CHAPTER - 2

REVIEW OF LITERATURE

The bamboo is one of the fastest growing plants on earth. Within 3 to 4 months, its culm reaches the height from 3 m to 30 m (Liese and Weiner, 1996). In general, 40 to 50 culms are found in a bamboo clump with additional increase of 10 to 20 culms yearly (Aminuddin and Latif, 1991). Relating to the height of the culm, the bamboo plants are categorised in three types as dwarf, medium and giant. Dwarf bamboos attain height of few centimetre (cm) only, while the medium size bamboo get height upto few meters (m) and the giant bamboos about 30 m. The bamboo plant can be divided into two major portions, the upper ground portion called culm and the underground portion called rhizome. Bamboo culms are cylindrical, hollow and contain most of the woody material. Bamboo culms are measure 0.635 to 1.2 cm of culm wall diameter and 30.48 to 3657.6 cm of total culm length (Dransfield, 1992; Lee *et al*., 1994; Wong, 1995). Unlike other woody plant, the bamboo culms are without bark and are covered with smooth outer cover presence of silica (Tewari, 1992). Since the bamboo plant is hard, vigorous with unique rhizome, the plant can survive and regenerate even after severe damage (Lobovikov *et al*., 2007). The most encouraging fact of bamboo forest is that, the bamboo growing area in the world has increased progressively whereas the forest area in many countries is decreasing rapidly (Ben *et al*., 2005).

Bamboo commonly grows in tropical and subtropical countries and almost in all type of soil and altitude. They grow well in plains, hilly and even mountainous region up to 3000 m from sea level except marshy and desert (Wang and Shen, 1987; Latif and Razak, 1991). The most suitable growing condition for the bamboo is warm climate with abundant moisture, though some bamboo grows in cold weather below -20^{o}C also (Wang and Shen, 1987). Tropical and sub-tropical region are the best climatic region for well growing of bamboo species while some taxa are grown well in the temperate region of Japan, China, Chile and USA (Grosser and Liese, 1971).

In bamboo culm diameter, culm wall thickness and length of internodes are the external structures while structure like fiber distribution and fiber characters are the internal structures. Both of these external and internal structures together determine the properties of bamboo (Amada *et al*., 1997). Bamboo can be regarded as a very special plant on the earth for its multiple uses. It shows very unusual fast growing rate and become ready for better bio-composite materials within very short span of time. Growing of bamboo can reclaim the soil. Vast area of aired land can be made fertile by growing of bamboo, which can also generate employment for poor and unemployment (Malavika, 2009).

The utilisation of bamboo is versatile. Sometimes, bamboos are used as a plant and sometimes, as a material. The bamboo as a plant performed certain activities including soil and water conservation, land reclamation or rehabilitation and carbon regulation, which can be considered as a promising future for world environment (Zhou *et al*., 2005). Bamboo as a living plant has great ecological value (Hsiung, 1991). Living bamboo with wide spread geographical region of growing, even in its raw form have many traditional and industrial uses. Inspite of diverse application, bamboo as a plant becomes more supportive to many animals and plant species (Waite, 2009). Bamboo is not only related to economic activities, but has also capacity to solve many environmental and social problems of today's world. The bamboo shows certain important characters that can bring solution of the problems of rapid shrinkage of tropical forest due to excessive deforestation. Biologically, bamboo solved many environmental problem including soil erosion and maintenance of CO_2 (Austin *et al*., 1970). Bamboo root and rhizome system have unique characters to prevent the soil erosion. The roots and rhizomes of bamboo which forms a mat-like underground structure hold the soil efficiently. The rhizome of bamboo helps in rapid recovery in top soil cover and nutrient. Many studies found that almost 80% of the root and rhizome present in 0 to 30 cm upper soil layer form the most effective soil holding layer which controls the soil erosion (Zhou *et al*., 2005). The bamboo foliage forms a good biomass. The annual biomass formation is measured around 10 t ha^{-1}. The bamboo leaves start falling when they are 12 to 18 months old. Once the old leaves fall, new leaves start to come (Ueda, 1960).

