

IMPACT RESISTANCE OF OIL PALM SHELLS LIGHTWEIGHT CONCRETE SLAB WITH BAMBOO FIBERS

Zakaria Che Muda ^(a), Salah F. A. Sharif ^(b), Lariyah Bte. Mohd Sideka ^(c), Nawfal S. Farhan ^(d)

(a) Reader, Centre for Sustainable Technology and Environment , Universiti Tenaga Nasional, Malaysia E-mail: MZakaria@uniten.edu.my , (b) Associate Prof Dr. Research Fellow at Universiti Tenaga Nasional, E-mail: salah@uniten.edu.my , (c) Associate Prof Dr Ir, Centre for Sustainable Technology and Environment, Universiti Tenaga Nasional, Malaysia, Email : Lariyah@uniten.edu.my , (d) Transportation Eng. E-mail: eng.nawfal@hotmail.com

ABSTRACT

Oil palm shells (OPS) has been used as an aggregate in concrete mixture, replacing the normal sense aggregate in many countries, since long time, and it is still an important aggregate in terms of quantity used. In Malaysia, the development of using oil palm shell as lightweight aggregate in construction industry, especially in structural application started about 30 years ago. Today; concrete is one of the most versatile construction materials. Many researchers found that OPS light weight concrete performances need to be enhanced especially when used for structural applications. In this research work an efforts were taken place to enhance OPS concrete performances by using bamboo fibers. Compressive strength, impact energy absorption and crack resistance were investigated for different mix design of bamboo fiber content and good results were gained. The compressive strength decreased marginally the percentage of bamboo fiber of 2% by cement weight. The impact energy absorption for 1% bamboo fiber increase about 1.9 times for service (first) crack and 1.5 times for the ultimate (failure) crack as compared to the service (first) crack and ultimate (failure) crack of the control sample with no bamboo fiber respectively. However, the impact energy absorption for 2% bamboo fiber increase considerably about 2.3 times for service (first) crack) and 1.8 times for the ultimate (failure) crack as compared to the service (first) crack and ultimate (failure) crack of the control sample with no bamboo fiber respectively. As such the 2% percentage of bamboo fiber has better performance than 1% percentage of bamboo fiber in term of impact energy absorption and crack resistance especially under service (first) crack condition. The difference in bamboo fiber length has only marginal effect on the impact energy absorption or surface crack resistance for service (first) crack and ultimate crack condition. The results show that oil palm shell light-weight concrete with bamboo fibers indicate a potential future of this material to be used as an impact resistance composite structures.

Keywords: Oil Palm Shells Concrete, Impact Resistance, Impact Energy, Crack Resistance, Bamboo Fibers.

1- Introduction

In many developed countries, due to the increasing cost of raw materials and the continuous reduction of natural resources, the use of waste materials is a potential alternative in the

construction industry. Waste materials, when properly processed, have shown to be effective as construction materials and readily meet the design specifications. Both natural and artificial aggregates are used in the construction industry. Furnace clinker (Expanded clay) and sintered pulverized fuel ash aggregates used in lightweight concrete are well known, but these artificial aggregates are limited in supply. (Mannan and Ganapathy, 2004).

The recycling or utilization of solid wastes generated from most agro-based industries and manufacturing industries is very rewarding. The anxiety about enormous waste production, resource preservation, and material cost has focused attention for the reuse of solid waste. Material recovery from the conversion of agricultural wastes and industrial wastes into useful materials has not only environmental gains, but may also preserve natural resources. It is thus appropriate that research on the effective utilization of various types of solid wastes has gained greater attention in the past several decades (Ma, A.N. et. al 1993).

Oil palm shell has been used as an aggregate in concrete mixture, replacing the normal sand aggregate in Britain for more than 90 years and it is still an important aggregate in terms of quantity used. In Malaysia, the development of using oil palm shell as lightweight aggregate in construction industry, especially in structural application started about 30 years ago. Today; concrete is one of the most versatile construction materials. Currently, researches have been directed towards the potential use of oil palm shell (OPS) as aggregate for the production of lightweight concrete. In this respect, University Malaysia Sabah (UMS) built a small footbridge of about 2 m in span in May 2001 and a low-cost house with a floor area of about 59 m² in 2003, both using OPS concrete. Both structures were constructed on the campus, which is located near the coastal area. This area has an annual rainfall of about 2500 mm, air temperature in the range of 22.9 to 32.2 C, and relative humidity of 71.6% to 91.0%. (Mannan and Ganapathy 2004).

Lightweight concrete has more problems than conventional concrete like lightweight aggregate are weaker than the matrix; therefore it was considered to be the weak constituent in a unit volume and difficulty in controlling the absorbed water in lightweight aggregate. For the production of such lightweight concrete there is a need for a better understanding of the mechanisms by which strength is generated in such systems. This is necessary for making the correct choice of ingredient proportions and developing guidelines for controlled production of lightweight aggregates for this purpose.

In this paper, efforts have been expressed to enhance the properties of OPS light weight concrete by Bamboo fibers and bars reinforcement. Objectives of this research work can be summarized then; (i) to develop oil palm shell light weight concrete by bamboo reinforcement, (ii) to study the impact properties of light weight concrete containing oil palm shell with additional bamboo fibers and bamboo bars as reinforcement.

2- The Palm Oil Shell as a Concrete Aggregates

In Malaysia, the annual production of the oil palm shell in the industry is approximately 4 million tons (Manan and Ganapathy, 2001). To dispose of the palm oil wastes poses risks to the environment, therefore the Malaysian government is researching on ways to reduce the waste or determine a usage for the waste. One of the possible waste utilization is to use the Palm Oil

Clinker as lightweight aggregate. From its initial judgment on its properties, it has great potential to join the others in the lightweight aggregate group, however further testing and more researches is required to prove and determine its reliability as concrete aggregate.

There are several researcher had begin research on the palm oil clinker as lightweight aggregate. In those researches, tests were conducted on full replacement of OPS as fine and coarse aggregates in the concrete mix. It was found that the density of such replacement will produce concrete with density ranging from 1800 to 1920 kg/m³. The compressive strength of the oil palm clinker concretes are found to be within the range of 17 to 40 MPa after 28 days of curing, which is satisfies the requirement if used as structural lightweight concrete (ASTM- C330 2004). From the previous research, it was suggested that the palm oil clinker concrete is suitable to be used as structural lightweight concrete since it has sufficient density and acceptable compressible strength.

In the lower density ranges lightweight concrete does not develop the compressive strength of plain concrete. This may be a disadvantage in plain concrete applications, but it is an advantage in a lightweight concrete applications. It should be considered that lightweight concrete and plain concrete are typically used for different types of applications. Each form of concrete exhibits a unique family of performance characteristics. Each should be utilized in the appropriate type of project. But a high strength of 33 Mpa could be achieved with high cement content OPS mix (ASTM C 330).

