

Flexural Behaviour of Lightweight Eco-friendly Concrete

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Abstract: Concrete is a very vital construction material and the demand for concrete is increasing rapidly day by day and production of concrete also leads to the production of carbon dioxide which badly effect the environment, causing air pollution. Cement and Concrete producing industries account for 2nd largest carbon dioxide producers in the world. A larger part of concrete is occupied by coarse aggregate and because of this usage of coarse aggregate is also increasing. To limit the usage of coarse aggregate we are required to search for alternate material that can partially replace coarse aggregate and is also eco-friendly so that the production of carbon dioxide can also be reduced. Coconut Shell is one of the materials that can be eco-friendly and at the same time partially replace the coarse aggregate. So, in this research work, we tried to find out the flexural strength of concrete using a waste material i.e., coconut shell as a partial replacement of coarse aggregate, and the effect of coconut fibre on the flexural strength of concrete is also analyzed by mixing coconut fibres in four different proportions of 0.5%, 1%, 1.5% and 2% of cement's weight in the concrete mix. Concrete beams using crushed coconut shell and coconut fibre were casted and tested under flexure and the result is compared with the control set beam which is casted by replacing 10% of coarse aggregate with crushed coconut shell and without using coconut fibre and tested under flexure. It was noted that the slump value of concrete keeps on decreasing with an increase in the percentage of coconut fibre in concrete. The test result shows that the flexural strength of plain concrete beam at 28 days when tested under flexure increased up to an extent and then kept on

decreasing with an increase in the percentage of coconut fibre. The Optimum content of coconut fibre came out to be between 1.0 % and 1.5% of the cement's weight.

Keywords: Crushed coconut shell, Coconut fibre, Flexural Strength, Coarse aggregate, Cement's weight.

1. Introduction

Concrete is used in almost every type of building, and the rate of consumption of concrete is also increasing day by day due to the rapid development of infrastructure and construction works [1]. Cement and Concrete production industries account for one of the major contributors to carbon dioxide production in the world [2]. And major part of concrete is occupied by coarse aggregate and due to this demand for coarse aggregate is also kept on increasing, to meet the demand and to reduce the dependency on natural coarse aggregate various research work is going across the world to find some alternative of coarse aggregate and they somewhat got some success in form of optimum use of various material [3], [4]. There are various waste materials available such as coconut shell, ground granulated blast furnace slag, rice husk ash, fly ash, silica fume etc that can be used [5]–[7]. Using 30% Ground granulated blast furnace slag can be used in foam concrete mix for higher compression, flexural & split tensile strength [8]–[10]. Amorphous Silica which is derived from Rice Husk Ash provide an essential alternative to

conventional silica [11]. The Addition of coal fly ash into concrete mix results in reduction of construction cost and also helps in proper waste management and green sustainable environmentally friendly construction [12]. MgO-SiO₂ mixture of concrete shows increase in hardening time upto 90 days and also led to significant increase in strength and also shows reduction in permeability [13], [14]. Crushed coconut shell has gained some popularity in recent times as a partial replacement for coarse aggregate because of its availability and waste product in nature [15]. Coconut Shell is a well-known agricultural by-product or we can say waste product of humid agricultural countries [16]. Coconut Shell is dumped as garbage most of the time once the consumable part is removed from it and it can be crushed into desired size and can be reused as a coarse aggregate [16]. Coconut is grown in more than 90 countries and territories across the globe with an overall production of 59 million tonnes in 2016 only [16]. The Philippines, Indonesia, and India produce around 72 percent of the world's total coconut. It is estimated that around 17000 million nuts were produced in India every

year. Coconut shell is discarded as waste and there is hardly any best possible utilization available to reduce the waste product like coconut shell researcher tried coconut shell as a partial replacement of coarse aggregate [12].

