloa albovestita, Gigantochloa rostrate, Gigantochloa thoii, Gigantochloa scortechinii, Gigantochloa holtumiana, Gigantochloa wrayi* and the other two species that only known as *Gigantochloa spp*. From 13 species of *Gigantochloa, Gigantochloa scortechinii* is the most abundant and popular bamboo species in Malaysia (Khairun, 2003).

Based on research by Razak *et al.*, (2009), *Gigantochloa scortechinii* can have a life span for 18 to 36 months after heat treatment, chemical treatment or painted with marine paints as to make a frame raft for aquaculture (Razak *et al.*, 2008). It is very eco-friendly and thus can reduce the cost of buying raw material to do the frame. It also can be easily cultivated and have a good structure that can suitable in industrial usage. *Gigantochloa scortechinii* also has been proven by its strength properties better than other species such as *Gigantochloa brang, Gigantochloa levis and Gigantochloa wrayi* (Razak *et al.*, 2015).

Gigantochloa scortechinii has many uses and has being used since ancient times to make a product such as in manufacturing of poultry cages, shade blinds and barbeque sticks, and tooth picks. Utilization of *Gigantochloa scortechinii* has a high industrial usage potential and has been label as the most promising alternative materials to be the supplement for timber in Malaysia and it has been identified as one of the most important and extensively used in bamboo industries (Norul *et al.*, 2006).

2.1.2 *Gigantochloa scortechinii* structure

Bamboo morphology is divided into two systems which are rhizome and culm system (Chaowana, 2013). *Gigantochloa scortechinii* is slightly different from other species where it has a lot of advantages that are all because of its bamboo structure. *Gigantochloa scortechinii* has a very good in structure and have a lot of benefits from its roots or rhizome and its culms (Anwar *et al.*, 2005).

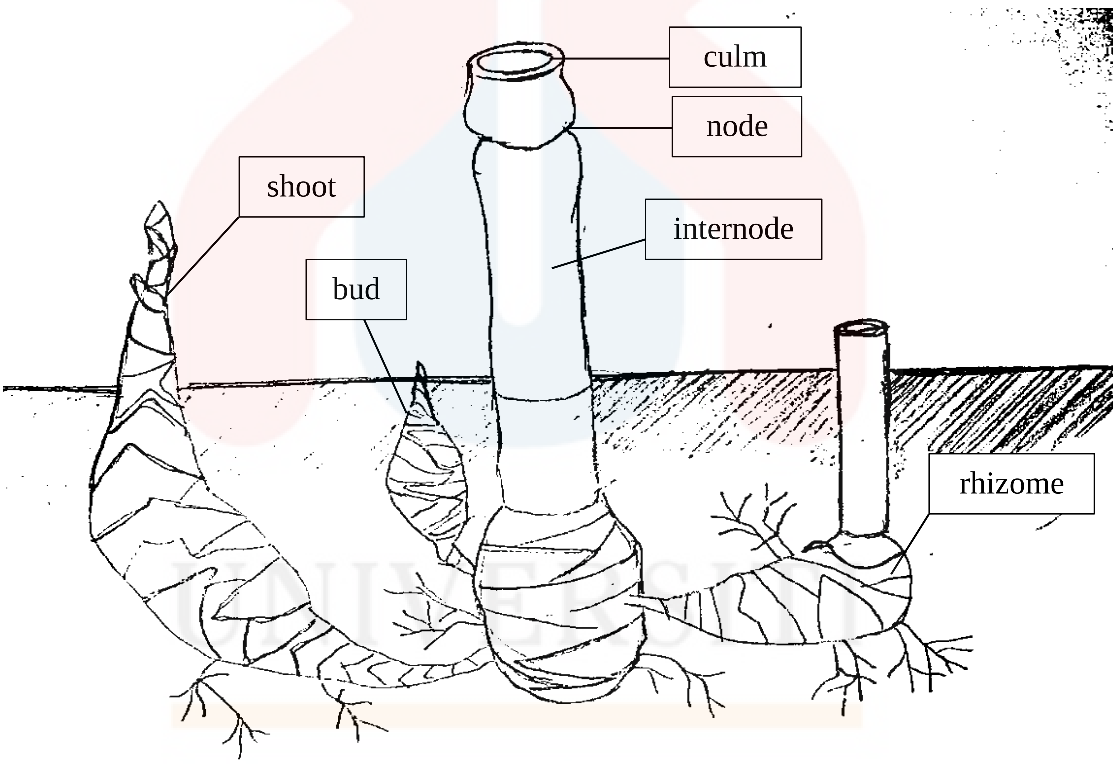

Figure 2.3: Structure of bamboo roots for sympodial or clumping bamboos

Source: (Nilsson, 2015)

Rhizome systems or subterranean stem is the part of underground. *Gigantochloa scortechinii* has rhizome-dependant system where the rhizome is densely tufted and sympodial. Figure 2.3 shows the structure of the roots that is sympodial which is also being called as clumping bamboo. It has axillary buds on the base stem that can help in developing shoots directly upwards and at the same time can grow new stems. It is classified as monocotyledon plants due to its fibrous roots, only have one cotyledon with the embryo and developed underground as the rhizome (Razak *et al.*, 2012).

For the culm systems, *Gigantochloa scortechinii* has a good structure of culms. *Gigantochloa scortechinii* can grow tall within 17 to 20 metres long. It also has thick culms wall and it is uniquely where it has uniform sizes between the nodes and internodes from the bottom culms up to upper culms. The wall thickness range can be in between seven to twelve centimetres while it internodes length will go up until 42 centimetres. The number of culms of a bamboo from this species is range from 50 up to 80 culms. This makes *Gigantochloa scortechinii* is very suitable and high in market demand in industrial market usage (Razak *et al.*, 2012). This is because all parts of its culms can be used and do not have to harvest too much in numbers to make certain products. It can be used to produce high value-added products like laminated panelling for parquets and furniture (Azmy *et al.*, 2011).

The *Gigantochloa* species are recognized by its straight culms, the absence of prominent auricles and also the long blade at culms sheath. The green culms sheath placed at the very base and it flushed an intense an orange to upwards that covered with dark brown to black hairs. This species usually can grow about 20 metres tall with diameter between six to twelve centimetres and also internode length between 30 to 40 centimetres long (Tran, 2010).

2.2 Physical properties

Physical properties of bamboo are varied for each species. Each species does not contain same properties and not all bamboo can be used to produce a product. As mention earlier, from total of 59 species of bamboo, only 14 of them that can be used or utilized commercially and the rest are left idle in their habitat (Khairun, 2003).

In this study, it will be more focus on basic density as to see the difference on ages of *Gigantochloa scortechinii* and even culms sample. It is including several properties of bamboo such as culms height, number of internodes per culms, internode length, internode diameter, culm thickness, moisture content, and basic density (Khairun, 2003).

