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The Use of Coconut Fibre in the Production of Structural Lightweight Concrete

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Abstract: The high cost of conventional construction materials is a dominating factor affecting housing system around the world. This has necessitated research work into alternative materials in the construction field. The aim of this study was to investigate experimentation on physical and mechanical characteristics of concrete produced using chopped coconut fibres composites incorporating different volume percentage of fibres 1.0, 3.0, 5.0 and 7.0 subjected to static loading. Prisms size of 100×100×300 mm and cubes having dimension of 100×100×100 mm were cast from the same batches of concrete. For coconut fibre, micro structural analysis (scanning electron microscopy) test was conducted in the laboratory to get a better understanding of the bonding behaviour of fibres. Chemically treated coir fibre reinforced specimens yielded better mechanical properties compared to the raw ones. The results of the tests showed that the compressive strength of the concrete decreased as the fibres volume percentage of the coconut increased in the concrete mix. Experimental results also demonstrated that the coconut fibre concrete performed satisfactorily on the growth of cracks, crack widths compared with conventional concrete. Finally, it is concluded that the use of coconut fibre has great potential in the production of structural lightweight concrete especially in the construction of low-cost concrete structures.

Key words: Structural concrete, density, static loading, compressive strength, tensile strength

INTRODUCTION

There is currently a great deal of interest in developing the technology for using natural fibre materials in cement composites. Natural fibres exist in reasonably large quantities all over the world and natural vegetable fibres are produced in most developing countries. Natural fibres have been used to reinforce inorganic materials for thousands of years. Examples include straw for bricks, mud and poles, plaster and reeds. During this century other fibres such as coconut, bamboo, wood cellulose fibres, wool or chips, bast fibres, leaf fibres, seed and fruits fibres have been used in cement-sand based products (Gram, 1983; Paramasivam *et al*., 1984; Sera *et al*., 1990; Duvaut *et al*., 2000; Brahmakumar *et al*., 2005; Asasutjarit *et al*., 2007; Ismail, 2007; Zain *et al*., 2010; Zain *et al*., 2011; Mulinari *et al*., 2011). Fibres may be classified as either natural or man-made, and the natural fibres further divided into different groups (Fordos, 1989; Kelly-Yong *et al*., 2011; Feng *et al*., 2011). The use of natural fibre as reinforcement in concrete (cement-sand matrix) has been comprehensively investigated in many countries (Rehsi, 1991; Atnaw *et al*., 2011) The natural fibre reinforced materials, which can be used in the production of building materials, are presently mainly those based on coconut, bamboo, cane, henequen and sisal fibres (Dawood and Ramli, 2011; Hamid *et al*., 2011). The main reasons for the use of natural fibres are abundantly available and are comparatively cheap. Natural fibre composites are also claimed to offer environmental advantages such as reduced dependence on non-renewable energy/materials sources, lower pollutant emissions, lower greenhouse gas emissions, enhanced energy recovery and end of life biodegradability of components (Joshi, 2003; Majeed, 2011; Hamzah *et al*., 2010). An appropriate method for manufacturing roof sheets of natural fibre concrete was rapidly developed and spread to countries in Central America, Africa and Asia through IT Building Materials Workshop in Great Britain and others. The method which involves reinforcing cement or concrete

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products with natural fibres such as coir, sisal and jute has been applied in at least 28 countries. When combining these fibres with the cement matrix the fibres are utilised in two ways. On one hand, the fibre in the fresh concrete makes it possible to mould a product in a simple manner. On the other, the fibre increases the toughness of the material so that the product can withstand handling and a structural load.

Coconut fibre are agricultural waste products obtained in the processing of coconut oil and are available in large quantities in the tropical regions of the world, most especially in Africa, Asia and America. Coconut fibre are not commonly used in the construction industry but are often dumped as agricultural wastes. However, with the quest for affordable housing system for both the rural and urban population in the developing countries, various schemes focusing on cutting down conventional building material costs have been put forward. One of the suggestions in the forefront has been the sourcing, development and use of alternative, non-conventional local construction materials including the possibility of using some agricultural wastes and residues as partial or full replacement of conventional construction materials. In countries where abundant agricultural wastes are discharged, these wastes can be used as potential material or replacement material in construction industry (Olanipekun *et al*., 2006; Nor *et al*., 2010). One such alternative is coconut fibre, produced in abundance has the potential to be used as substitute coarse aggregate in concrete (Adeyemi, 1998, Zain *et al*., 2010). The huge amount of coconut fibre waste that are produced in the factories. The current waste disposal practice of incineration within the industry is normally done in an uncontrolled manner and contributes significantly to atmospheric pollution. Thus, these residues are becoming expensive to dispose by satisfying the requirements of environmental regulations. In such a situation, efforts are going on to improve the use of these by-products' through the development of value-added products. One of the ways of disposing these wastes would be the utilisation of coconut fibre into constructive building materials. Oil Palm Shell (OPS) are the hard endocarp that surrounds the palm kernel.