Normal Concrete using normal aggregate has a density of around 2400 kg/m³ whereas concrete has a density of less than 2000 kg/m³ and compressive strength greater than 20 N/mm². Partial replacement of coarse aggregate with crushed coconut shell decreases the density of overall concrete and made concrete lightweight [17], [18]. Lightweight concrete offers flexibility in design due to reduced self-weight and it also improves the seismic response of the structure and also reduces foundation costs. Lightweight concrete reduces the dead weight of the overall building. Lightweight concrete can be used in partition walls [19]–[21]. One of the major drawbacks of lightweight concrete is it required more amount of binder to produce the same comparable strength as normal concrete and it can be easily rectified by partially replacing cement with pozzolanic manufacturing waste [22]. Cement paste and Coconut shell aggregate possess better bonding and it continues to remain in good quality even in later years also. There is no additional deflection, bending, cracks, or damage in coconut shell

concrete when subjected to practical loading for almost five years [23], [24].

In recent years there is an increase in the use of polymer concrete and there is no. of research currently going on to find innovative ideas to strengthen the concrete. It has been observed that there is a practice of adding fibres to construction materials in many regions [25]. Natural Fibre is easily available across the globe and is lesser the price in comparison to artificial fibre and also possesses more stiffness and can be easily recycled [26]–[32]. Natural Fibre has emerged as one of the very promising reinforcing materials in regards to sustainability and biodegradability and it is also non-toxic and environmentally friendly which helps in reducing carbon dioxide emissions [33], [34]. Coconut shell along with coconut fibre is abundantly available as waste material. Coconut fibre is a very well-known fibrous waste and presence of high lignin content it is very durable, elastic and resistant to rotting. Due to availability, less cost, and adequate tensile strength it can be used in the construction industry [35]. Coconut Fibre also plays a major role in preventing the development and propagation of cracks by acting as a bridge between concrete constituents i.e., cement, sand, and coarse aggregate, damaging effect brought by harsh environmental conditions can also be

reduced with the use of coconut fibre in reinforced concrete, the dosage of coconut fibre should be kept minimum and it should not exceed 1.2% of cement's volume, due to drawback of natural degradation. 0.25% coconut fibre (by total weight of aggregate) in the concrete mix provides almost 20 percent improvement in 28 days of flexural and compressive strength. The ductility and toughness of mortar mix are increased with an increase in higher coconut fraction in concrete mix. Flow ability and passing of concrete mix are decreased with an increase in the percentage of coconut fibre and marble waste in concrete mix and the addition of coconut fibre in concrete mix improves the mechanical performance of concrete up to 2 percent and then a decline in performance is observed when increased further. In this paper, an attempt has been made to study the flexural behavior of lightweight eco-friendly concrete when we use 10% coconut shell aggregate as a replacement of coarse aggregate and we also use coconut fibre in various proportion ranging from 0% to 2% in accordance to the cement's weight to study changes in flexural strength of concrete. This Experiment was carried out at Madan Mohan Malaviya University of Technology in Gorakhpur, Uttar Pradesh India.

2. Materials and methods

2.1. Materials

Coconut Shells and coconut fibre were collected from the temple, nearby to our college premises, and coconut shells were broken into small pieces with the use of a hammer and pestle set. Figure 1 and Figure 2 show the process of breaking coconut shell and coconut fibre respectively. Only broken coconut shell passing through the 12.5 mm sieve and retained on the 4.75 mm sieve is used as partial replacement of coarse aggregate. Crushed coconut shells and coconut fibres are washed and sun-dried before it used in concrete. Coconut Fibre was in the bunch and separated by hand. The length of fibre varies from 10mm to 250mm and the larger bunch was first cut into half and then separated which brings the maximum average length to around 80-90 mm. The properties of coconut fibre and coconut shell was listed in Table 1 and table respectively.

Ordinary Portland Cement (OPC) 43 grade conforming to Indian Standard IS: 8112-2013 was used as a binder. Natural sand is used as fine aggregate confirming to zone II having a specific gravity of 2.64 and sand passing through 4.75 mm was used. Coarse aggregate and natural sand were brought from a nearby local shop. Coarse aggregate passing from the 20mm sieve and retained on the 4.75 mm sieve was used.