The growing bamboo brakes not only provide valuable products but also important habitats for wildlife. Bamboos are cultivated in many rural parts of the world to meet up the animal feed, manure and housing. This support of bamboo as a plant can reduce pressure on grazing and forest timber. The adverse effect of shifting cultivation can reclaim in short span of time by growing of bamboo. Uses of bamboo as a food and medicine are mentioned by Hossain *et al*. (2015). The tribal communities of different countries of the world use bamboo shoot as food and the traditional methods for preparation of bamboo shoot of different communities are different. The bamboo shoots are eaten as vegetables. It is used in preparation of curry and soup by mixing with fish and meat. Bamboo shoots pickle is popular in North-Eastern states of India. Bamboo from both sympodial and monopodial give rise to edible shoots. In many Asian countries including China and Japan, the bamboo shoot of *Phyllostachys edulis, P. pubescens* and *P. mitis* are commonly used to prepare several delicious items (Hossain *et al*., 2015). The nutritional value of bamboo shoot is different in different species and even in same species growing in different localities. They are nutritionally rich with good amount of fibers, presence of essential amino acids, low calories and low fat (Bal *et al*., 2012).

In case of medicinal purpose, bamboo and bamboo extracts are use as medicine from ancient time in many parts of the world. In Korea, paralysis, sweating, hypertensions like ailments are treated traditionally by using bamboo extract. Antioxidant and anti-inflammatory properties of bamboo extract have been exploited for the treatment of several diseases (Jung *et al*., 2005; Hu *et al*., 2000). The phyto-pharmacological properties of *B. arundinacea* have been studied by Jaimik *et al*. (2011). Bud extract of *B. bambos* L. shows anti-fertility effect on rats. In North Lakhimpur of Assam, this species is used in birth control (Tewari, 1992; Sethi *et al*., 1992). The leaves extract of *B. bambos* L. have wide ranges of antibacterial properties, which can be explored as clinically active compound (Durgesh *et al*., 2014). Reports of many modern research shows several health benefits of bamboo shoots including treatment of cardiovascular disease, digestion and appetite, weight loss, antioxidant and anti-inflammatory activities (Lu *et al*., 2005).

It was early 1960s where the paper manufacturer like Bataan Pulp and Paper Mills Inc. produced unbleached kraft paper by using bamboo as a raw material. This was the first time in the Philippines that paper was made out of bamboo. Many workers including Nicolas and Navarro, 1964; Escolano *et al*., 1964; Gonzales and Escolano, 1965; Monsalud *et al*., 1965; Semana, 1965; Semana *et al*., 1967 ; Bawagan, 1968; Escolano and Semana, 1970, studied on sustainable uses of certain Philippine bamboo for pulp and paper making. Around 35 species of bamboos are now used in pulp and paper producing industries as a source of raw materials. In China, large plantation programme has been carried out to make availability of this increasingly important raw material in pulp and paper industry (Hammett *et al*., 2001). The utilisation of wood based fiber is endless, hence creates a demand. To meet up this demand, bio-based fibers other than forest wood are getting focused. The application of possible alternatives will reduce the extraction from forest and helps in conservation activity. Bamboo is a commonly available alternative with suitable physical and mechanical characters which can be compared with many forest woods. As an alternative, bamboo shows suitability for diverse application (Lakkad and Patel, 1981; Jain *et al*., 1993; Janssen, 1995; Shupe *et al*., 2002).

Although bamboo is used for various day to day activities including as building materials by rural people, but their scientific information is not properly dessiminated among them till now. Due to lack of scientific information regarding the properties and qualities of bamboo, the local users utilize the bamboo only for limited end uses. They use bamboo only in certain regular activities including in making of rural houses and low cost fencing construction. The using of bamboo species as building and construction material has remain limited in Ghana due to non availability of proper information on its properties and lower standard of processing technique. To promote the bamboo and some less utilised timber species as local building materials their technological properties needed to be studied and documented. In Ghana, workers including Ebanyele and Oteng (2007); Tekpetey *et al*. (2007) have studied on certain morphological and physical characters of bamboo species (Appiah *et al*., 2014).