Extensive research and development in the understanding and applications of fibre concrete materials are still taking place all over the world. These activities include, amongst other things, the development of new, stronger fibres, better fibre reinforced composites and new substitutes (Fordos, 1989). Mechanical properties of coconut fibres reinforced polyester composites conducted by Mulinari *et al*. (2011). In this work, chemical modification of the coconut fibres by alkaline treatment was determined in order to use them as reinforcement in polyester resin. The mechanical properties were evaluated by tensile and fatigue tests. The surfaces of the fractured specimens were examined in order to assess the fracture mechanisms. The test results presented a decrease in fatigue life of composites when applied greater tension, due to bonding interfacial, which was not adequate.

Gunasekaran and Kumar (2008) have investigated the possibilities of using coconut shell as aggregate in concrete. The findings indicated that water absorption of the coconut shell aggregate was high about 24% but the crushing value and impact value was comparable to that of other lightweight aggregates. They found that the average fresh concrete density and 28-day cube compressive strength of the concrete using coconut shell aggregate were 1975 kg m^{-1} and 19.1 N mm^{-1}, respectively. It is concluded that crushed coconut shells are suitable when it is used as substitute for conventional aggregates in lightweight concrete production.

Previous study by Olanipekun *et al.* (2006) has shown that coconut shell is suitable as substitute for conventional aggregates in the structural concrete production. The results also indicated cost reduction of 30% for concrete produced from coconut shells. Apart from its use in production of fibre-roofing material, the other possibility of using coconut fibre as an aggregate in concrete production has not been given any serious attention. However, Adeyemi (1998) carried out for one mix ratio (1:2:4) the suitability of coconut fibre as substitute for either fine or coarse aggregate in concrete production. It is examined that the coconut fibres were more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production. Coconut fibre is the hard stony endocarp but lightweight and naturally sized. Due to the stiff surfaces of organic origin, they will not contaminate or leach to produce toxic substances once they bound in the concrete matrix. In addition, coconut fibres are lighter than the conventional coarse aggregate so the resulting concrete will be lightweight. Therefore, it can be used as a good replacement of coarse aggregate to produce structural concrete in the construction industry.

This study reported the results of an investigation carried out on the utilisation of chopped coconut fibres composites in concrete as substitutes for conventional coarse aggregate. The physical and mechanical properties of plain concrete are also compared with coconut fibre composites concrete. The main objective was to encourage the use of these 'seemingly' waste products as construction materials in low-cost housing and where crushed stones are costly for producing lightweight concrete. It was also expected to serve the purpose of encouraging housing developers in investing in house construction incorporating these low-cost materials.

MATERIALS AND METHODS

Materials investigations

Coconut fibres: Coconut fibres were collected from shop that came from Sri Lanka. It was obtained after the oil extraction in the factory from the outer periphery of the coconut fruit. The shells were then washed properly and air dried for five days under ambient temperature and later graded in accordance with the ASTM C330 (2009). Fibres were chopped with sharp scissors maintaining a length from 15 to 35 mm. Chopped fibres were oven dried at 80°C for 5 h and used desiccators for cooling. Chopped fibres were used to determine the length, diameter, thickness, natural humidity, water absorption capacity and density of fibres.

Aggregates: The coarse aggregate form crushed granite was collected from igneous origin. The particle size used ranges between 5 to 20 mm. River sand as fine aggregate was used to mix the concrete according to the ASTM Standard C33 (2006). All particles passing through ASTM sieve No. 4 aperture 4.75 mm but retained on sieve No. 230, aperture 63 μm.

Cement and water: Ordinary Portland cement type whose properties confirm into the requirement of ASTM Type I was used for mixing of concrete and the water was collected from the laboratory stand post.