Physical properties can be measured without changing its composition matter. Before using bamboo for various applications, physical properties are considering as an important factor in determining the suitability culms of bamboo from different age groups to turn it out into end-product. It also can determine the suitable age of bamboo to be used in treatment, dimensional changes and the attack of insects and fungi (Razak *et al.*, 2009).

2.2.1 Basic density

Bamboo densities are categorized into three groups which is basic density, fresh density air dried density and absolute dry density. It varies depends on its culms, species and ages of the bamboo. This research only focussed on basic density of bamboo in certain species which is *Gigantochloa scortechinii*. Density are varying depends on its culms, species and ages of bamboo. If the density of bamboo higher, the more strength the bamboo has in the same culms (Gutu, 2013).

Basic density is defined by oven-dry mass of sample divided by its green volume in order to know the strength of bamboo after being oven-dried. It is one of the most important criteria to be tested before turn the bamboo into a product. This is because basic density of the bamboo will show the perfect bamboo source neither the ranges of age of bamboo nor the culms itself. It can affect the quality of product totally as every each of them has different basic density. For example, if used bamboo as one of a raw material in construction, it need to have a higher basic density as the higher basic density, the higher the strength of the bamboo. From basic density determination, amount of wood pulp that can be produced, workability of the material or its shipping weight can be known (ASTM, 2014).

Even though basic density is including in physical properties, it cannot be determining by through see, feel and taste. It should support by the formula which is displacement method and need to be oven-dried as to see the difference between before and after oven-dried for 48 hours.

2.3 Product of bamboo

Bamboo is famous with its strength and its durability when it has been turns out to products. Bamboo on its physical looks is hard and has strong in properties rather than a wood. However, it has hollow at the internodes compared to the woods (Anokye *et al.*, 2016).

Creativeness of human occurs due to creation of a product from bamboo in order to help in their daily life. History of bamboo handicraft and traditional designs have already known from ancient times and it is written in the history of human life because their creativeness and their diligence (Anokye *et al.,* 2014; Babarmahal, 2011).

Nowadays, there are still have products that is made from bamboo namely, from handicraft to structural material like scaffolding but not widely be made. Scaffolding before has been used at China and Japan to help human to make higher buildings. It actually embraces good mechanical and strength properties as good as woody material properties. Bamboo strength and elasticity also stronger than steel, cements and plastics which contribute in construction (Suhaily *et al.*, 2013).

Table 2.2: The bamboo product based on their species

Species	Local names	Uses
Bambusa blumeana	Buluh duri	toothpicks, furniture, musical instruments, shoots as food
B. heterostachya	Buluh galah	toothpicks, chopsticks, blinds
B. vulgaris	Buluh minyak	paper, furniture
Dendrocalamus asper	Buluh belong	fences, bridges, baskets, shoots as food
Gigantochloa scortechinii	Buluh semantan	satay sticks, toothpicks, blinds
Schizostachyum brachycladum	Buluh nipis	chopsticks, handicrafts

Source : (Poh, 1994)

Table 2.2 shows the production of bamboo based on its species and local name. The production of bamboos in ancient time has been utilized as it popular with its strength and the long lasting. Until the arrival of new technology, bamboo have been studied and learned by humans, and find out that bamboo has more than use raw product from itself. Our ancestors have already utilized bamboo from a few centuries ago. Traditionally, they used bamboo to make bridges, woven bamboo houses, woven mats, rafts, skewers, chopstick, handicraft and charcoal (Anokye *et al.*, 2014).

2.3.1 Sustainable product from bamboo

Nowadays, there are a lot of products that has been produced and promote sustainability in order to save our planets from destroy. The uses of too much plastics and cutting trees can be a threat to Earth as plastic cannot be demolished and cutting trees can contribute to deforestation. Sustainable itself, bring the definition of the ability to meet the needs of the present without compromising the future generation to meet their own needs (Robert *et al.*, 2005).

The advance of technology and high education lead people in doing research further to substitute the raw material in a product. It is a good and intelligence idea as it can reduce the production cost and at the same time can reduce in contribution of environmental pollution. Environmental pollution is one of the hot issues nowadays which can give a bad impact to Earth and also to human health and these problems are come from the human activities (McMichael *et al.*, 2003).

In order to save the environment and also the ecosystems, people nowadays tend to know the awareness and have high self-esteem, the product has been created to become more innovative and sustainable. Bamboo has a great potential to save our environment and ecosystems as it has the role for controlling erosion, riverbank protection, landslide prevention and land rehabilitation (Janssen, 2000).

The uniqueness and attractiveness of bamboo give advantages which it can help to some extent in our nature preserve. Bamboo has very fast growth and unique appearance material where it can help in deforestation and thus can produce a quality product. Bamboo has been investigated by number researchers due to its excellent strength properties which can be perform as good as other building materials such as steel, concrete and timber (Anurag *et al.,* 2013).

The examples of sustainable product from bamboo are like it can be converted into engineered products such as composites, particle board (PB), medium density fibreboard (MDF), plywood and furniture (Chaowana, 2013; Anwar *et al.,* 2012). Bamboo is environmentally friendly to be used. This is because the advantages of using bamboo in producing a product are it is low in cost and readily available, it is easy to maintain or replace at the same place, easily to dispose of once it has been damaged and it has no threat to the environment (Razak *et al.,* 2013).

CHAPTER 3

MATERIAL AND METHOD

3.1 Material

The main material used in this research is *Gigantochloa scortechinii*. Three (3) defect free bamboos of 1, 2, 3, 4, and 5-year old has been harvested from Forest Research Institute Malaysia (FRIM), Batu Melintang, Jeli, Kelantan. The selected bamboos were filtered based on good form and have long straight culms, decay, and insects free. Chainsaw and handsaw has been used to cut the bamboo based on desire size and transportation. Aluminium foil also been used to fold the end of culms to avoid losing its moisture. All selected and cut bamboos then transported back to Universiti Malaysia Kelantan, Jeli Campus for further processing.

3.2 Sample Preparation

In this research, *Gigantochloa scortechinii* or also known as Semantan bamboo was being selected because of it can be easily found and widely distributed in Kelantan especially in Jeli area. The selected bamboos from 1 to 5-year-old of *Gigantochloa scortechinii* has been cut and separated at different internodes segment started with even numbers of 2 up to 26. Even numbers sample was chosen because to make or to see the difference between data taken. The data may be not very varies if the data collect for each culms. Thirteen (13) internodes culms of 1, 2, 3, 4, and 5-year-old with three (3) replications will be used in determining the basic density of *Gigantocholoa scortechinii*. Three replications were needed in order to account this variation among sample and the determination of basic density.

The bamboo samples have been cut according to the age of bamboo or with the easiest to cut down first. *Gigantochloa scortechinii* were cut randomly from the age of 1, 2, 3, 4 and 5-year old using chainsaws to facilitate and accelerate the process of cutting.

Figure 3.1: Cutting the bamboo at the first culm or from the bottom of the *Gigantochloa scortechinii*.