Bamboo, a plant from grass family grows in most of the tropical and few temperate areas of the world. Although, the application of bamboo is multidimensional and wide ranges from food and furniture to paper products, but, its main application is still for construction of different traditional structure (Lobovikov *et al*., 2007). During the construction of rural houses bamboo are used in making of beams, frames, wall, ceilings, doors, windows, from round or split culms. Scaffolding and bamboo mats are used in the construction of high urban buildings. Bamboo bridges are useful for small streams which are constructed by tying together the several long bamboo culms and even shallow rivers can be crossed by using bamboo raft (Hsiung, 1991).

Gathering of knowledge on physical, chemical and anatomical characters of a bamboo culm are very important to qualify its utility for housing materials, furniture making and construction works. Physical, chemical and anatomical properties are the important characters to convert a bamboo into different finished product, (Zenita and Espiloy, 1987). The physical and mechanical properties of bamboo have influence in choosing of bamboo for varieties of uses like industrial application, housing and other construction work. Bamboo that have old age history of application and one of the most commonly used material for varieties of activities still need sufficient studies on its physical and mechanical properties (Yu, 2007). Use of correct bamboo species at right age helps in useing of its products and durability (Abd. Latif, 1987). The technological ability of bamboo including the basic density, shrinkage, modulus of elasticity and modulus of rupture are required to be understand to select them for industrial applications. Bamboo is the suitable replacement of tropical timber resources for making of furniture, construction of building and other structures. Since there is experience of existing of hundred years old bamboo structure, it can be considered as the strongest wood based construction materials (Appiah *et al*., 2014).

The influence of age of harvested bamboo on processing and utilisation is not well established. However certain cares that have been taken for the improvement of harvesting is age and desired quality. Studies on physical characters and properties of bamboo on different parameters like culm height, number of internodes, internode length, internode diameter, culm wall thickness, moisture content helps to understand the applicability of its uses and dealing with chemicals to maintain the properties (Liese, 1985). Studies on culm sheath characters, branching pattern and uses of bamboo were done by Sarkar (1983). The characteristic of bamboo varies from species to species and even within the species depending on the factors like region of growing and genetic factors (Banik, 1997; Soeprayitno *et al*., 1990). The Bamboo is different from other woody plant and even from other grasses by having certain extra features in their gross culm characters (Yulong, 2001). Due to structural changes by ageing, the properties and utilisation of bamboo also changes. In bamboo after growth of several month minor changes comes in anatomical structure of meristematic tissue within internodes and along the culm length (Liese and Weiner, 1996).

Total culm height, number of internodes, length of internodes, culm diameter, culm wall thickness, moisture content and basic density are the physical characteristics which determines the suitability of bamboos for different uses (Narasimhamurthy *et al*., 2013). Some species of bamboo show larger culm wall thickness at the bottom and decrease towards top. Around 0.25 mm thickness of the outermost layer of the bamboo culm contain higher percentage of silica which performs the function of protection of bamboo plant. Due to high percentage of silica content, it makes the machineries dull during uses (Janssen, 2000). The gross wood quality of bamboo culm including strength, straight, lightness, hardness, flexibility, varying sizes, availability and requirement of less effort to grow, makes enhance the suitability of it for multiple application and production of numbers of products (Jayanetti, 2001). As the mechanical properties of bamboo can be compared with other conventional construction material like rod and steel, it can be considered as successful construction material for future.