3- Bamboo As An Engineering Material

In consequence of the consumers choosing industrialized products, among other effects, activities are suppressed in rural areas or even in small towns, and renewable materials are wasted and causing permanent pollution. In this sense, it becomes obvious that ecological materials satisfy such fundamental requirements, making use of agricultural by-products such as rice husk, coconut fibers, sisal and bamboo and therefore minimizing energy consumption, conserving non-renewable natural resources, reducing pollution and maintaining a healthy environment Bamboo is one material, which will have a tremendous economical advantage, as it reaches its full growth in just a few months and reaches its maximum mechanical resistance in just few years. Moreover, it exists in abundance in tropical and subtropical regions of the globe (Ghavami K, Rodrigues CS).

The energy necessary to produce 1 m³ per unit stress projected in practice for materials commonly used in civil construction, such as steel or concrete, has been compared with that of bamboo. It was found that for steel it is necessary to spend 50 times more energy than for bamboo. The tensile strength of bamboo is relatively high and can reach 370 MPa. This makes bamboo an attractive alternative to steel in tensile loading applications. This is due to the fact that the ratio of tensile strength to specific weight of bamboo is six times greater than that of steel. (Dunkelberg K, et al)

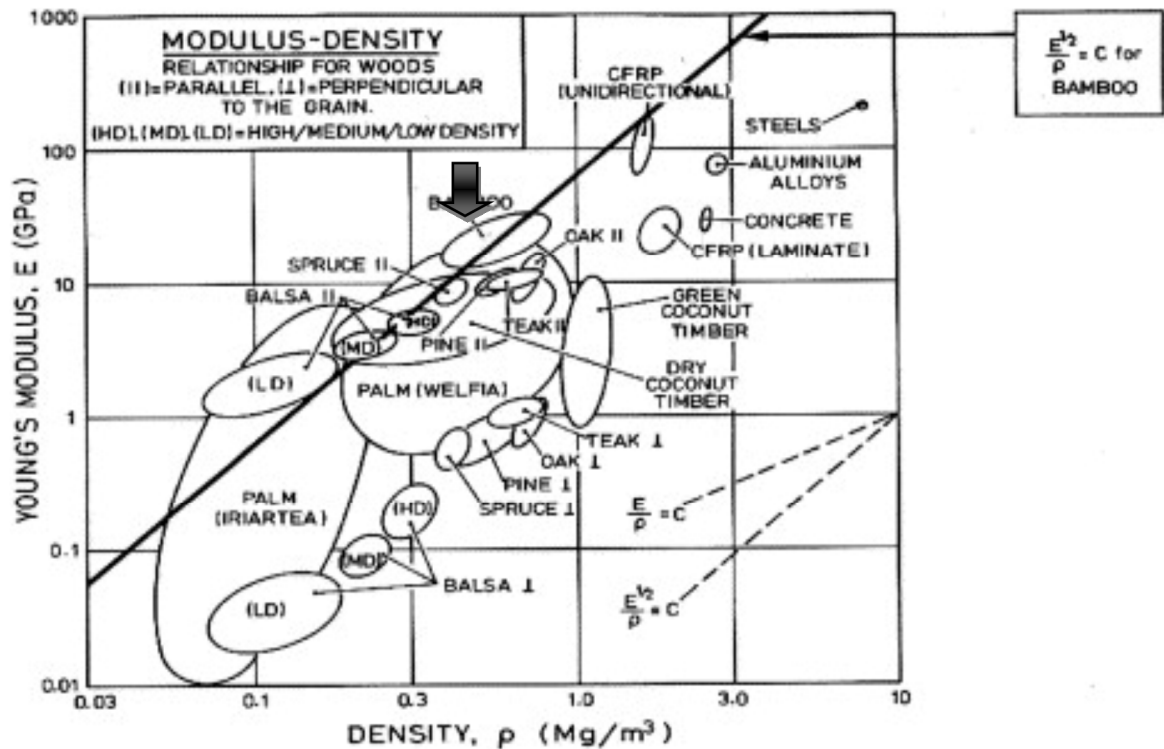


Fig (1): Performance of Bamboo and Other Materials, In Relation to Their E and ρ,

3.1- Basic Characteristics of Bamboo

Bamboos are giant grasses and not trees as commonly believed. They belong to the family of the Bambusoideae. The bamboo culm, in general, is a cylindrical shell, which is divided by transversal diaphragms at the nodes. Bamboo shells are orthotropic materials with high strength in the direction parallel to the fibers and low strength perpendicular to the fibers respectively (Ghavami K, Hombeeck RV).

Bamboo is a composite material, consisting of long and parallel cellulose fibers embedded in a ligneous matrix. The density of the fibers in the cross-section of a bamboo shell varies along its thickness. This presents a functionally gradient material, evolved according to the state of stress distribution in its natural environment. As seen in Fig (2) the fibers are concentrated in regions closer to the outer skin. This is consistent with the state of stress distribution when the culms are subjected to wind (Barbosa NP, Toledo FilhoRD, Ghavami K).

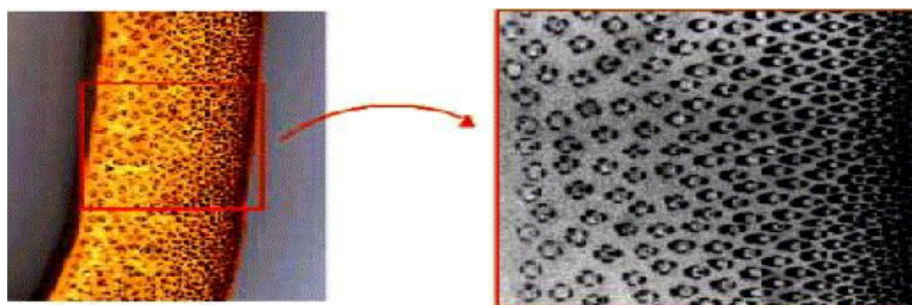


Fig (2): Non-Uniform Fiber Distribution on Cross-Section of Bamboo.

3.2- Durability of Bamboo as an Engineering Material

Just like timber, bamboo is vulnerable to environmental degradation and attacks by insects and moulds. Its durability varies with the type of species, age, conservation condition, treatment and curing. Curing should be initiated when bamboo is being cut in the bamboo grove. There is a strong relation between insect attacks and the levels of starch plus humidity content of bamboo culms. In order to reduce the starch content, bamboo receives a variety of treatments including curing on the spot, immersion, heating or smoke (Janssen JA).

Drying bamboo is fundamental to its conservation for various reasons. Bamboo with low humidity is less prone to mould attacks especially when humidity content is less than 15%. Physical and mechanical properties of bamboo increase with a decrease in its humidity content. Bamboo to be treated with a preservative needs to be dry to facilitate penetration and obtain a better result and reducing transport costs. Bamboo can be dried in air, green house, and oven or by fire. The durability of bamboo depends strongly on the preservative treatment methods in accordance with basic requirements: its chemical composition should not have any effect on the bamboo fiber and once injected it must not be washed out by rain or humidity. The preservative can be applied using simple systems such as leave transpiration, immersion, impregnation and (Modified Boucherie Method). Boucherie Method is a sophisticated modern equipment of cauldrons and special chambers working with vacuum or pressure (Janssen JA).