Preparation of the test specimens: Concrete cubes sizes of 100×100×100 mm and prisms having dimension of 100×100×300 mm were cast for both plain and coconut fibre reinforced concrete for the determination of different properties of concrete. The mix proportion of 1:2:3 by the weight of ordinary Portland cement, river sand, crushed stone and coconut fibre were used to cast the specimens. The water/cement ratio was used 0.4 for the mix. The water/cement ratio was maintained constant at all different volume percentage of fibres. Adhesive named as seal frost also used for quick setting of concrete. 70 grams seal frost was used per 1 kg cement. In preparing the specimens, at first, sand and cement were properly mixed in the machine and then crushed stones were added. In case of fibre reinforced concrete, fibres were also added in the mixture known as premix method. All ingredients were mixed properly with use of concrete mixture machine. Fresh concrete workability was investigated immediately after the final mixing of the concrete using slump test. To avoid void, hammer and vibrator was used for compaction. The cubes and prisms were cast by filling each mould in three layers; each layer had been compacted normally with 25 blows from a steel rod of 16 mm diameter before the next layer was poured and for prism vibrator was used. Slump values were achieved 54 and 38 mm for plain and coconut fibre concrete, respectively, which representing high and medium workability. All specimens were left in the moulds for 24 h to set under ambient temperature. They were removed from the mould and transferred into a curing tank. The curing temperature was 30±2°C. The concrete mixes and the specimens were prepared in accordance with the provisions of ASTM C330 (2009), ASTM C469, (1987) and BS 8110-1 standards.

Compressive strength test: Two types of universal testing machine were used to determine the compressive strength of coconut fibre reinforced concrete. Avery Denison testing machine is manufactured in the United Kingdom. The rate of loading of this machine is 10-3000 kN min^{-1}. Experiments were done using this machine with a loading rate of 136 KN min^{-1}. Once in a year, calibration is needed for this machine. Dartec testing machine was also used to determine the compressive strength of coconut fibre reinforced concrete. This machine can plot automatically a graph of load vs. remote. From the given graph or data, it is possible to make stress-strain graph of a specific sample. The loading capacity of this machine is up to 500 KN. The compressive rate of this machine is from 0.00015 to 2.0 mm sec^{-1}. The experiment has been done using this machine with a compressive rate of 0.00015 mm sec^{-1}. Compressive strength test of plain and coconut fibre reinforced concrete was carried out to find out the ultimate failure load, compressive strength, number of cracks and it's length and width and finally to observe the stress-strain relation. Static loading test were done with use of DARTEC testing machine. Experimental compressive strength test was done in the laboratory as shown in Fig. 1.

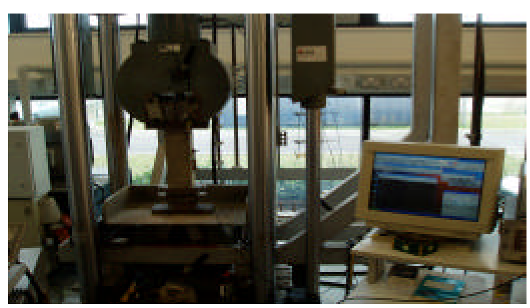

Fig. 1: Experimental compressive strength test

Scanning electron microscope (SEM): The scanning electron microscope was used to determine the thickness and cross section of fibres. SEM is capable to produce high resolution images of a sample surface. A SEM can resolve much smaller feature than a standard microscope, down to nearly 2 nanometres. In a classical Scanning Electron Microscope (SEM), electrons are thermionically emitted from a tungsten or lanthanum hexaboride (LaB6) cathode and are accelerated towards an anode alternatively; electrons can be emitted via Field Emission (FE). Tungsten is used because it has the highest melting point and lowest vapour pressure of all metals, thereby allowing it to be heated for electron emission. When the primary electron beam interacts with the sample, the electrons lose energy by repeated scattering and absorption within a teardrop-shaped volume of the specimen known as the interaction volume, which extends from less than 100 nm to around 5 μm in to the surface.