Figure 3.1 shows the initial internodes bamboo cut at the first culm which been used in this study is culm number 2 starting from the bottom of the bamboo's culm growth followed by culm number 2, 4, 6, 8, 10 until 26. Then, the next following steps are shown in Figure 3.2.

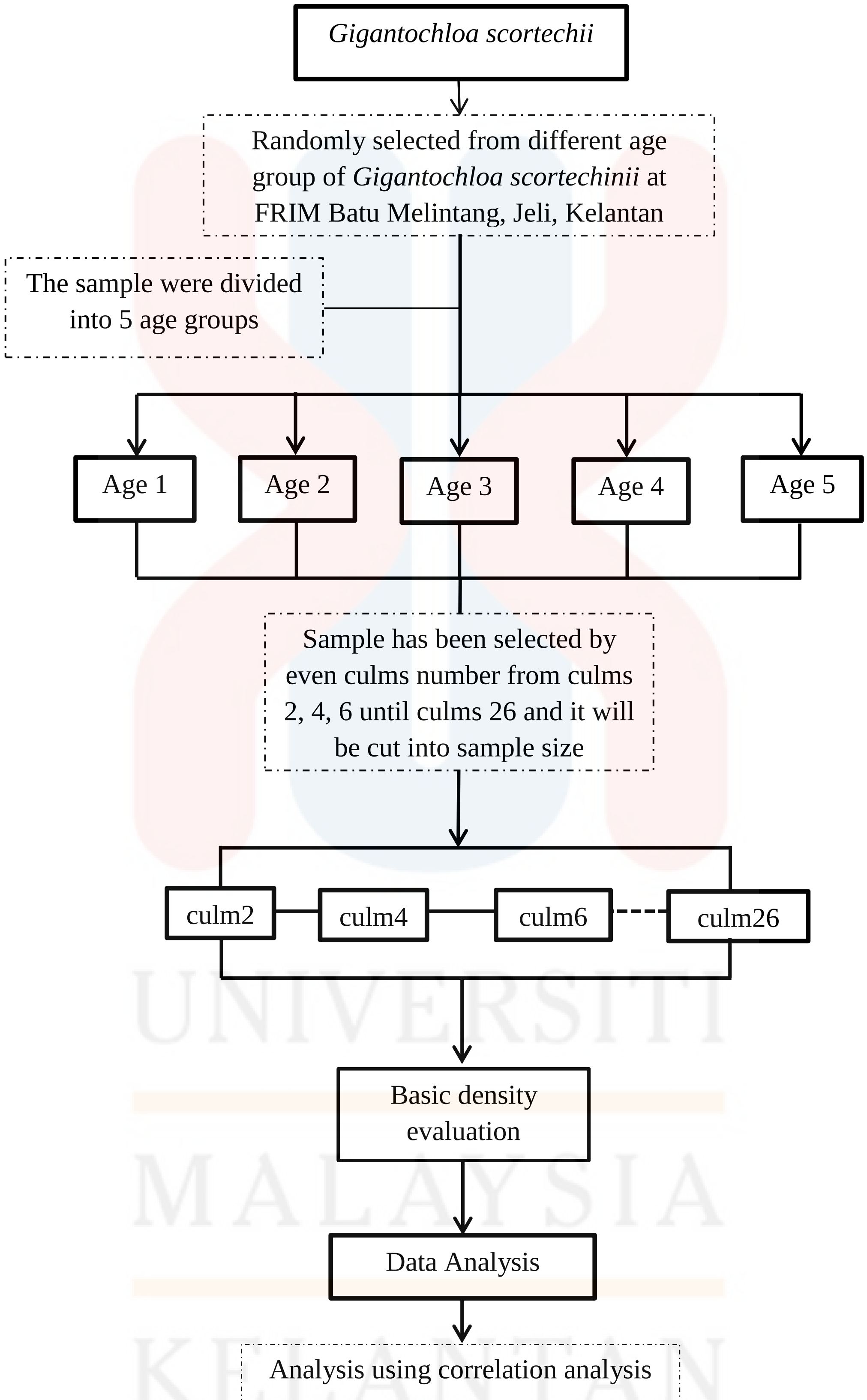

Figure 3.2: The method flowchart of this research

3.3 Determination of Basic Density

The basic densities of bamboo were being measured by American Standard Testing Material (ASTM) D-2395 with modification which was for Standard Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials. Modification was needed in order to suitable the standard method with the bamboo as the standard was only for the wood and wood-based materials and bamboo was categorized as non-wood material.

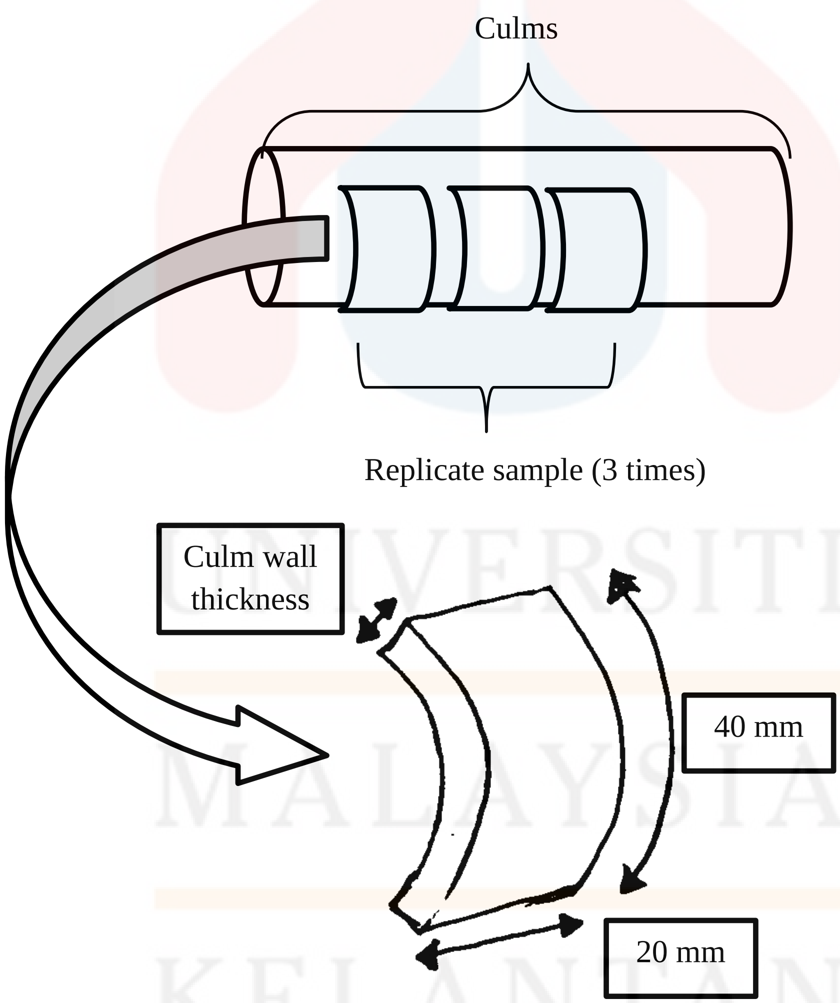

Figure 3.3: Sample were cut into size sample that is 20 × 40 × culms wall thickness (mm)

A total of 195 samples from each internodes and age with three (3) replications been used in this study. All of the internode samples were cut to size sample which was 20 mm × 40 mm × culms wall thickness (mm) as shown in Figure 3.3. This was the standard size for testing the displacement method.