Bamboo has been used in building structures for many years. Many steel and concrete structures built in the past 30 years reveal serious deterioration caused mainly by the corrosion of the steel reinforcement. In Fig (3) a steel reinforced concrete column after 10 service years and the first bamboo reinforced concrete beam tested at PUC-Rio in 1979, are presented and compared. The steel reinforced column is part of the tunnel structure of Rio's Metro. The bamboo reinforced beam after testing has been exposed to open air in the university campus. It can be observed that the bamboo segment of the beam reinforcement, treated against insects as well as for bonding with concrete, is still in satisfactory condition after 15 years.

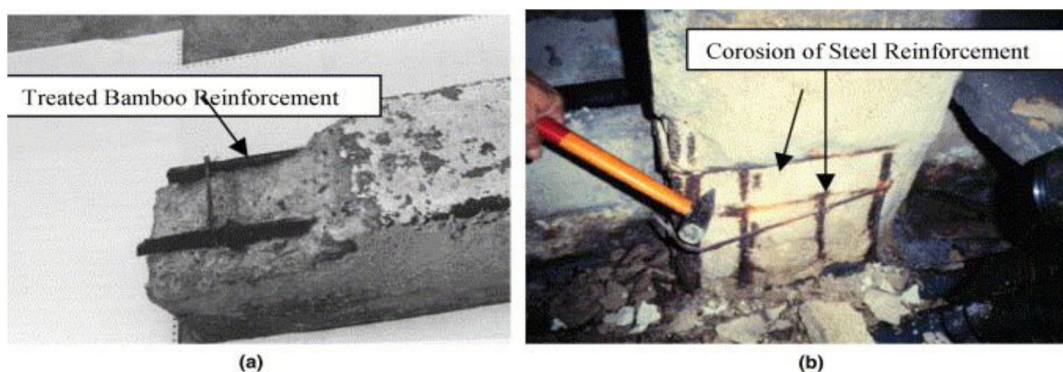


Fig (3): Durability of Bamboo and Steel Reinforcement in Concrete Elements (a) Bamboo Reinforcement of a Tested Beam Exposed In Open Air after 15 Years. (b) Steel Reinforcement of a Column in the Tunnel of Metro after 10 Years in Closed Area (After Janssen JA).

However, the steel reinforcing bars of the column are severely corroded and need to be replaced. The bamboo segments of the beam were taken out of the tested concrete beam to establish its mechanical strength. Compared to the original untreated bamboo a slight deterioration of tensile strength was observed in the weathered samples of bamboo reinforcement. Beside the treatment of bamboo, extensive research however shows that the combination of low alkali cementations materials, chemical admixtures could improve the durability of concrete reinforced with vegetable fibers.

3.3- Effect of water absorption

One of the main shortcomings of bamboo is water absorption when it is used as a reinforcement and/or permanent shutter form with concrete. The capacity of bamboo to absorb water was studied on several species. A summary of the results is presented in Fig (4), which shows DG, Bambusa, Vulgaris Schard (VS) absorbed the least amount of water among all compared species. The dimensional variations of the transversal section of bamboos DG and VS reached up to 6% after 7 days immersion in water. The dimensional variation of untreated bamboo due to water absorption can cause micro or even macro cracks in cured concrete as shown in Fig (6) (M.F. Ashby).

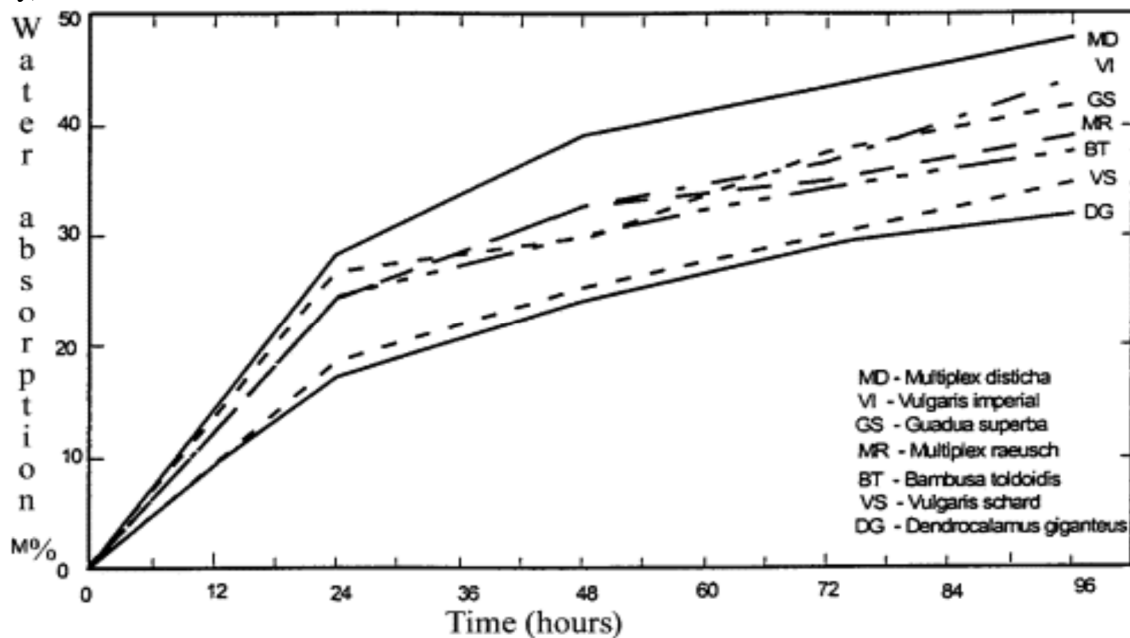
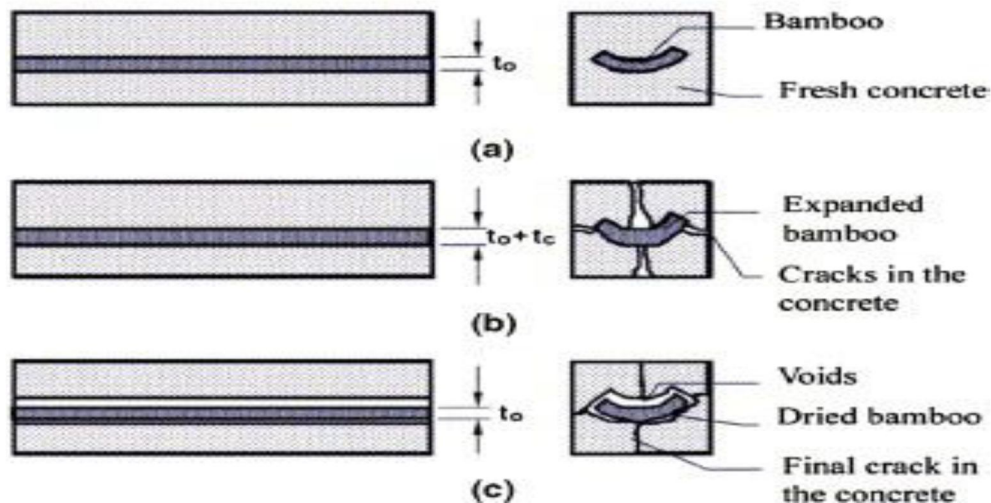