Tensile strength test of coconut fibre: To determine the tensile strength of coconut fibre, Hounsfield tensile testing machine was used. This machine can plot automatically load vs. extension graph. From given data, the stress and strain to failure of coconut fibres can be made. Tensile strength test of coconut fibre was carried out to investigate the behaviour of fibre under tensile load, maximum extension of fibres under tensile load and breaking point. Hounsfield tensile testing machine was used to carry out this experiment. After complete testing, this machine can plot automatically a graph Load vs. extension. From the load-extension data, the value of stress and strain can be obtained as follows:

$$\text{Stress} = \frac{\text{Load}}{\text{Original area of sample}}$$

$$\text{Strain} = \frac{\text{Extended length}}{\text{Original length of sample}}$$

Four different thicknesses of fibres were tested under tensile strength test. Fibres fitted in the jaw of the tensile testing machine with gauge length (clear fibre length from one jaw to another) of 35 mm. After tightly fitted with the jaw, the machine started to go on the progress of test. Generally jaws are pulled the fibre in two opposite direction. The fibre breaks down automatically when reached in its ultimate expansion. The point where the fibre breaks down is known as breaking point. All tests were done with a speed of 15 mm min^{-1}.

RESULTS AND DISCUSSION

Physical structure of coconut fibre: Scanning Electron Micrograph (SEM) was used to observe the physical

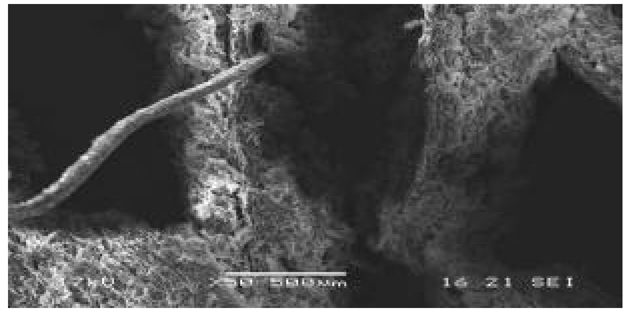

Fig. 2: Scanning electron micrograph showing bunch of coir fibre (x50)

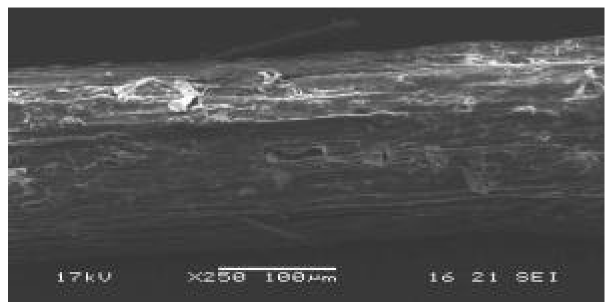

Fig. 3: Scanning electron micrograph showing single strand of coir fibre (x250)

Fig. 4: Scanning electron micrograph showing cross section of coir fibre (x500)

formation of coconut fibres. Figure 2-4 are showing the SEM photograph of bunch of fibres, surface of fibres and cross-section of fibres respectively. From Fig. 2, it has been observed that the fibre generally looked at an open eyes is eventually attached with 5/6 single fibres. Left hand side of Fig. 2 showed the single fibre, which is 5 to 6 times less than other fibres. It has also been observed that the surface of coconut fibre is not smooth refer to Fig. 3. So in a matrix, it can make strong bond with other materials. Cross section of fibre has clearly shown a hole in the middle of it and small holes around it as illustrated in Fig. 4. It is roughly estimated 15-20% holes exists compared with a single cross section of fibre.

Physical properties of fibre

Length of coconut fibre: Generally, the natural lengths of coconut fibres are from 60-230 mm. The lengths of fibres were measured using steel ruler and 30 pieces were randomly chosen to find out the length of coconut fibre. However, in this study chopped coconut fibres used with size of 15-35 mm.

Diameter of coconut fibre: To determine the diameter of coconut fibre, micrometre was used with precision of 0.01 mm. It has been observed that diameter of coconut fibre is from 0.17-0.24 mm.

Natural humidity of coconut fibre: To determine the natural humidity, fibres were at first open air-dried for 5 days and then the same fibres were dried in an oven at 80°C for 5 h. The weights of fibres were measured using electronic bench scale with a precision of 0.01 g. The natural humidity "H" was calculated using Eq. 1 and found the natural humidity of coconut fibre is 12.2%. It can be seen that humidity percentages are nearly similar for different types of coconut fibre samples:

$$H = \frac{W_d - W_o}{W_o} \times 100\% \quad (1)$$

where, W_d and W_O are the weight of air-dried and oven dried fibres, respectively.