Then, the initial weight of sample were taken before inserted into the oven. The sample has been oven-dried at 103±2°C for 48 hours. Then, sample will be taken out from oven and put into the desiccator jar until the constant mass achieved. After that, the mass of a sample of oven-dried will be recorded by using density meter. Next, the sample was immersed in a beaker filled with water to know the green volume of bamboo sample. The formula to find the basic density shown in Equation 3.1.

Basic Density (g/cm^3) = m / v …………………………………… Equation 3.1

Where,

m = oven-dried mass (g)

v = green volume (cm^3)

3.4 Statistical Analysis

For better understanding in basic density of *Gigantochloa scortechinii*, the experimental data was calculated and analyse by using statistical data analysis. The correlation analysis has been analysed in order to support the relative importance of effect of study variables age groups and different internodes of *Gigantochloa scortechinii.*

CHAPTER 4

RESULT AND DISCUSSION

The study was conducted on the physical properties of bamboo species *Gigantochloa scortechinii*. For this research, basic density was chosen and the factor of ages and the different internodes have been used to investigate the physical properties of basic density in more detail.

From the previous study by Azim (2013), the basic density were recorded as fluctuated where average of basic density for 1 year-old was recorded higher than 2 year-old bamboo which was 0.87 g/cm^3 and 0.78 g/cm^3 respectively. It increased again at 3 year-old with value of basic density, 0.85 g/cm^3 and stop increasing at 4th year of *Gigantochloa scortechinii* with value 0.89 g/cm^3. At 5 year-old of *Gigantochloa scortechinii*, the basic density was recorded decrease a bit from the previous, 0.87 g/cm^3. This was happened due to the faster undergoes maturation process through years and increaasing in fibre and parenchyma cell walls (Azim, 2013).

From the previous study, the estimated result can be determined by basic density is higher based on the ages and also from the various number of bamboo culms. The portion of internodes of the culm also play as a big role in determination of physical properties (basic density).

4.1 Basic Density

Table 4.1 shows the average of the basic density per culm with plus minus of standard deviation based on number of even internode and different ages from 1 year old to 5 year old of *Gigantochloa scortechinii*. The sample has been harvested at Forest Research Institute Malaysia (FRIM), Batu Melintang, Jeli, Kelantan which was divided with even number.

Table 4.1 : Average of basic density per culm on different ages

		Basic Density (g/cm^3)				
	Age	1	2	3	4	5
Number of Even Internode	2	0.55±0.02	0.61±0.04	0.61±0.00	0.68±0.00	0.60±0.02
	4	0.61±0.00	0.64±0.01	0.71±0.01	0.68±0.01	0.63±0.01
	6	0.62±0.00	0.68±0.02	0.72±0.01	0.72±0.01	0.72±0.01
	8	0.59±0.01	0.72±0.01	0.72±0.01	0.74±0.01	0.67±0.02
	10	0.59±0.01	0.75±0.01	0.69±0.00	0.68±0.00	0.67±0.02
	12	0.57±0.16	0.75±0.05	0.70±0.03	0.66±0.01	0.72±0.01
	14	0.58±0.02	0.69±0.01	0.68±0.07	0.64±0.01	0.74±0.01
	16	0.62±0.01	0.73±0.01	0.72±0.01	0.69±0.01	0.80±0.01
	18	0.69±0.01	0.71±0.00	0.68±0.03	0.68±0.01	0.82±0.01
	20	0.64±0.00	0.69±0.11	0.62±0.02	0.66±0.01	0.76±0.02
	22	0.64±0.04	0.74±0.01	0.74±0.01	0.74±0.01	0.79±0.02
	24	0.65±0.01	0.75±0.04	0.84±0.01	0.84±0.14	0.77±0.01
	26	0.60±0.00	0.72±0.02	0.76±0.08	0.76±0.00	0.75±0.02
Average Culm per Year		0.61±0.06	0.71±0.05	0.71±0.05	0.71±0.07	0.73±0.07

Note: mean ± standard deviation

For 1 year-old *Gigantochloa scortechinii*, the average basic density was recorded and the data was flactuated. From the first internode, culm 2, the basic density was recorded increasing until third internode about 7% and it decrease and uniform at culm 8 and 10 with value of basic density 0.59 g/cm^3. Then, it increase steadily again at culm 12 until culm 18.

At culm 20, the value of basic density decreased and in uniform rate until culm 24 with the value of 0.64 g/cm^3 and decrease at last culm (internode 26) with value of basic density 0.60 g/cm^3. This could be due to the bamboo is matured faster than the actual ages. There was also a variation in strength along the culm height (Razak *et al.*, 2013).

The average of basic density bamboo, *Gigantochloa scortechinii* of 2 years-old shown in Table 4.1. The basic density was increase from first culm which is internode number 2 to 8 and and in uniform rate until internode number 24. At internode number 26 which is last internode, the basic density recorded was drop 3% which was 0.72 g/cm^3 from 0.75g/cm^3 for culm 24. This is may be due to the longer period taken during harvesting bamboo sample which resulting moisture loss. The top part of bamboo may has loss a lot of water to atmosphere as it far from the main source of roots which collects water from underground water and thus affect the basic density value.

Basic density for 3 years-old has been recorded which the internode 2 has the least value of basic density (0.61 g/cm^3 and followed by internode 4 until 16, it was in uniform rate and flactuate respectively. At internode 18, the basic density value drop to internode 20 about 10%. Then, basic density increased again at culm 22 and stop at culm 24. At culm 26, the basic density drop at 8%. For overall, the basic density of 3 years-old *Gigantohcloa scortechinii* was increased from the first culm until 24^{th} culm and decrease at culm 26.

The results from the test of basic density of 4 years-old of *Gigantochloa scortechinii* was presented in Table 4.1. According to the results, the value of basic density of 4 years-old culms of *Gigantochloa scortechinii* was uniform at culm number 2 and culm 4 with value 0.68 g/cm^3 . Then, it start increase at culm 6 until culm with the increasing rate was 4%. The next culm decrease until culm 20 and increase again at 18% with the value of basic density at culm 24 was 0.84 g/cm^3. On last culm, the basic density was recorded lower than 24th culm with 0.76 g/cm^3 amount of basic density. The flactuation may occurs due to the moisture loss during the sample preparation as the process to cut the sample takes some times and give effect to basic density data.