Fig (4): Water absorption of different species of bamboo



**Fig (5): Behavior of Untreated Segment Bamboo as Reinforcement in Concrete:
(a) Bamboo in Fresh Concrete, (b) Bamboo during Curing of Concrete and
(c) Bamboo after Cured Concrete.**

3.4- Selection and Preparation of Bamboo

The following factors should be considered in the selection of bamboo culms (whole plants) for use as reinforcement in concrete structures:

- a- Use only bamboo showing a pronounced brown color. This will insure that the plant is at least three years old.
- b- Select the longest large diameter culms available.
- c- Do not use whole culms of green, unseasoned bamboo. Avoid bamboo cut in spring or early summer. These culms are generally weaker due to increased fiber moisture content

Preparation and Sizing are very important in bamboo industry. Splints (split culms) are generally more desirable than whole culms as reinforcement. Larger culms should be split into splints approximately 3/4 inch wide. Whole culms less than 3/4 inch in diameter can be used without splitting. Splitting the bamboo can be done by separating the base with a sharp knife and then pulling a dulled blade through the culms. The dull blade will force the stem to split open; this is more desirable than cutting the bamboo since splitting will result in continuous fibers and a nearly straight section. When possible, the bamboo should be cut and allowed to dry and season for three to four weeks before using. The culms must be supported at regular spacing to reduce warping. Bamboo can be permanently bent if heat, either dry or wet, is applied while applying pressure. This procedure can be used for forming splints into C-shaped stirrups and for putting hooks on reinforcement for additional anchorage.

Waterproof Coating. When seasoned bamboo, either split or whole, is used as reinforcement, it should receive a waterproof coating to reduce swelling when in contact with concrete. Without some type of coating, bamboo will swell before the concrete has developed sufficient strength to

prevent cracking and the member may be damaged, especially if more than 4 percent bamboo is used. The type of coating will depend on the materials available. A brush coat or dip coat of asphalt emulsion is preferable. Native latex, coal tar, paint, dilute varnish, and water-glass (sodium silicate) are other suitable coatings. In any case, only a thin coating should be applied; a thick coating will lubricate the surface and weaken the bond with the concrete (M.F. Ashby).

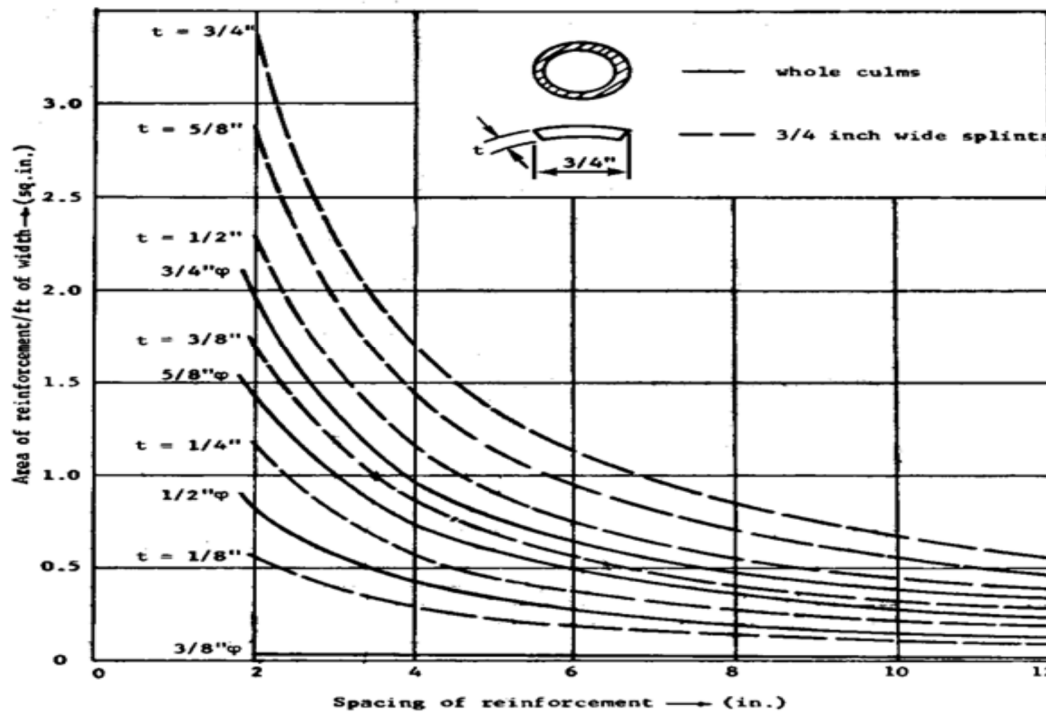


Fig (6): Size and spacing of bamboo reinforcement in slabs and walls.

4- Experimental work

It can be seen, from the above review, that studies on the impact strength characteristics of natural fiber composites, in general, have been rather rare and not exhaustive. In the present study a projectile impact test was adopted for evaluating the impact strength of slab specimens with OPS and bamboo natural fibers. The experimental set-up was specially fabricated and manually-operated for the present study.

The slab composites were also used to evaluate the relative performance of the chosen natural fibers, as part of the preliminary investigations carried out in this study. Slab specimens of size 300 x 300 x 20mm were casted with bamboo natural fibers at a fiber contents (0.5%, 1.0%, 1.5% and 2.0% by weight of cement) and using two fiber lengths (20 and 40mm). Ordinary Portland cement and quality river sand were used. The water content corresponding to the selected flow value is 0.45, which was maintained constant for casting all slab specimens and for all mix combinations considered for this test. Altogether mortar slab specimens (36 mortar slab specimens with natural fibers and three without fibers) were cast and cured for 28 days. At the

end of the above curing period, the slabs were tested and the impact test set-up, as shown in fig (7-a), with the specimen mounted on a M.S. frame. The height of fall (300mm) and the weight of metallic ball (1 kg) were maintained constant for testing all the specimens. The test set-up was so adjusted such that the metallic ball falls exactly at the centre of the specimen and it was also ensured that the four edges of the specimens were freely supported.