Water absorption: During mixing and drying of matrix, the fibres absorb water and expand. The swelling of the fibres pushes away the concrete, at least at the micro-level. Then at the end of the drying process, the fibres lose the moisture and shrink back almost to their original dimensions leaving very fine voids around themselves. The water absorption capacity "W" was calculated using Eq. 2:

$$W = \frac{W_{sw} - W_{ad}}{W_{ad}} \times 100\% \quad (2)$$

where, W_{sw} and W_{ad} are the weight of soaked fibres in drinking water and weight of air dried fibres, respectively. The measurements were carried out at 24 h intervals for 7 days. Experimental data has shown that the maximum water absorption of the coir fibre occurs during the first 24 h and until increase up to 120 h. After 120 h, the fibre

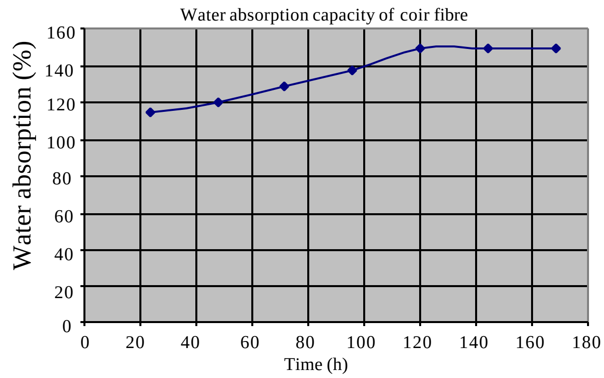

Fig. 5: Water absorption capacity of coconut fibre

get into fully saturated condition and this state continue for last as illustrated in Fig. 5.

Density of fibre: Density of each fibre is an important parameter. For composite materials, density of fibre has a significant effect. The weight of fibre in a composite matrix is depends on the density of fibre. The density of coconut fibre, ρ_f was calculated using Eq. 3 and found the density of coconut fibre is 1.18 g cm^{-3}. It was observed that densities of coconut fibres are almost same for different type's samples:

$$\rho_f = \frac{m_f}{\frac{m_w}{\rho_w} - \frac{m_w}{\rho_w}} \quad (3)$$

where, m_f is the mass of fibre, m_w is the mass of water, m_{w*} is mass of water reduced by fibre volume, ρ_w is the density of water.

Mechanical properties of fibre

Tensile strength of coconut fibre: Tensile strength test of coconut fibre was carried out to investigate the behaviour of fibre under tensile load, maximum extension of fibres under tensile load and breaking point. Hounsfield tensile testing machine was used to carry out this experiment. Four different thickness of fibre were taken and got the following results as mentioned in Table 1. Fig. 6 and 7 show the load versus extension of coconut fibres for samples 2 and 3, respectively.

Experimental data has shown that the average strength of coir fibre is 19.51 MPa and strain to failure is 2.83. It was also observed that the strength and strain to failure is not depended on area of fibre. The more area of fibre is not always given the more strength and strain to failure. Mainly the strength of fibre depends on its

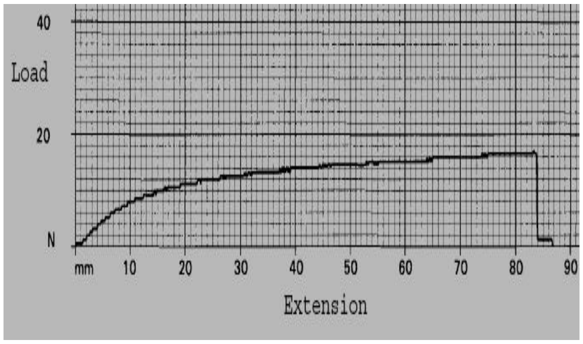

Fig. 6: Tensile strength test of fibre (sample 2)

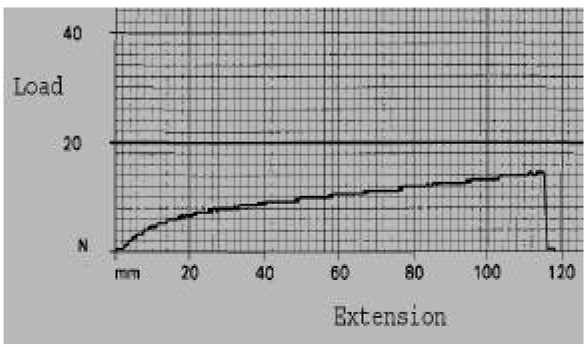

Fig. 7: Tensile strength test of fibre (sample 3)