Next is the result of basic density for 5 year-old *Gigantochloa scortechinii*, which show that the first internode has the lowest amount of basic density which was 0.60 g/cm^3 and the result was rose steadily until culm 18 with the value basic density, 0.82 g/cm^3. Then, the amount of basic density decline to 7% from internode 20 until the last internode, 26th which the amount basic density culm was 0.75 g/cm^3. The decreasing value may be due to the maturity of the bamboo and depends on the anatomical structure. The quantity and the distribution of fibres around the vascular bundles along the culm wall decreases from bottom towards the top and the production of fibres and vuscular bundles increase due to the thickness wall of the culm (Razak *et al*., 2013; Anokye *et al*., 2016). The wall thickness at the top parts of bamboo of 5 year-old were smaller than the bottom part (Razak *et al.,* 2013).

Lastly is for the average culm per year as shown in Figure 4.1 which was between basic density versus year of *Gigantochloa scortechinii*. It show that the basic density of *Gigantochloa scortechinii* is fluctuated where at second year the average per culm show the increasing but the on third year, the average of basic density is uniform until 4th year with the value average per culm of basic density was 0.71 g/cm^3. On 5 year-old *Gigantochloa scortechinii*, the average of basic density per culm increased about 2% with value 0.73 g/cm^3.

From this result, the average culm per year do not show the increase from the 1 year-old until 5 year-old *Gigantochloa scortechinii*. The uniform rate that has been recorded in the bar chart may be due to this species which was grow as sympodial bamboo. Each clump of sympodial bamboos consists of many culms that connected through rhizome systems. It will create the interdependence between the individual culms. The bamboo sample may have in low sufficient number of roots as it majority depends on nutrients provide by mother rhizome. Thus, it affect the bamboo culms in the clump on quality of the bamboo products. Basic density also being expressed in term of number culms per clump (Tran, 2010).

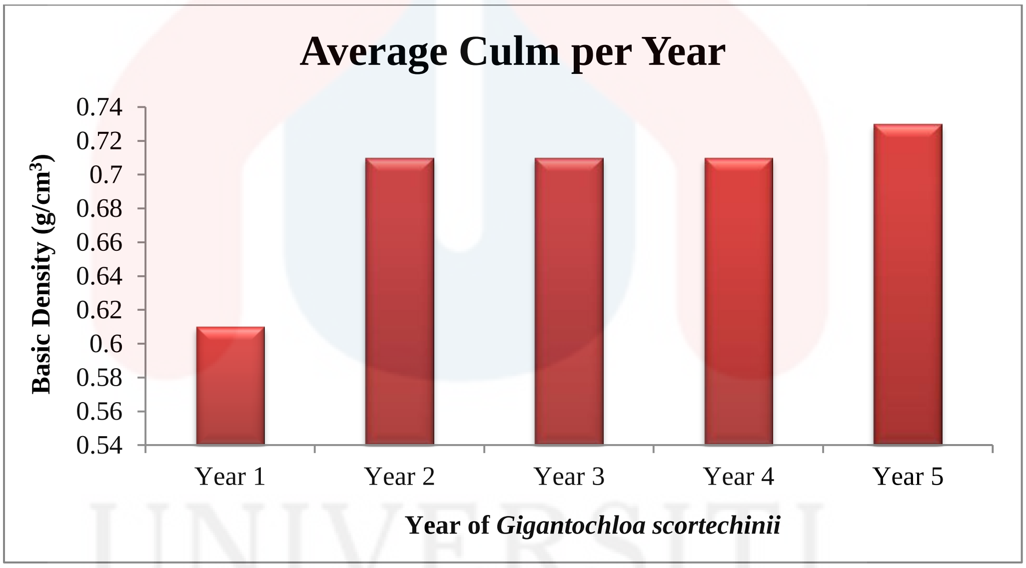

Figure 4.1 : Average culm per year of basic density on age of *Gigantochloa scortechinii*

4.2 Correlation Coefficient between Physical Properties (Basic Density) and Various Age Group of *Gigantochloa scortechinii*

The result on correlation coefficient was obtained by using SPSS. The relationship between all the dependent and independent variable as given in Table 4.2. It indicates the correlation coefficient between different age of bamboo, internodes and basic density of bamboo sample, *Gigantochloa scortechinii*. The r-value was recorded in the table which was in the range of 0 to 1 which indicates the positive value of results.

Table 4.2: Correlation coefficient on different age of bamboo with internode versus density

		1 year-old	2 year-old	3 year-old	4 year-old	5 year-old
		D	D	D	D	D
I	Pearson Correlation	0.221	0.620*	0.468	0.374	0.809**
	Sig. (2-tailed)	0.468	0.024	0.091	0.208	0.001

I : Internode
D : Density

* <0.05 (significance)
** <0.01 (significance)

There was no significant between internodes and density at 1 year-old of *Gigantochloa scortechinii*. The correlation value between internode and density was r = 0.221 meanwhile p value was 0.468 which it indicates there was no significance as the strength of correlation was classified very weak but still positive in result.

For bamboo sample for 2 year-old the correlation coefficient was recorded as significance which was r = 0.620 where p = 0.024 and recorded as 0.05 of level of significance. The r-value was classified in strong and fairly positive result for the strength of correlation.

The analysis show that the correlation coefficient of 3 year-old of *Gigantochloa scortechinii* was not significance where the r-value was 0.468 with p value = 0.091. The significance value was recorded as in moderate and positive result.

Next was for the 4 year-old bamboo sample. The correlation coefficient was recorded as not in significance between internode and basic density as the average value of basic density culm per year was in uniform rather than increase in value. The r-value for 4 year-old *Gigantochloa scortechinii* was 0.374. The significance value indicates moderate in correlation and in positive result. The p value was 0.208.

Lastly, the analysis of correlation coefficient on 5 year-old. The correlation analysis was recorded with r value of 0.809 and p value 0.001. The r-value was nearer to 1 which it can conclude as the positive result and with strong in significance value between internode and basic density.

For overall, the correlation coefficient analysis was recorded in positive value which in range 0 to 1. From Table 4.2, it shows that there were only two of them that have significant in value which were for 2 year-old and 5 year-old. 5 year-old sample show very strong in correlation coefficient as the value of significance was very nearer to 1 which indicates the perfect positive correlation. This show that 5 year-old sample have higher in basic density rather than the others. This can be conclude that 5 year-old was the best and quality bamboo rather than the other ages as it has been matured and have strong physical properties.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, the physical properties especially basic density is very important to be test before using bamboo as a product. Bamboo has been used worlwide as it has a lot of benefit through it properties and usage. That is why this study should have a further study as to know more specified about the properties of bamboo especially in Malaysia as Malaysia also known for having a lot of bamboo tree because the earth's surface and temperate climate help the growth of bamboos.

From this research, it show that the basic density are increase at the bottom part and flactuate at the middle and decrease at the top part through the various age. It can be conclude that the basic density of *Gigantochloa scortechinii* in this study has uniform value through the age and flactuate at the each internode. The relationship between the basic density of *Gigantochloa scortechinii* and various age groups are conclude as very strong in significant for 5 year-old sample.