4.1- Theoretical Base for Evaluating Performance

The impact energy absorbed high tile mortar slab specimen were computed based on the number of blows required initial to surface crack and the number of blows required to cause ultimate failure and the impact energy per blow (i.e.0.93 Joules). They were compared with that of the reference mortar specimens, to evaluate the performance of the mortar slab composites under an impact load. Based on the energy absorbed, the maximum crack width (W), crack length (L) at failure, the ultimate crack resistance (R) and the crack resistance ratio (C) were calculated.

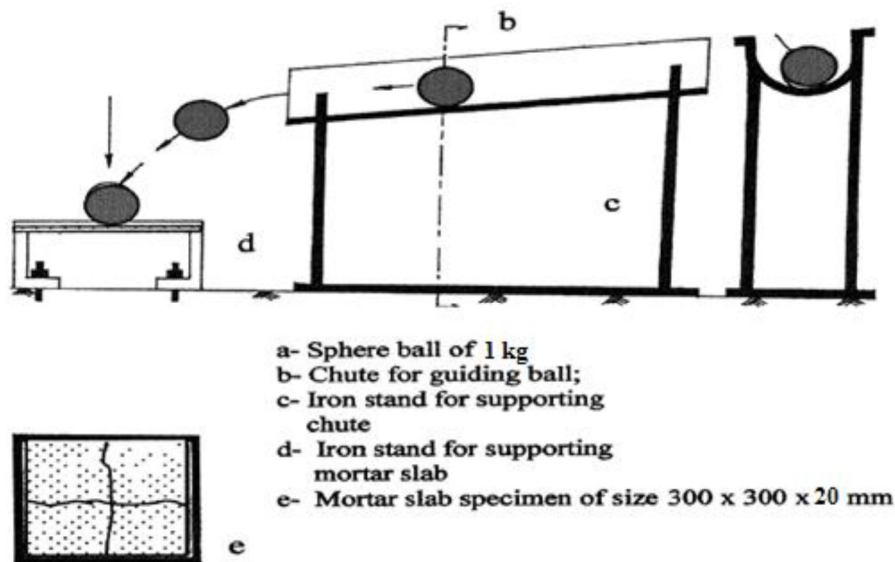


Fig (7): Experimental Set-Up Details of Impact Test on Mortar Slabs

When a slab is subjected to a load released from a defined height thereby constituting an impact loading, in general, there is a loss in the potential energy which is absorbed and dissipated as strain energy, causing cracks due to stresses developed in the element. The width of the crack thus developed is related to the intensity of the energy the amount of energy absorbed and the properties of concrete. The energy absorbed dissipated in the for1 of cracks and patterns of cracks are produced from the impact loading and that the crack pattern is also dependent on the properties of the material (i.e. composites in this case). A relationship for the potential energy (P.E) of an impact loading due to a falling body and the strain energy dissipated in the cracks that develop in target can be expressed based on fundamentals of ‘Mechanics of Material’ approach and as proposed by Kankam (1999) is given by:

$$Ne = R_u * l_c * d_c * w_c \dots\dots\dots (eq. 1)$$

Where, N = number of blows, e= energy (in Joules) blow, l = total length of cracks, d = maximum depth of crack, w = maximum width of crack.

Using (eq.1), the ultimate crack resistance (R_u) of the mortar slab specimens was calculated. A dimensionless factor “impact crack resistance ratio” (C_r) as proposed by Kankam and as given by (eq.2), is also evaluated for the various slab specimens:

$$C_r = R_u * f_{cu} \dots\dots\dots (eq. 2)$$

Where C_r = impact crack-resistance ratio, f_{cu} = compressive strength of reference mortar in MPa (i.e. for 1:3 mix and for a specimen size of 150 x 150 x 150 mm).

Kankam used the above approach for studying the resistance to impact loading of concrete slabs reinforced with palm shell fibers, by loading it as a pavement slab (i.e. placing the slabs over sand bed). He has assumed that the total computed energy imparted to the slab specimen is fully absorbed by it alone, even though the actual experimental condition was not close to theoretical approach proposed and used by him and his investigations.

However in this study, the experimental set-up closely simulates the theoretical approach and hence (eq. 1), is suggested to be used with confidence to study the behavior of specimens subjected to impact loading. The method proposed by Kankam involves lengthy calculations. Hence, in order to evaluate quantitatively the improvement in the impact resistance characteristics, especially of fiber cement / cementations composites easily, a simple parameter called “residual impact strength (I_{rs})” has been defined and it is given by (eq. 3):

$$\text{Residual impact strength ratio } (I_{rs}) = \frac{\text{(Energy absorbed at ultimate failure)}}{\text{(Energy absorbed at initiation of first crack)}} \dots\dots (eq. 3)$$

I_{rs} , as defined above, helps to evaluate the “post - crack behavior of the composites very easily and can also be taken as a measure of ductility” of the composite imparted by the fibers incorporate into the matrix. The impact resistance (R), residual impact strength ratio (I_{rs}), impact crack-resistance ratio (C_r) and the condition of fiber at ultimate fiber (i.e. mode of failure) were considered as the pre-set indicators to evaluate the relative performance of the cement mortar natural fiber reinforced slab specimens, when subjected to an impact load.

4.1- Materials Used and Mix Design

As mentioned above, ordinary Portland cement (OPC) used as a binder and good quality river sand free from silt and other impurities used as the fine aggregate. Two types of natural material, namely, oil palm shell and bamboo, which are locally available in processed form, were used in this study. Four different fiber contents (0.5%, 1.0%, 1.5% and 2.0% by weight of cement) and two fibers lengths (20mm, 40mm) were considered (fig 8). Contents of oil palm shell (OPS)

were (45%). The results have been obtained shown that the addition of the above natural fibers increased the impact resistance by 3–18 times than that of the reference (i.e. plain) mortar slab as it will shown below.



Fig (8): Materials Used in the Mix Design.

Different mix design was used in this work, as shown in the tabulated results in the next section. Mix T1, for instance, started 20 Dec 2011 which was include 0.37 water cement ratio, 0.8 OPS cement ratio, 1.6 sand cement ratio, 20% silica fume and 1% SP. For this mix design a cube test was made to find the strength for duration of four days and the result was 1.31MPa and for the estimated full test was 2.62Mpa. The density of the sample was 1522.963 kg/m³. This mix design is considered to be very weak because of the high percentage of the Oil palm shell OPS and silica fume SF was 20%. This leads to reduced durability and dry mix, which shows a low strength concrete.

4.3- Experimental Tests Performed

Many preparation and essential tests were performed through this research work, as it is mentioned above and will be shown in results tables. The essential necessary tests are:

- a- Slump Test:** The concrete slump test is, in essence, a method of quality control. For a particular mix, the slump should be consistent. A change in slump height would demonstrate an undesired change in the ratio of the concrete ingredients; the proportions of the ingredients are then adjusted to keep a concrete batch consistent. This homogeneity improves the quality and structural integrity of the cured concrete.
- b- Compressive Strength Test:** The compressive strength tests are performed on hardened concrete samples after being cured for certain number of days, as shown in tables. This test is a common test because it is relatively easy to perform and since there is a strong correlation between the compressive strength and many desirable properties. (Neville 1981; Mehta and Montiro 1993). The cube used is sized 150*150 mm. The size chosen for the specimens are usually dependent on the aggregate size; preferably the diameter of the specimen used must be three (3) times the nominal maximum size of the coarse aggregates.