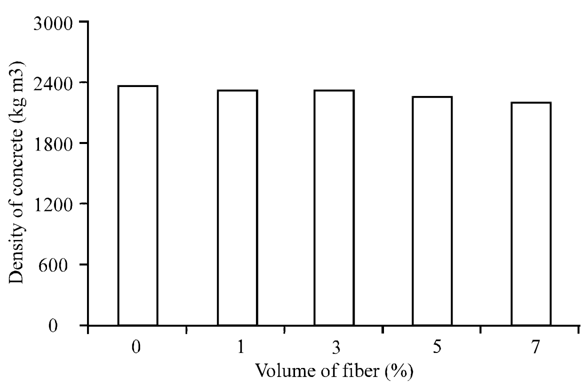

Fig. 8: Density of plain and coconut fibre reinforced concrete

Table 1: Stress and strain to failure of coconut fibre

Sample No.	Original length (mm)	Area (mm 2)	Load (N)	Extension (mm)	Stress (MPa)	Strain to failure
1	35	0.92	18.67	120	20.29	3.42
2	35	0.88	17.33	86.67	19.69	2.48
3	35	0.82	14.67	117.91	17.89	3.37
4	35	0.86	17.33	71.54	20.15	2.04

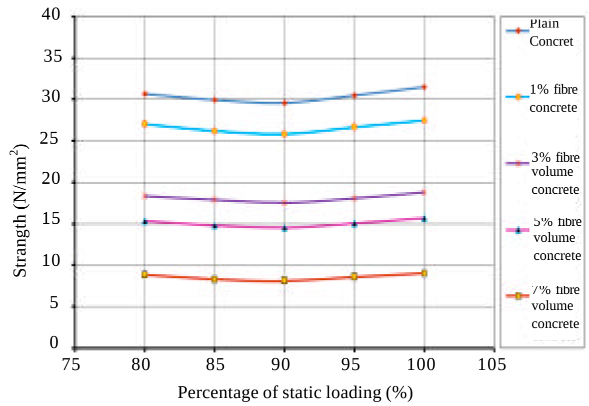

Fig. 9: Strength of plain and fibre reinforced concrete

and chemical composition, process of fibre separation, treatment, humidity, temperature etc.

Density of plain and coconut fibre reinforced concrete: The weight and volume of plain and fibre reinforced concrete was measured before the compressive strength test. The obtained weight of each concrete was divided with its volume to find out the density. Figure 8 is presenting the density of plain and fibre reinforced concrete. Experimental result has shown the density of plain concrete is more than the fibre reinforced concrete. It is also observed that the density of concrete has decreased with increase in the volume of coconut fibre in the conventional coarse aggregate as illustrated in Fig. 8.

Comparison the properties of plain and fibre reinforced concrete: Plain and fibre reinforced concrete was loaded under static loading, to find out the ultimate compressive strength of different fibre volume concrete as shown in Fig. 9. The numbers, length and width of cracks were also measured for both plain and coconut fibre reinforced concrete after loaded with static loading as shown in Fig. 10 to 12. Also, the stress-strain relationship and modulus of elasticity of plain and coconut fibre reinforced concrete are shown in Fig. 13 and 14, respectively.

It was observed from the test results (Fig. 9) that the compressive strength decreased gradually due to the increase of fibre volume percentage in conventional concrete. For the conventional concrete with 0% fibre volume have the highest compressive strength values for the specified mix ratio. In case of crack nos., length and width of fibre reinforced concrete shown optimistic behaviour compared with plain concrete. It is concluded that the concrete strength depends on the strength, stiffness and density of coarse aggregates. Generally, lower the density causes lower the strength. Increased volume percentage of coconut fibre lower the density of concrete and hence, giving less compressive strength.