In conclusion, the evaluation of basic density at different internodes, various age groups of Gigantochloa scortechinii has been obtained and also the relationship between basic density of *Gigantochloa scortechinii* and age groups. From the correlation result, it shows that 5 year-old of *Gigantochloa scortechinii* has a perfect positive correlation which can be conclude that 5 year-old is very high in basic density and very suitable to be used as raw material in products that relate in strength and have strong relationship between basic density of *Gigantochloa scortechinii* and age groups.

5.2 Recommendation

In this study, there are several suggestions that can be pointed out for further research. The recommendation for further research are as below.

Firstly, make the research at only several part of bamboo which are at bottom, middle and top. This is because the basic density data only show a bit of varies and cannot be interpret as data in statistical analysis. In this research, the sample has been taken at even internodes, the data still not varies as sometimes it does have the same value of density. and at the upper part of bamboo show the increaseness of basic density. The research also can be done start with bottom part until the internode 18 only because at the upper part of bamboo does not show the increase in basic density.

Lastly is do research on the strength variation from inner and outer layer of the bamboo. As the basic density are define to determine the stength of the raw material. So, the strength is very related to basic density and it should be tested together to know the real strength of the material. The strength might be varies along the culm height and also among the year of bamboo. Species also varies in strength as different species has different thickness of culm's wall.

REFERENCES

Anokye, R., Bakar, E. S., Ratnansingam, J. and Awang, K. (2016). Bamboo Properties and Suitability as a Replacement for Wood. *Pertanika Journal of Scholarly Research Reviews (PJSRR).* 2(1), 63-79.

Anokye, R., Bakar, E. S., Alhassan, Y. A., Regina, M. K., Atiku, M. (2014). The Difference in Density along the Bamboo Culms of *Gigantochloa scortechinii* and *Bambusa vulgaris. International Journal of Emerging Technology and Advanced Engineering.* 4(10), 638-643.

Anurag, N., Arehant, S. B., Abishek, J., Apoorv, K., and Hirdesh, T. (2013). Replacement of Steel by Bamboo Reinforcement. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE).* 8(1), 50-61.

Anwar, U. M. K., Paridah, M. T., Hamdan, H., Zaidon, A., Roziela, A. H., and Nordahlia, A. S. (2012). Adhesion and Bonding Properties of Low Molecular Weight Phenol Formaldehyde-treated Ply-bamboo. *Journal of Tropical Forest Science.* 24(3), 379-386.

Anwar, U. M. K., Zaidon, A., Hamdan, H., and Tarmizi, M. M., (2005). Physical and Mechanical Properties of *Gigantochloa scortechinii* Bamboo Splits and Strips. *Journal of Tropical Forest Science.* 17(1): 1-12.

ASTM D2395-14e1 (2014). Standard Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials, ASTM International, West Conshohocken, PA, www.astm.org

Azim, M. A. S. (2013). *Study on Relationship between Basic Density with Age of Gigantochloa scortechinii in Jeli, Kelantan*. (Dissertation of degree of Bachelor of Faculty of Earth Science, Universiti Malaysia Kelantan)

Azmy, H. M., Sulaiman, O., Razak, W., and Rokiah, H. (2011). Physical Characteristics and Weight Relationship of *Gigantochloa scortechinii* (Buluh Semantan) 1-, 2-, and 3-Year Old Natural Stand Bamboos. *Pertanika Journal of Tropical Agricultural Science*. 34(1), 25-32.

Babarmahal, K. (2011). *Review of Traditional Designs and Technologies of Bamboo and Rattan Products in Nepal. Market Development of Bamboo and Rattan Products with Potential Project.* (Department of Forest Research and Survey, Kathmandu, Nepal). Kathmandu, Nepal: Market Development of Bamboo and Rattan Products with Potential (MDBRPP) Project, Kathmandu.

Benton, A. (2015). The Plant and its Uses. W. Liese, M. Ko¨hl (eds.): Springer International Publishing Switzerland.

Chaowana, P. (2013). Bamboo: An Alternative Raw Material for Wood and Wood-Based Composites. *Journal of Materials Science Research,* 2(2), 90-102.

Chakravarty, S., Ghosh, S. K., Suresh, C. P., Dey, A. N., and Shukla, G. (2012). Deforestation: Causes, Effect and Control Strategies. *Global Perspectives on Sustainable Forest Management*. Europe: InTech. http://www.intechopen.com/books/globalperspectives-on-sustainable-forest-management/deforestation-causes-effects-and-control-strategies

Galvin, J. F. P. (2009). The Weather and Climate of the Tropics, Part 9 – Climate, Flora and Fauna. *Weather-Royal Meteorological Study*. 64(4), 100-107.

Gutu, T. (2013). A Study on the Mechanical Strength Properties of Bamboo to Enhance Its Diversification on Its Utilization. *International Journal of Innovative Technology and Exploring Engineering* (IJITEE). 2(5), 314-319.

Huang, P., Chang, W. S., Ansell, M. P. and Chew, Y. M. J. (2015). Density Distribution Profile for Internodes and Nodes *edulis* (Moso bamboo) by Computer Tomography Scanning. *Elsevier Ltd.* 93, 197-204.

Ismail. M. (2011). *Gigantochloa scortechinii* – National Seminar Exhibition of Gaharu at Universiti Putra Malaysia, Serdang, Selangor, Malaysia. http://gigantochloascortechinii.blogspot.my/?view=classic

Janssen, J. J. A., (2000). Designing and Building with Bamboo. *International Network for Bamboo and Rattan (INBAR).* 20, 1-211.

Jawaid, M. (2012). Bamboo: Versatile Material for Polymer Composites. *Institute of Tropical Forestry and Forest Products* (INTROPica). (7), 3-5.

Kamaruddin, K. H. (2009). Buluh: *Khazanah Hutan Berharga.* Kuala Lumpur: Dawama Sdn. Bhd.

Khairun, A. U. M., Zaidon, A., Paridah, M. T. and Razak, W. (2004). The Potential of Utilizing Bamboo Culm (*Gigantochloa scortechinii)* in the Production of Structural Plywood. *Journal of Bamboo and Rattan.* 3(4), 393-400.

Khairun, M. A. U. (2003). *Properties and Utilisation of Tropical Bamboo (Gigantochloa scortechinii), for Structural Wood.* (Phd dissertation Faculty of Forestry, Universiti Putra Malaysia)

Lasius, B. (2005). Perbandingan Daya Ketahanan Buluh Betung (*Dendrocalamus asper)* Menggunakan Minyak Kelapa Sawit dan Minyak Diesel sebagai Media Rawatan Haba. (Ijazah Sarjana Muda Sains Dengan Kepujian Program Perhutanan Tropika Antarabangsa, Sekolah Perhutanan Tropika Antarabangsa Universiti Malaysia Sabah)

Lockman, M. S., Shahwahid, M. H. O., Poh L. Y. and Saroni J. (1992). Distribution of Bamboo and The Potential Development of the Bamboo Industry. *Proceedings of the National Bamboo Seminar I. Towards the Management, Conservation, Marketing and Utilization of Bamboos*. FRIM, Kepong, Kuala Lumpur, Malaysia. 6-19.