The mechanical properties of bamboo are correlated with concentration of fibers across the culm wall thickness. Fiber content, fiber diameter and cell wall thickness are the important factors that regulate the specific gravity (SG) of bamboo, and hence the mechanical properties (Janssen, 2000). The extraordinary qualities of bamboo culm shows more efficient performance in terms of tensile and bending properties in compared to other artificial materials (Hidalgo, 1996). Tube shape hollow structure of bamboo culm has certain advantage that shows almost two times more strength in comparison to solid beam of wood. In comparison of strength to weight ratio, some bamboo species have twice the compression strength in the same ratio of the steel (Adewuyi *et al*., 2015; Hidalgo, 1996). Result of studies on *B. blumeana* shows that, bamboo culm have culm circumference of about 300 mm when centre loaded on 1.25 m can hold 500 Kg weight and the same portion of bamboo when used as column or as a post around 1.22 m can hold 4000 Kg weight for any engineering structure (Espinosa, 1930). The differences in bending properties of bamboo culm at different height level and different species were found very little. Chaowana (2013) described the mechanical properties (MOR, MOE and Compression strength) of *B. blumeana*. The *B. blumeana* and cement binding OSB (Cabangon *et al*., 2009) could be a bench mark for mechanical properties. The bending stress and modulus of elasticity is *vice-versa* along the culm, as bending stress decreases and modulus of elasticity increases with the height along the culm (Janssen, 1981). There are also differences in bending and compression potential in between green and air dry bamboo (Lee *et al*., 1994; Chung and Yu, 2002). Shrinkage in radial direction is almost twice than tangential shrinkage whereas longitudinal shrinkage is negligible (Lee *et al*., 1994). The growth and maturation of bamboo culm have correlation with structural properties, same with all the woody materials. The applications of bamboo for different purpose also depend on its gross wood properties. The gross wood properties of bamboo vary species to species, however the utilisation of bamboo resources are affected by physical and anatomical characters (Santhoshkumar and Bhat, 2014).

Along with other components the bamboo culm has significant quantity of moisture. The influence of anatomical characters on physical and mechanical properties was studied on *B. bluemeana*. This study tells about the uncertain effect of height and age of bamboo culm on moisture content. The young bamboo has more moisture content than the old aged bamboo. The average moisture content of a bamboo culm ranges from 57 to 97% (Abd. Latif *et al*., 1993). The moisture content of bamboo varies with species, age of the culm and harvesting season. Maximum differences in moisture content are noticed in bamboo culm when it is in green condition. There is a relation between moisture content and the mechanical properties of bamboo. Moisture content in bamboo culm effect the mechanical properties, as the higher moisture content make lesser the potency of elements. Moisture content, culm location, culm orientation, presence of node influences the mechanical properties. The moisture content along with cellulose and lignin content influence the mechanical properties of bamboo culm (Naik, 2004). In *B. blumeana* and *G. leuis,* there is decreasing rate of moisture content, shrinkages on thickness and width along the top whereas, the rate of relative density increases towards the top. Regarding moisture content (MC), there is a usual character of increasing rate from lower to upper along the culm (Espiloy, 1985). The moisture content (MC) in bamboo is higher as compared to other wood. The dry weight basis of measurement of moisture content of a freshly cut bamboo may be read around 100%. The cross sectional studies through culm wall thickness showed that all the bamboo species have higher moisture content in inner layer than outer and middle layer. In a cross sectional position the moisture content of bamboo ranges with 70% in the outer layer and 150% in the innermost layer. Along the culm height the moisture content decreases from the bottom to the top and across the culm wall it decreases from the inner to the outer layer (Janssen, 1981). There could be corelation between anatomical structure and higher moisture content in inner layer, as it shows less number of vascular bundle distributions and higher moisture content percentage (Razak *et al*., 2013).