The numbers, length and width of cracks were measured for both plain and coconut fibre reinforced concrete after loaded with static loading. Cracks were counted in those surface where developed more than other surfaces. Experimental data has shown the development of crack is less in fibre reinforced concrete. Seven percent fibre volume reinforced concrete has developed least nos. of crack among rest fibre volume reinforced concrete. Figure 10 shows the nos. of crack of plain concrete and the different fibre volume percentage concrete. Plain concrete has developed more cracks compared with fibre reinforced concrete. Generally, in concrete cracks occur when the stress reaches the modulus of rupture of the concrete. For all the specimens, the crack appeared in the middle height position of the concrete cubes. The vertical pattern of cracks indicates that they were flexural cracks. It can be seen from test that crack spacing of plain concrete was highest then the different fibre volume percentage of reinforced concrete.

Experimental data has shown the length of crack is less in fibre reinforced concrete compared with plain concrete. There is a linear relationship between length of crack and nature of loading. For all concrete, the more length of crack has been found with 80% of static load. Therefore, coir fibre reinforced concrete can limit the length of crack. Length of cracks in plain and fibre reinforced concrete are shown in Fig. 11.

Experimental data has shown the width of crack is less in fibre reinforced concrete compared with plain concrete as shown in Fig. 12. In case of 1% fibre volume concrete, the width of crack is decreased with the decrease of loading. On the other hand, the width of crack in 3, 5 and 7% showed different result in the static loading. It has been clearly revealed the width of plain concrete is more than all fibre volume content. So, coir fibre reinforced concrete can limit the width of crack. Moreover, closed spaced cracks or more number of cracks, leads to smaller crack width. The reason for this behaviour is that the crack spacing is a function of both the tensile strength and the bond strength of the concrete. The decrease in the tensile strength of concrete is due to the decrease in its strength for the contribution of fibre volume percentage then the decrease in the bond strength of concrete. When the different fibre volume percentage added on the conventional concrete, thus the crack position a shorter distance is required for the tensile force in the fibre to be retransferred to the surrounding concrete, which implies shorter crack spacing.

Used the Load (KN) vs. remote (mm) graph and data, stress-strain curve for both plain and fibre reinforced

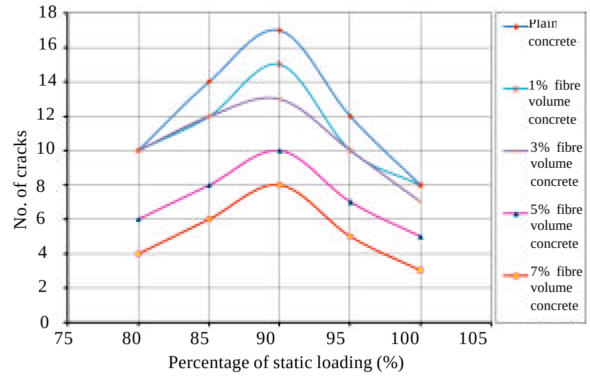

Fig. 10: No. of cracks developed in plain and fibre reinforced concrete

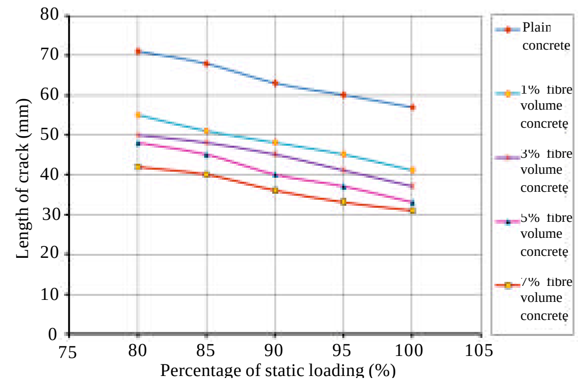

Fig. 11: Length of cracks in plain and fibre reinforced concrete

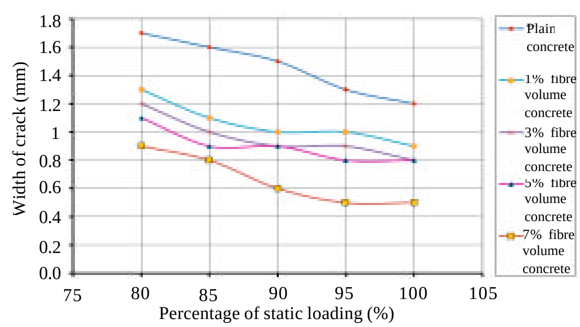

Fig. 12: Width of cracks in plain and fibre reinforced concrete

concrete were plotted. Figure 13 presents the stress-strain relation of plain and fibre reinforced concrete. It is observed that plain concrete exhibits higher stress than the fibre volume mixed concrete. Consequently, fibre volume concrete shows higher strain values than the conventional concrete. It's implies that fibre volume concrete cannot resist greater amount of load and show brittle failure at the ultimate stages of loading.