McMichael, A. J., Campbell-Lendrum, D.H., Corvalán, Ebi, K. L., Githeko, A. K., Scheraga, J. D., and Woodward, A. (2003). Climate Change and Human Health – Risks and Responses. World Health Organization (WHO). Malta: Publication of World Health Organization, Geneva.

Naszroul, H. R. (2012). Bamboo: Versatile Material for Polymer Composites. *Institute of Tropical Forestry and Forest Products* (INTROPica). (7), 6-8.

Nelli, I. S. (2012). *Examining the Potential of Strand Woven Bamboo as an Alternative to Wood Construction Material in Japan.* (PhD dissertation Science in International Cooperation Policy, Ritsumeikan Asia Pacific University)

Nilsson, J. (2015). Bamboo Land PTY LTD. 87 Old Coach Road Torbanlea QLD, 4662. http://www.bambooland.com.au/information/about-bamboo

Norul, H. H., Othman, S., Rokiah, H., Latif, A. M., Ani, S., and Tarmizi, M. M. (2006). Characterization of Bamboo *Gigantochloa scortechinii* at Different Ages. *Journal of Tropical Forest Science.* 18(4), 236-242.

Poh, L., Y. (1994). *Non-Wood Forest Products in Asia*. Bangkok: FAO Regional Office for Asia and The Pacific (RAPA).

Pramono, A. A., Fauzi, M. A., Widyani, M., Heriansyah, I. and Roshetko, J. M. (2011). Managing Smallholder teak plantation – Field guide for farmers. Bogor, Indonesia: Center for International Forestry Research (CIFOR).

Razak, W., Othman, S., Hashim, W. S., and Izyan, K. (2008). Bamboo as an Eco-friendly Material for Use in Aquaculture Industry in Malaysia. *Journal of Sustainable Development.* 1(2), 49-54.

Razak, W., Mohamed, A., Mustafa, M. T., and Hassan, A. (2009). Physical Characteristics and Anatomical Properties of Cultivated Bamboo (*Bambusa vulgaris* Schrad.) Culms. *Journal of Biological Sciences.* 9(7), 753-759.

Razak, W., Tarmizi, M. M., Othman, S., Aminuddin, M., Affendy, H., Izyan,K. (2010). Anatomical and Physical Properties of Cultivated Two- and Four-year-old *Bambusa vulgaris. Sains Malaysiana.* 39(4), 571-579.

Razak, W., Mustafa, M. T., Rahman. S., Salam, M. A., Othman, S., Sudin, M., and Sukhairi M. M. R. (2012). Relationship between Physical, Anatomical and Strength Properties of 3-year-old Cultivated Tropical Bamboo *Gigantochloa scortechinii*. *ARPN Journal of Agricultural and Biological Science.* 7(10), 782-791.

Razak, W., Othman, S., Mustafa, M. T., Norashikin, M. F., & Izyan, K. (2013). Bamboo: *Properties and Utilization.* Kota Bharu, Kelantan: Universiti Malaysia Kelantan, Pengkalan Chepa, Kota Bharu, Kelantan.

Razak, W., Mustafa, M.T., Salam, M.A., Izyan, K., Sukhairi, M. M. R., and Irshad, U. H. B. (2015). Comparison in the Physical and Strength Properties of 3 Year-Old *Gigantochloa brang* and *Gigantochloa scortechinii. Research Journal of Pharmaceutical, Biological and Chemical Sciences.* 6(4), 690-697.

Robert, W. K., Thomas, M. P. and Leiserowitz, A. (2005). What is Sustainable Development? Goals, Indicator, Values and Practice. *Issue of Environment: Science and Policy for Sustainable Development.* 47(3), 8-21.

Suhaily, S. S., Khalil, A. H. P. S., Nadirah, W. W. O., and Jawaid, M. (2013). Bamboo Based Biocomposites Material, Design and Applications. *InTech Open Science.* 19, 489-517.

Ted J. M. (2010). *Bamboo for Gardens*. Portland, OR: Timber Press Pocket Guide to Bamboos.

Tran. V. H. (2010). *Growth and Quality of Indigenous Bamboo Species in the Mountainous regions of Northern Vietnam.* (Dissertation to obtain the degree of Doctor of the Faculty of Forest Science and Forest Ecology, Georg-August-Universität Göttingen).

APPENDICES

Bamboo Culm	Age of Bamboo : 1 year-old			
	Initial Mass (m_1) (g)	Final Mass (m_2) (g)	Green Volume (V) (cm^3)	Basic Density (g/cm^3)
2	10.60	4.67	10.40	0.57
	9.95	4.24	10.60	0.54
	9.53	4.34	9.69	0.54
4	9.05	4.12	8.71	0.57
	8.74	4.02	8.41	0.56
	8.42	3.86	8.03	0.57
6	7.33	3.57	6.11	0.62
	7.45	3.66	6.09	0.62
	7.17	3.57	5.82	0.62
8	6.59	3.16	5.87	0.58
	6.42	3.16	5.42	0.60
	6.46	3.15	5.52	0.60
10	5.84	2.82	5.14	0.59
	6.08	2.87	5.43	0.59
	6.17	3.01	5.27	0.60
12	5.69	2.74	7.70	0.38
	5.53	2.68	5.51	0.52
	5.51	2.69	4.67	0.61
14	5.55	2.54	5.40	0.56
	5.05	2.31	4.76	0.58
	5.31	2.46	4.83	0.59
16	5.25	2.55	4.41	0.61
	5.64	2.77	4.60	0.62
	5.14	2.51	4.22	0.62
18	4.96	2.71	3.22	0.70
	4.74	2.54	3.18	0.69
	4.94	2.65	3.38	0.68
20	4.49	2.32	3.37	0.64
	4.62	2.34	3.51	0.65
	4.29	2.22	3.25	0.64
22	4.04	2.12	3.17	0.61
	4.19	2.17	3.11	0.65
	3.93	2.08	2.80	0.66
24	3.95	2.10	2.81	0.66
	4.00	2.11	2.86	0.66
	4.17	2.21	3.09	0.64
26	3.60	1.85	2.87	0.61
	3.96	2.06	3.33	0.57
	3.94	2.01	3.16	0.61