Physically both bamboo and wood shows several different characters. In absence of knots there is symmetrical distribution of stress along the bamboo culm. The bamboo culm is a hollow cylindrical with varying culm wall thickness. Due to difference in characters the piece of bamboo is more difficult to join than the piece of wood. There are differences in chemical content of wood and bamboo. The chemical content in bamboo facilitates to glue it properly (Janssen, 1995). The certain mechanical characters of bamboo is very much similar to that of wood, as the strength in bending has co-relation with specific gravity (SG) or relative density (RD) (Heck, 1956). The density of bamboo depends on species, growing environment and also the position in the culm. Most of the bamboo has density ranges from 700 to 800 Kg/m^2. The rate of density in bamboo increases towards the top along the culm height (Janssen, 2000; Amada *et al*., 1996). Differences in specific gravity (SG) and bending properties of Moso bamboo have been studied. Bamboo culm shows decreasing pattern of bending and specific gravity towers inner side (Li, 2004). The close relation among specific gravity, vascular tissue and ground tissue were mentioned by Janssen (1981); Espiloy (1987); Widjaja and Rashid (1987). There are differences in specific gravity in different location along the bamboo culm. The nodes have higher specific gravity than internodes. The variation in fiber wall thickness in nodes and internodes influence the difference in specific gravity within nodes and internodes of a bamboo culm. Thicker fiber wall and greater ratio of fibers in the vascular bundle and higher concentration of vascular bundle are the probable reason for more rate of specific gravity in the nodal region of the bamboo culm (Razak *et al*., 2013). Base on difference in anatomical structures the specific gravity in bamboo ranges around 0.4 to 0.8 g/cm^3. And across the culm wall (outer, middle, inner) the specific gravity (SG) is higher in the outer layer than in the inner layer along all the culm height position (bottom, middle and top) (Ghavami *et al*., 2003; Li, 2004).

The mechanical properties of bamboo are different in different species for all ages and portions of the culm (Abd. Latif *et al*., 1990). This finding supports the findings of many workers like (Susuki, 1948; Anonymous, 1972; Kawase, 1981; Espiloy, 1987; Widjaja *et al*., 1987). The physical and the mechanical properties of bamboo vary species to species, however, growing area, soil and climatic condition along with other aspects like age, density, moisture content, also influence the physical and chemical properties of bamboo (Lee *et al*., 1994). The age and the height of the culm influence the gross physical and mechanical characters of a bamboo. Most of the bamboo species from tropical areas attain highest utility strength at the age of 3rd and 4th years (Janssen, 2000; Ghavami, 2005; Li, 2004). Li (2004) also reported that older *Dendrocalamus strictus* culms are 40 to 50% stronger and stiffer as compared to younger culm.The mechanical properties including strength of a bamboo culm depends on chemical and an anatomical property (Liese, 1985; Wang *et al*., 2011). The anatomical characters of a bamboo signify the physical and mechanical properties (Abd. Latif *et al*., 1993). Due to its suitable mechanical properties for production of fibreboard and paper pulp, bamboo is always considered for alternatives to timber (Wang *et al*., 2011; Hammett *et al*., 2001; Ahmad, 2003; Janssen, 1995).

To assess the suitability of bamboo for various products, the understanding of its chemical and anatomical properties is necessary. This property indicates workability of bamboo (Kamruzzaman *et al*., 2008). Bamboo culm which is the major usable part of a bamboo plant is hollow with varying size in diameter, colour and hardness. The cross section of bamboo culm shows numerous spots of cellulose fibres along the culm, and supply nutrient from roots to leaves. The important component other than cellulose fibre is the lignin which is stronger than cellulose.

The composition of chemicals in plant shows quantitatively difference from plant to plant. Even different portion of the same plant show this differences. Some growing factors like climate and soil conditions, age of the plant, geographical area also contribute to bring variation in chemical composition in plants. Water is the major chemical constituent of a living plant, while carbohydrates along with lignin, extractives, proteins, starch and few inorganic constitute the dry weight of a plant. Along with physical and mechanical properties, the chemical properties of bamboo are also important characters for selection of bamboo for different uses. The important chemical content of certain bamboo species have been studied. The important content of bamboo culm is 60 to 70% holocellulose, 20 to 30% lignin with resins, tannins, waxes and inorganic salts (Tomalang *et al*., 1980). Cellulose, hemicelluloses and lignin are the three primary polymeric substances that constitute cell wall of a bamboo. About 90 to 98% of total constituent of cell wall is made up of large molecules of these substances. The rest 2 to 10% are the extractive with lower molecular weight compounds (Razak *et al*., 2013).