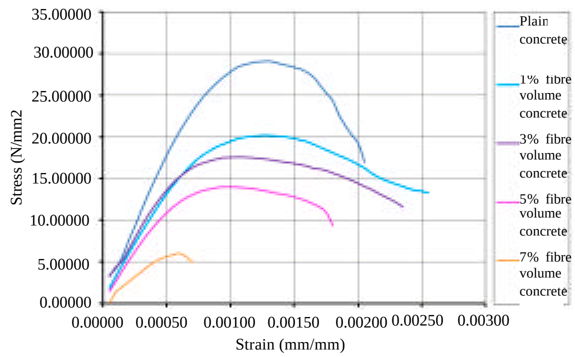

Fig. 13: Stress-strain relationship of plain and fibre reinforced concrete

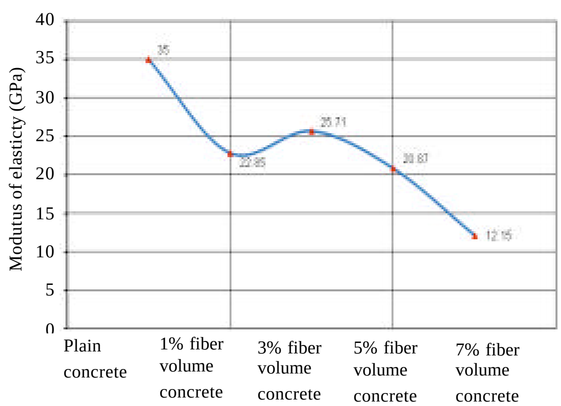

Fig. 14: Modulus of elasticity of plain and fibre reinforced concrete

Modulus of elasticity is the slope of a stress-strain curve. Stress-strain curves often are not straight-line plots, indicating that the modulus is changing with the amount of strain. In this case the initial slope usually is used as the modulus. Modulus of elasticity is also called as Young's modulus. The tangent of stress- strain curve of plain and coir fibre reinforced were calculated to determine the modulus of elasticity. Figure 14 presents the modulus of elasticity of plain and fibre reinforced concrete. Experimental result has also shown modulus of elasticity is slightly higher in plain concrete compared with fibre reinforced concrete. It is remarkable that 3% fibre volume concrete has shown more modulus of elasticity rather than 1% fibre volume concrete. This is mainly attributed to the less stiffness value of the coconut fibre compared to gravel. The development of E values of concrete is influenced by the type of coarse aggregate, type of cement, w/c ratio of the mix, aggregate size and curing age (Alexander and Milne, 1995). Generally, the modulus of elasticity of concrete depends on the stiffness of coarse aggregate. Also, the interfacial zone between the aggregates and paste and the elastic properties of component materials influence the modulus of elasticity of concrete.

CONCLUSION

This study has presented the results of an experimental program investigating the physical and mechanical properties of reinforced concrete incorporating different volume percentage of coconut fibre. Based on the experimental results and observations, the following conclusions can be stated:

- In all cases, the compressive strength of the concrete decreased as the volume percentage of coconut fibres increased in the concrete mix
- Test results showed that the compressive strength of plain concrete after 28 days curing period is 31.57 N mm^{-2}. However, concrete compressive strength with the 3% coconut fibre volume is between 18.85 N mm^{-2} at the curing age 28 day and it satisfies the structural requirement of lightweight concrete
- The authors propose that the 3% coir fibre volume reinforced concrete had the optimum set of mechanical properties in comparison with other fibre volume reinforced concrete
- Conventional concrete specimens were fully crashed when reached their ultimate failure load but the specimens in case of 1% and 3% of coconut fibre by the total volume did not crash when reached their ultimate failure load. Thus, coconut fibre reinforced concrete can enhance higher toughness
- Coconut fibre reinforced concrete has shown less number of crack developments and crack width. So, it can be a good alternative in construction area. Further work needs to be done in order to observe the effects of coconut fibre on concrete with various lengths and volume
- It is concluded that coconut fibre has the potential to be used in the conventional concrete for the production of structural lightweight concrete

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