5- Results and Discussion

In this section, there are collections of selected data acquired from the laboratory tests including the cube tests carried out during the fabrication of the test specimens for 7, 14, 21, 28 and the 36 day compressive strength of the test specimens. More studies were carried out to study the impact resistance test (impact absorbed energy and crack resistance) for the specimen size of 300 x300 x 20 mm thick for different percentage of fiber contents and fiber lengths.

Data will be presented as graphs instead of tables for the ease of analysis.

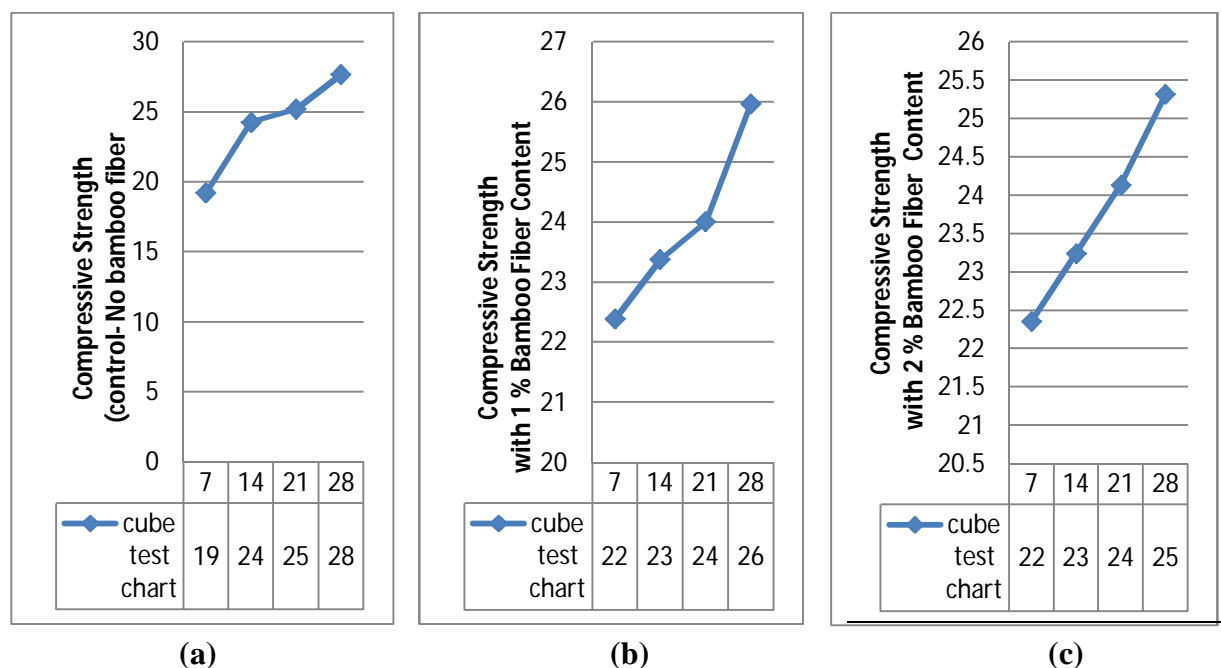


Fig (9): Compressive Strength versus Age of Concrete, (a) Control (No Bamboo fiber content), (b) 1% Bamboo fiber content to cement weight (c) 2% Bamboo fiber content to cement weight.

The 28 day strength in Figure (9) for 2% fiber content by cement weight showed a reduction of about 8.6 % against the control and 6.2% against the control for 1% fiber content. The fiber content has only marginal effect on the compressive strength of the oil palm shell concrete.

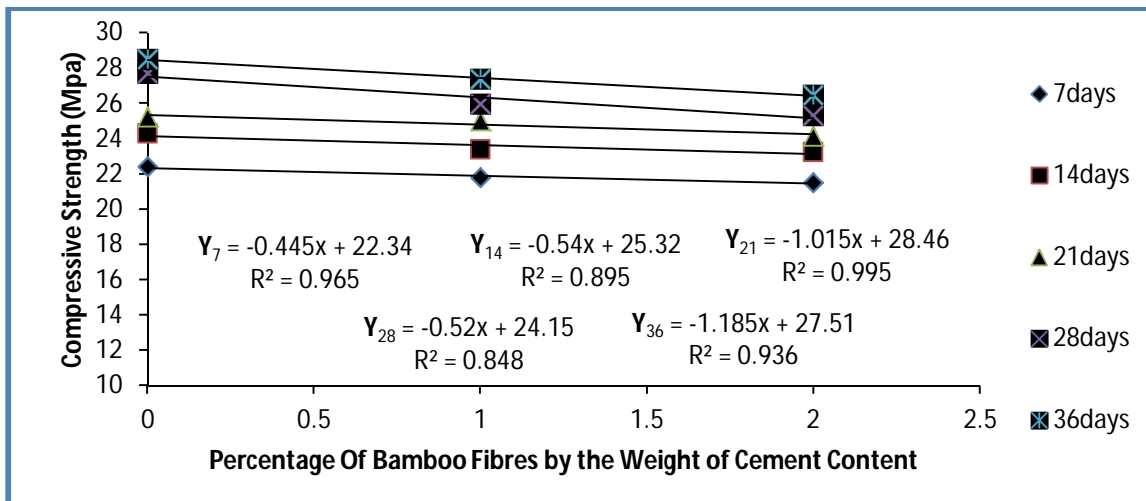


Fig (10): Relationship between Compressive Strength and Bamboo Percentages.

The graph in Figure 10 indicate a linear relationship between compressive cube strength against the percentage of bamboo fibers content by cement weight for all the ages of the concrete. There is a linear marginal reduction of strength as the bamboo fibers content increases.