The holocellulose content of bamboo does not show much difference with the age, whereas the content of α-cellulose, lignin, extractive and ash increase with the increasing age (Yusoff *et al*., 1992). It has studied that the starch content in bamboo remains throughout the age, as the ground parenchyma of 12 years old bamboo have starch along the culm length (Liese and Weiner, 1997). The carbohydrate content has relation with natural durability of bamboo as many biological agents that degrade bamboos withstand these chemicals. Bamboo is very particularly harmed by mold, fungi and borer insects. The natural durability of a bamboo varies from 1 to 36 months depending on species and climatic conditions (Liese, 1980). High amount of starch content makes bamboo very vulnerable to staining fungi and powder-post beetles attack

(Mathew and Nair, 1990). The primary inorganic minerals that constitute the ash content of bamboo culm are Ca, K, Mg and Mn. It has reported that the higher ash contain in some bamboo species have negative effect in processing. The percentage of silica content is high in epidermis layer with less content in nodes and even absent in internodes. Along the culm of bamboo, the internodes as compared to node contain higher ash, alcohol-toluene solubility and hot water solubility (Li, 2004).

In case of lignin, the bamboo lignin is unique as compared to other lignin. Chemically, it is made up of three phenyl-propane units, *viz. p*-coumaryl, coniferyl and sinapyl alcohols through biosynthesis (Liese, 1987). The lignin content of a bamboo has positive and negative relation with fiber morphology. Fiber length and lignin content has no relation while fiber diameter has relation as in smaller fiber diameter lignin content is more (Maya and Narasimhamurthy, 2015). In bamboo, the most prominent part is the culm which is mostly hollow and different in sizes. Some species have bigger diameter, some have smaller of different colours and also different in texture. In a cross section of a hollow culm, the cellulose fibers are seen as black spot along the culm height which helps in the movement of nutrients from roots to leaves. Other then cellulose fiber another constituent of bamboo culm is the lignin. Cellulose as compared to lignin is stronger component of bamboo culm (Li, 2004).

The durability and strength of a bamboo culm are influenced by its physical and anatomical properties (Liese, 1985; Abd. Latif and Tamizi, 1993). Similar results were also noticed by Razak *et al*. (2010) on cultivated *B. vulgaris.* Gathering of knowledge on anatomical properties can help in the determination of possible suitability for different applications of bamboos. With the help of such knowledge many traditionally used bamboo species could be promoted for industrial uses. More knowledge is required on anatomy, physical and hardness properties to make the bamboo applications modern and advance (Razak *et al*., 2012).

The anatomical studies of bamboo culm of different species have been studied by different workers. The structure of *B. vulgaris*, *B. bluemeana and G. scortechinii* are studied by Abd. Latif and Tamizi (1993). The hollow culm of bamboo is segmented by nodes. The portion of the culm in between two segmented nodes is the internode. Along the culm diameter, the outermost epidermis layer is the waxy cutinised cell and the innermost is the sclerenchyma cell. The culm wall cross sectional tissue of bamboo consists of parenchyma cell and vascular bundles, with bundle elements, sieve tubes, companion cell, fibers and vessel (Razak *et al*., 1995). The main constituents of bamboo culms are conducting tissue including vessels, sieve tubes, parenchyma cells and fiber. The total compositions of this constituent are about 50% parenchyma cells, 40% fiber and 10% conducting tissue (Liese, 1987; Janssen, 2000).