Bamboo Culm	Age of Bamboo : 2 year-old			
	Initial Mass (m_1) (g)	Final Mass (m_2) (g)	Green Volume (V) (cm^3)	Basic Density (g/cm^3)
2	10.56	5.36	7.89	0.66
	9.17	4.65	7.97	0.58
	9.69	4.88	7.86	0.61
4	8.55	4.70	6.24	0.62
	7.85	4.27	5.77	0.68
	7.81	4.30	5.29	0.61
6	8.13	4.51	5.39	0.67
	8.75	4.38	6.35	0.69
	8.37	4.58	5.45	0.70
8	7.15	4.10	4.22	0.72
	7.57	4.30	4.61	0.71
	7.22	4.14	4.18	0.74
10	6.27	3.87	3.43	0.75
	6.57	4.98	3.38	0.77
	6.04	3.66	3.21	0.74
12	5.96	3.57	3.08	0.78
	5.13	3.24	2.50	0.76
	5.25	3.20	2.91	0.71
14	6.40	3.45	4.28	0.69
	5.82	3.25	3.79	0.68
	6.01	3.37	3.79	0.70
16	5.26	3.17	2.88	0.73
	4.98	2.99	2.82	0.71
	5.08	3.11	2.64	0.74
18	6.07	3.35	3.79	0.72
	5.46	3.06	3.49	0.69
	5.40	3.13	3.14	0.72
20	4.60	2.89	2.27	0.75
	4.65	2.99	2.24	0.74
	4.27	2.74	2.57	0.59
22	4.27	2.63	2.25	0.73
	4.41	2.77	2.19	0.75
	4.63	2.88	2.35	0.75
24	4.08	2.62	1.87	0.78
	4.90	2.46	1.94	0.76
	4.86	2.38	2.01	0.73
26	3.32	1.93	1.99	0.70
	3.62	2.20	1.96	0.73
	3.89	2.23	2.27	0.73

Bamboo Culm	Age of Bamboo : 3 year-old			
	Initial Mass (m_1) (g)	Final Mass (m_2) (g)	Green Volume (V) (cm^3)	Basic Density (g/cm^3)
2	11.62	5.73	9.76	0.60
	11.81	5.74	9.65	0.63
	11.30	5.58	9.51	0.60
4	8.74	4.85	5.40	0.72
	8.78	4.79	5.62	0.71
	8.63	4.75	5.57	0.70
6	8.45	4.72	5.09	0.73
	8.07	4.53	4.85	0.73
	7.77	4.31	4.85	0.71
8	7.15	3.98	4.35	0.73
	7.66	4.19	4.88	0.71
	7.64	4.13	4.95	0.71
10	6.43	3.48	4.30	0.69
	7.26	3.92	4.82	0.70
	6.86	3.70	4.57	0.69
12	6.85	3.80	4.49	0.68
	6.25	3.46	3.99	0.70
	6.38	3.52	3.98	0.72
14	5.44	3.20	2.97	0.75
	5.40	3.23	3.43	0.63
	5.88	3.49	3.69	0.65
16	6.27	3.61	3.67	0.73
	5.98	3.39	3.64	0.71
	6.22	3.48	3.84	0.72
18	5.88	3.26	3.67	0.71
	5.70	3.25	3.34	0.73
	5.56	3.23	3.12	0.75
20	5.22	3.14	2.67	0.78
	4.85	2.94	2.49	0.77
	5.30	3.16	2.83	0.75
22	5.61	3.24	3.17	0.75
	5.26	3.07	2.96	0.74
	5.49	3.18	3.14	0.74
24	4.24	2.66	2.04	0.78
	4.24	2.67	2.02	0.78
	4.43	2.71	2.27	0.76
26	4.08	2.65	1.82	0.79
	3.76	2.44	1.70	0.78
	3.92	2.46	2.17	0.67

Bamboo Culm	Age of Bamboo : 4 year-old			
	Initial Mass (m_1) (g)	Final Mass (m_2) (g)	Green Volume (V) (cm^3)	Basic Density (g/cm^3)
2	13.36	6.90	9.36	0.69
	12.04	6.11	8.79	0.67
	14.08	7.01	10.27	0.69
4	10.50	5.55	7.11	0.70
	10.95	5.55	8.08	0.67
	11.01	5.57	8.05	0.68
6	10.17	5.17	7.48	0.67
	9.32	5.92	4.31	0.80
	11.73	4.85	10.01	0.69
8	7.72	4.22	4.78	0.73
	7.85	4.33	4.70	0.75
	7.84	4.33	4.71	0.75
10	7.92	4.11	5.58	0.68
	7.60	3.91	5.45	0.68
	7.81	4.16	5.35	0.68
12	7.07	3.55	5.54	0.63
	6.54	3.25	5.51	0.60
	6.49	3.33	5.09	0.62
14	6.62	3.54	4.78	0.65
	6.44	3.29	5.11	0.62
	6.24	3.38	4.47	0.64
16	6.82	3.68	4.55	0.69
	6.45	3.43	4.39	0.69
	6.24	3.38	4.09	0.70
18	6.11	3.30	4.16	0.67
	6.15	3.25	4.27	0.68
	5.73	3.14	3.82	0.68
20	6.13	3.07	4.95	0.62
	5.75	2.96	4.53	0.62
	5.52	2.91	4.14	0.63
22	5.29	3.20	2.79	0.75
	5.26	3.07	3.03	0.72
	4.74	2.79	2.65	0.74
24	4.97	3.10	1.92	0.97
	4.49	2.83	2.13	0.78
	4.75	2.98	2.30	0.77
26	4.71	2.94	2.34	0.76
	4.48	2.77	2.27	0.75
	4.47	2.75	2.26	0.76

Bamboo Culm	Age of Bamboo : 5 year-old			
	Initial Mass (m_1) (g)	Final Mass (m_2) (g)	Green Volume (V) (cm^3)	Basic Density (g/cm^3)
2	12.59	6.18	10.92	0.57
	11.15	5.42	9.74	0.62
	11.73	5.80	9.83	0.60
4	10.39	5.18	8.30	0.63
	10.30	5.22	8.01	0.63
	10.49	5.21	8.51	0.62
6	9.46	5.09	5.99	0.73
	9.70	5.27	6.18	0.72
	9.20	5.05	5.84	0.71
8	8.94	4.49	6.85	0.65
	8.97	4.70	6.34	0.67
	8.58	4.50	6.01	0.68
10	7.08	3.80	5.07	0.65
	7.71	4.17	5.16	0.69
	7.82	4.18	5.32	0.68
12	6.72	3.81	4.01	0.73
	6.79	3.79	4.21	0.71
	6.71	3.76	4.15	0.71
14	7.22	4.18	4.19	0.73
	7.11	4.10	4.05	0.74
	6.77	3.93	3.86	0.74
16	5.74	3.59	2.65	0.81
	5.79	3.58	2.75	0.80
	6.15	3.80	2.95	0.80
18	5.81	3.69	2.55	0.83
	5.87	3.72	2.59	0.83
	5.82	3.65	2.68	0.81
20	6.59	3.74	3.78	0.75
	6.49	3.72	3.66	0.76
	5.71	3.38	2.99	0.78
22	5.62	3.45	2.69	0.81
	5.71	3.48	2.82	0.80
	5.70	3.41	2.95	0.78
24	5.09	3.13	2.47	0.79
	5.24	3.09	2.83	0.76
	5.33	3.13	2.84	0.77
26	5.64	3.24	3.13	0.77
	5.79	3.28	3.50	0.74
	5.57	3.19	3.21	0.74