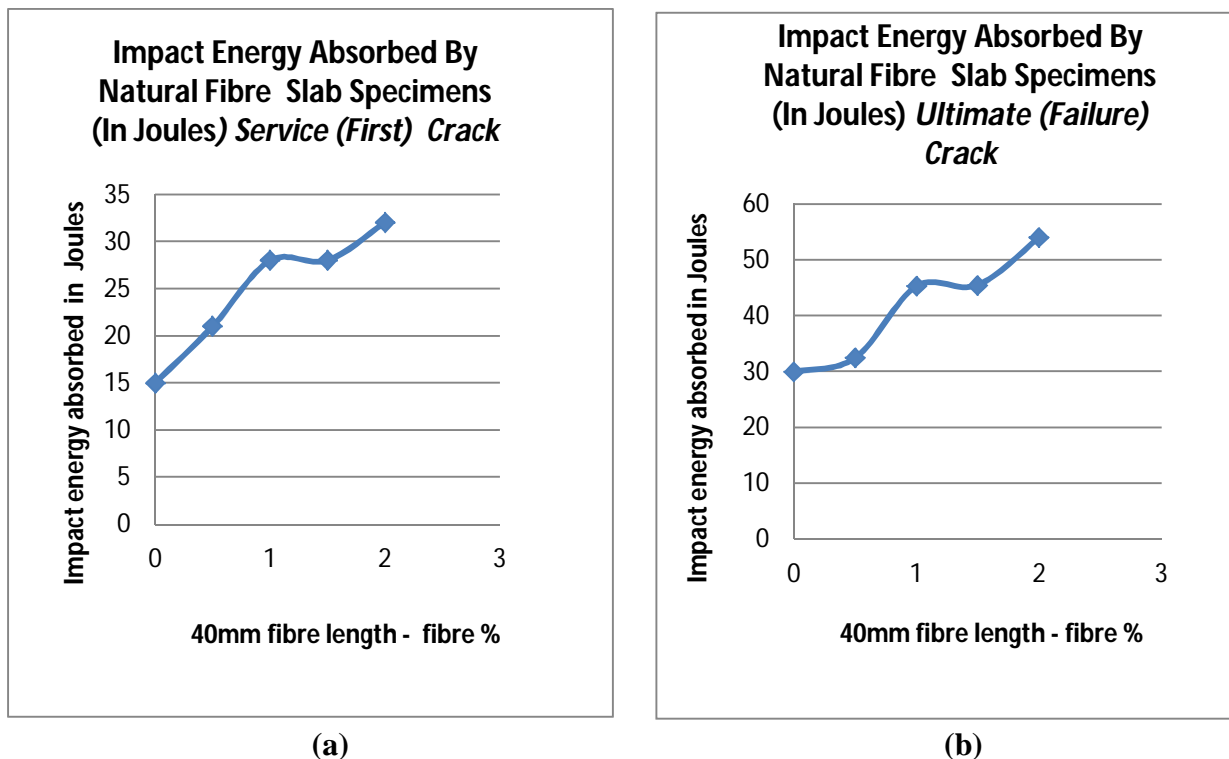


Fig (11): Impact Energy Absorbed versus 40mm length bamboo fibers percentages (a) At Service (First) crack (b) At Ultimate (Failure) crack

Figure 11 indicate that at service crack, the 2% bamboo fiber content with 40 mm fiber length has an impact energy absorption 2.13 times against the control (with no bamboo fibre) whilst the 1% bamboo content is 1.87 times than the control (with no bamboo fibre). At ultimate crack, the 2% bamboo fiber content with 40 mm fiber length has an impact energy absorption 1.80 times against the control (with no bamboo fibre) whilst the 1% bamboo content is 1.51 times than the control (with no bamboo fibre). 2% bamboo fiber has better energy absorption than the 1% bamboo fiber both at service and ultimate crack.

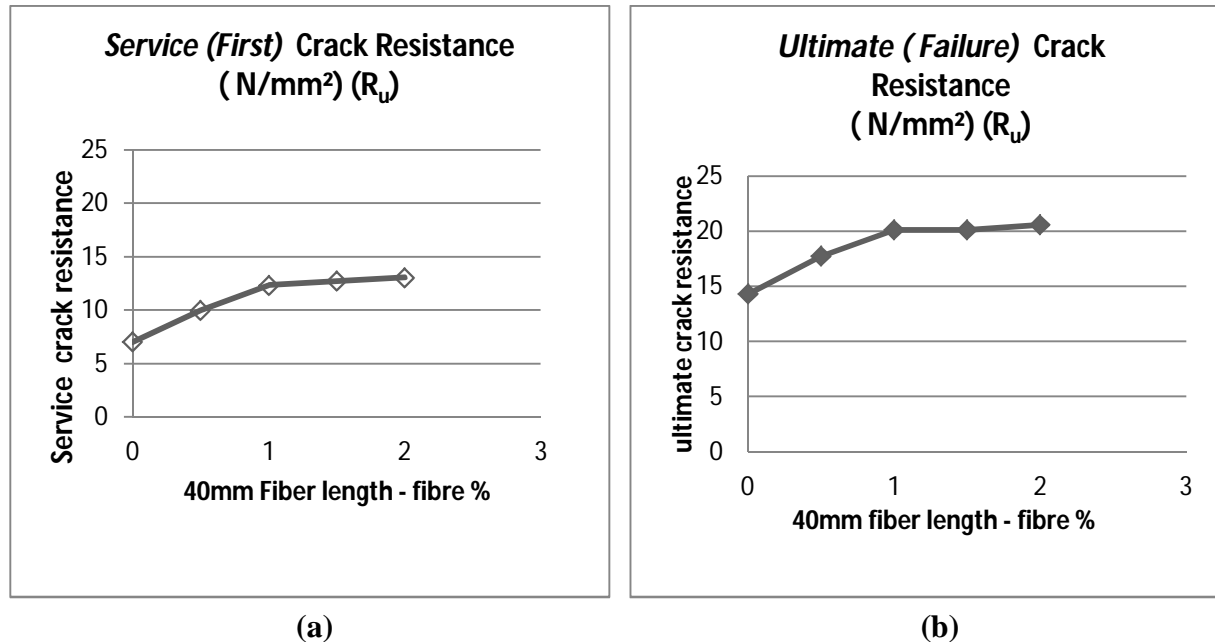
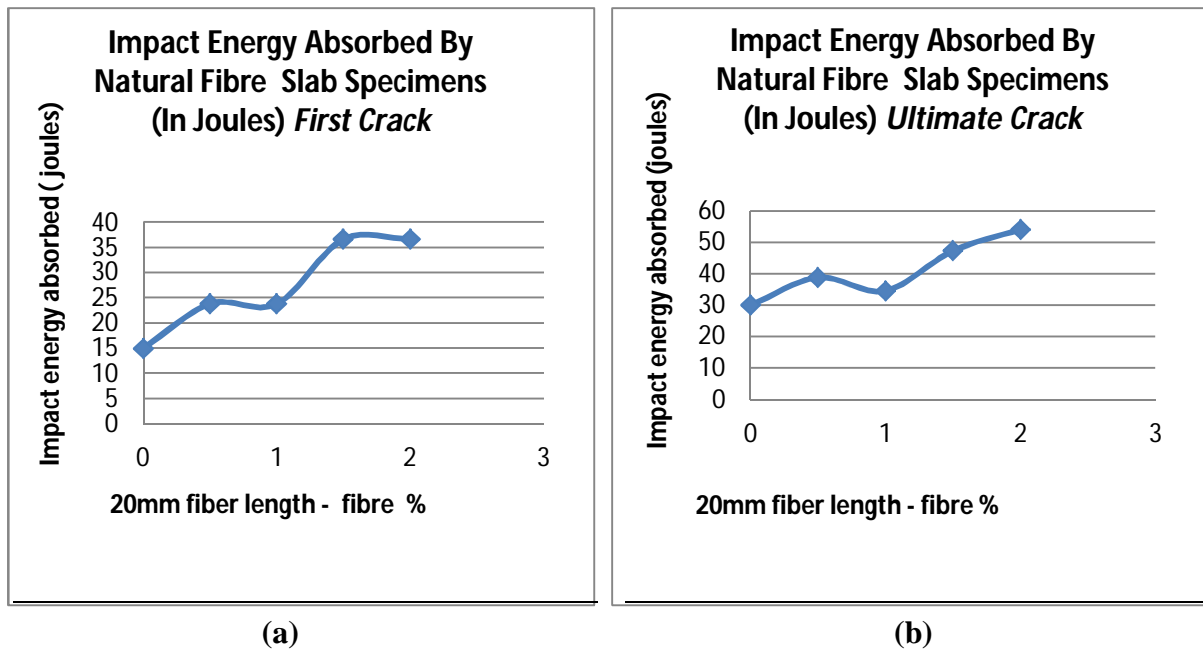