The length and weight of the vascular bundle are not significantly influenced by the age of the culm. The larger size vascular bundle is in the bottom and the size gradually decreases towards the top (Grosser and Liese, 1971). Regarding the size of the vascular bundle, the longer and smaller vascular bundles were found at the outer layer and shorter and larger vascular bundle towards the inner layer (Wang *et al*., 2011). Due to the smaller size of the vascular bundle the outer layer has higher concentration of vascular bundle and mechanical strength as compared to the middle and inner layer (Zhou, 1981; Liese, 1985). In bamboo, the concentration of vascular bundle is not influenced by age and length of the culm. It is studied that the concentration of vascular bundle along the culm upward increases as the culm wall thickness gradually decreases along the culm upward (Grosser and Liese, 1974). The cross sectional area of culm wall thickness (outer, middle and inner), shows the higher concentration of vascular bundle at the outer layer and decreases towards inner. Similar findings were reported by Grosser and Liese, 1971; Wang *et al*., 2011 and Huang *et al*., 2015.

The fiber length character and applicability of bamboo was studied by Liese (1992); Horn and Setterholm (1990); Ververies *et al*. (2004). They mentioned about the comparatively shorter fiber length in some bamboos including *Phyllostachys edulis* (1.5 mm), *P. pubescens* (1300 µm) in compared to other longer fiber containing bamboo like *Dendrocalamus giganteus* (3200 µm), *Oxytenanthera nigrocilliata* (3600 µm), *D. membranaceus* (4300 µm). There is countless application of bamboo fibers starting with building and construction to high performance composite. Bamboo fibers are regenerated to maintain certain mechanical properties, with high tensile strength, high

UV protection and moisture absorption. Bamboo fiber shows antibacterial and biodegradable properties. Bamboo fiber always maintains its suitability for different uses because they are good absorbent of moisture and fast drying. Today, the regenerated bamboo fiber is used in hygiene and sanitation product and home furnishings (Tyagi *et al*., 2011). In textile industries, bamboos are explored in two different ways. First method is applying chemical and physical treatment to bamboo to obtain natural fiber while the other method is to regenerate the bamboo fiber from the pulp. Using of bamboo fiber in textile industries have certain advantage since the bamboo fibers are eco-friendly and produced from the bamboo plant which are regenerated within very short span of time (Wang *et al*., 2009).

Bamboo does not have a secondary growth. After one year of full height, the additional size gained by it is due to deposition of material to the cell. The anatomical structure of bamboo shows that the fiber bundle is covering the vessel. The fiber length and fiber diameter varies across the culm wall (outer, middle and inner) within same internodes (Wakchaure *et al*., 2012). Out of 60 to 70% total weight of bamboo, 40% is the fiber by volume and the rest constituents are the vessel, capillaries and parenchyma. In a cross section of culm wall the length of fiber varies. Often length of fiber increases from periphery to middle and decreases from middle to inner whereas there are no remarkable differences in fiber length except slide reduction from base to top along the culm. There are differences in fiber length within the internodes as the shortest fiber length is found near the nodes and the longer in middle. Due to the shorter fiber, node region gets reduced and mark the breaking point of bamboo culm (Liese, 1992). Although, the age of the culm has no significant affect on fiber length, but the length of bamboo fiber is significantly different in different species. The distribution of sclerenchyma fibers is increasing from bottom to top along the culm (Grosser and Liese, 1974). The size and length of fibers varies along the cross section of culm, as compared to top and bottom. The middle part of the culm has greater size of fibre while the upper side of the culm has longer fiber than the inner (Kawase, 1981). Longer fiber length with greater vascular bundle size gives unpleasant characters in bamboo as it makes bamboo culm not easy to bend or take the requisite shape. The corelation between shear strength and fiber length of bamboo is negative while modulus of elasticity (MOE) and modulus of rupture (MOR) have positive and negative relation respectively with fiber wall thickness (Abd. Latif *et al*., 1990). The anatomical features of a bamboo are influenced by its physical and mechanical properties. Since the seasoning and preservation of a bamboo is affected by its anatomical properties, ultimately the suitability of application gets influenced (Abd. Latif *et al*., 1993, 1990; Grosser and Liese, 1971; Janssen, 1991).