Fig (12): Crack Resistance Versus (40mm Length) Bamboo Fiber Percentage
 (a) Service (First) Crack (b) Ultimate (Failure) Crack

Figure 12 indicate that at service crack, the 2% bamboo fiber content with 40 mm fiber length has a crack resistance of 1.86 times than the control whilst the 1% bamboo content is 1.76 times than the control (with no bamboo fibre). At ultimate crack, the 2% bamboo fiber content has a crack resistance of 1.44 times than the control whilst the 1% bamboo content is 1.40 times than the control (with no bamboo fibre). There is no significant gain in crack resistance between 1% and 2% bamboo fiber content. It is envisage that there will be no further gains for the crack resistance for the oil palm concrete shell (OPCS) above 2% bamboo fiber content.



**Fig (13) Impact Energy Absorbed versus 20mm length bamboo fibers percentages
 (a) At Service (First) crack (b) At Ultimate (Failure) crack**

Figure 13 indicate that at service crack, the 2% bamboo fiber content with 20 mm fiber length has an impact energy absorption 2.44 times against the control (with no bamboo fibre) whilst the 1% bamboo content is 1.59 times than the control (with no bamboo fibre). At ultimate crack, the 2% bamboo fiber content with 20 mm fiber length has an impact energy absorption 1.81 times against the control (with no bamboo fibre) whilst the 1% bamboo content is 1.15 times than the control (with no bamboo fibre). 2% bamboo fiber has better energy absorption than the 1% bamboo fiber both at service and ultimate crack.

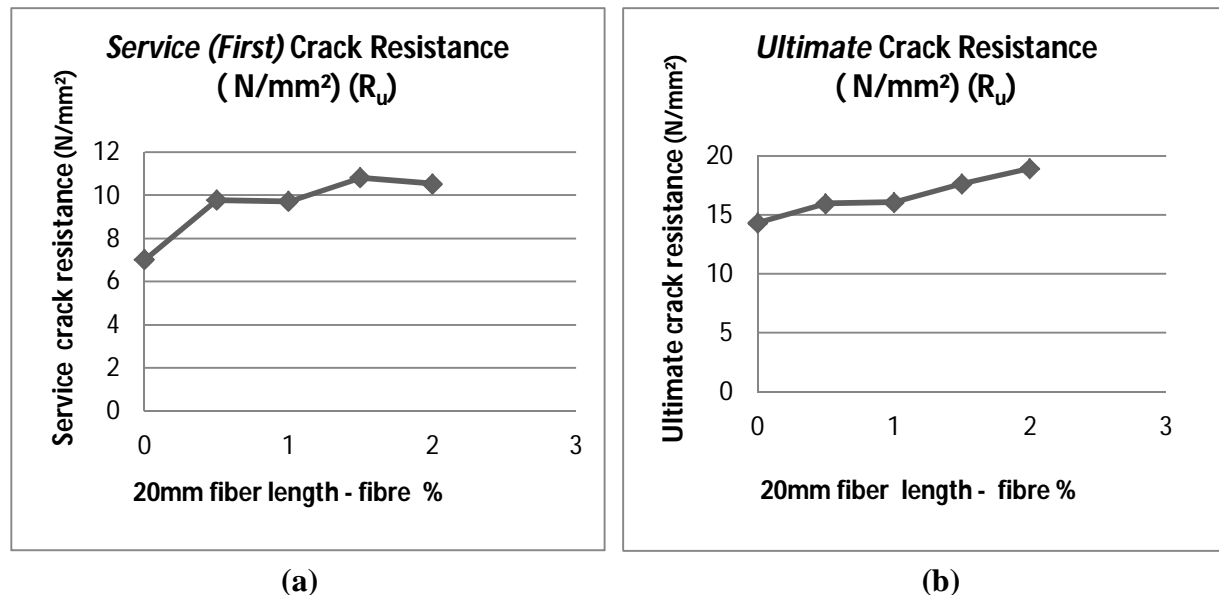


Fig (14): Crack Resistance Versus (20mm Length) Bamboo Fiber Percentage
 (a) Service (First) Crack (b) Ultimate (Failure) Crack

Figure 14 indicate that at service crack, the 2% bamboo fiber content with 20 mm fiber length has a crack resistance of 1.50 times than the control whilst the 1% bamboo content is 1.39 times than the control (with no bamboo fiber). At ultimate crack, the 2% bamboo fiber content has a crack resistance of 1.44 times than the control whilst the 1% bamboo content is 1.12 times than the control (with no bamboo fiber). There is no significant gain in crack resistance between 1% and 2% bamboo fiber content at service crack however some gains for ultimate crack.

Overall the 2% percentage of bamboo fiber has better performance than 1% percentage of bamboo fiber in term of impact energy absorption and crack resistance especially under service (first) crack condition. The difference in bamboo fiber length has only marginal effect on the impact energy absorption or surface crack resistance for service(first) crack and ultimate crack condition except at service crack the longer 40 mm fiber length has better service crack resistance than the 20 mm fiber length.

CONCLUSION

The conclusions derive from the above results are as follows;

1. The reduction of concrete strength decreased slightly by only 6.2% for 1% fiber content and 8.6 % for 2% fiber content against the control sample without bamboo fiber.
2. The impact energy absorption and crack resistance increase with the increase in the bamboo fibers content. The 2% bamboo fiber content considerably performs better than the 1% bamboo fiber content.

3. The use of 2 % of bamboo fiber shows an optimal design in terms both the compressive strength, impact absorbed energy and crack resistance of the oil palm shell concrete with bamboo fiber.
4. The absorbed energy and crack resistance results indicated that no much difference for 20mm fiber length compared with 40mm fiber length.

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