The role of plastic as a daily used material in our life can not be undermined (Athijayamani *et al*., 2010; Burguenoa *et al*., 2005; Dweib *et al*., 2004). Most of the plastic products are prepared from petroleum based with negative effects to environment. To overcome this situation, an alternative material is needed. The replacing of materials is not just a solution, at the same time care should be taken to provide the materials that have suitability for uses in terms of mechanical, physical, thermal efficient and cost effectiveness of the final product. This is the reason of gaining of acceptance of natural fiber-plastic composites in the market of plastic (Athijayamani *et al*., 2010; Burguenoa *et al*., 2005; Dweib *et al*., 2004; Rowell *et al*., 1997). The problem of incompatible between polymer and bamboo fiber are now reduced by fiber treatment technique and application of fiber compatibilizing chemicals NaOH or PPMA. It enhances the adhesion mechanism of matrix with fiber by minimising the interfacial tension. Bamboo composite can be used as supplements for many fiber based activities and virtually an alternation of petroleum based composite for different applications with several benefits of environment, agriculture, production and consumer (Krishnaprasad *et al*., 2009; Han *et al*., 2008; Chung *et al*., 2002). The versatility of mechanical properties of bamboo composite positively influence on materials. This is the reason why renewable natural base composite is cost effective and is suitable replacement of polymer based product for different applications (Rassiah *et al*., 2013). Uses of bamboo based composite is now another dimension of bamboo application. Composites are obtained by mixing of two or more physically distinct phases. In a composite, out of two materials one is called matrix which performs the function of binding and the others are fiber like reinforcement materials. As compared to conventional materials, the composite materials have higher strength, strong quality which can make the design of structure more dynamic. Short bamboo fiber reinforced polyester based composite have been developed for modern and complete fabrications. Bamboo fibre reinforced composites are used in certain special areas of industries like structures specially designed for desert, low cost housing, industrial fans and production of pipes to carry coal dust (Sreenivasulu *et al*., 2014).

In tropical and subtropical regions, the people have been using bamboo as building materials since time immemorial. Many of the rural building materials are prepared from bamboo including frame, walls, windows, doors, partition and many other items. In the 20th century, bamboos got attention worldwide as they are versatile raw materials for industrial uses, especially for wood based composites production (Chaowana, 2013). The bamboo plant has significant characters of easy propagation and fast growing with vigorous regeneration. The rapid maturity and versatile form of it makes this plants people friendly. Bamboo plant has ideal qualities for technological purposes by having straight and light culms with high fiber content. Bamboo is the oldest plant that is utilised by mankind for construction of their shelter (Abd. Latif *et al*., 1990).

The uses of bamboos are wide in dimension. The application of bamboo is broad and plentiful with different uses beyond imagination. Sometimes, selection of species gets priority for different uses, some species get prevalence and are suitable for certain uses whereas others are neglected or even not used. The suitability for different uses and processing are related to its gross wood properties. Therefore, to recommend a bamboo species for various utilisations, a thorough knowledge is required regarding its relation between structures, properties, behaviours in processing and qualities of product (Liese, 1987). The importance of bamboo application is never being undermined among the rural community. Due to its versatile, multipurpose nature, the bamboo not only occupies important position among the users but also help in various economic activities by providing different high valued goods. Even in today’s world of plastic and steel, bamboo maintains its significance as an important raw material (Tewari, 1992). The traditional idea of common users regarding the quality of bamboo relating to hardness and durability is based on external size of the bamboo. In recent years, numbers of researches on bamboo has been increasing which make us understand about this plant relating to their improved processing and variety of uses (Liese, 1987). Millions of people from tropical and subtropical regions are influenced by bamboo application in their day to day life. Viewing the shrinkage of forest and timber supply, new method for bamboo processing with the advancement of science and technology is highly needed to make the bamboo and bamboo product more durable and usable building materials. Studies have been done on basic properties as well as composite product for few bamboos only. Many more studies are required for different species of bamboos to promote and make it suitable to modern world (Abd. Latif *et al*., 1990, 1993; Chew *et al*., 1992; Tomalang *et al*., 1980; Lee, 1994).