Table 1: Properties of coconut fibre

Table 2: Properties of coconut shell

Properties Name	Value
Maximum Size (mm)	12.5
Thickness (mm)	3.5-8.5
Specific gravity	1.22
Water Absorption (%)	26
Crushing (%)	2.5
Impact (%)	8
Fineness Modulus	6.25

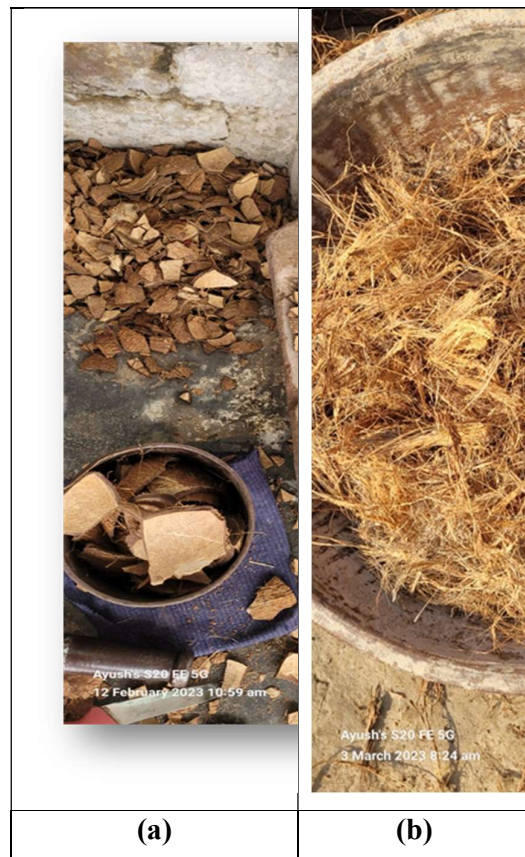


Figure 1 a) Coconut Shell aggregate b)
Coconut Fibre

Properties Name	Range
Length (mm)	10-250
Diameter(mm)	0.1-1
Tensile Strength (MPa)	15-405
Modulus of Elasticity (GPa)	4-22
Density (g/cm ³)	0.6-10
Water Absorption (%)	130-180
Elongation (%)	25-75

2.2.Mix Proportions and Methodology

The concrete mix was designed for M25 grade of concrete as per IS 10262.2009. Five mixes were prepared with coarse aggregate replaced with 10 percent of coconut shell aggregate. Mix M1 is for the control set with 0% percent coconut fibre. M2, M3, M4, and M5 were prepared with 0.5%, 1%, 1.5%, and 2% coconut fibre respectively. OPC 43 grade cement, natural sand, coarse aggregate, coconut shell aggregate, coconut fibre, and tap water were used. All the below work mentioned are performed at Madan Mohan Malaviya University of Technology, Gorakhpur, UP, India. Every constituent used here are weighted according to the proportions mentioned below in table 3 and then mixed by hand until the mixture looks uniform and consistent. A slump test was performed on each of the mixes and the average value is noted. A mould of a beam of size (100x100x500 mm) is first cleaned and then proper oiling is done on each of the

inside faces and the nut and bolt were tightened properly before filling of a freshly prepared concrete mixture. Concrete was filled layer by layer with each layer tamped equally and after that mould was placed on

a spring table vibrator for full compaction of concrete. Beam Mould was then opened the next day and kept into the curing tank filled with tap water until the day of testing at 7 & 28 days.

Table 3: Mix proportions of constituent materials used for coconut shell concrete production

Mix	Cement (Kg/m ³)	Fine Aggregate (Kg/m ³)	Coarse Aggregate (Kg/m ³)	Coconut Shell Aggregate (Kg/m ³)	Coconut Fibre (%)	Water (Kg/m ³)	W/C Ratio
M1	372	697	1058	117.61	0.0	186	0.5
M2	372	697	1058	117.61	0.5	186	0.5
M3	372	697	1058	117.61	1.0	186	0.5
M4	372	697	1058	117.61	1.5	186	0.5
M5	372	697	1058	117.61	2.0	186	0.5



Figure 2 a) Moulding of Beam b) Concrete beam

2.3. Testing Methods

According to Indian Standard IS: 1199-2018 slump tests was performed before the casting of concrete mix using slump cone of height 300mm, top and bottom diameter of 100mm and 200mm respectively. Concrete mould was unmoulded on the very next day. Flexural strength was determined using flexural testing machine. Four-point loading method was adopted for determination of flexural strength. Concrete beams are tested immediately after removal from curing tank. Using the concrete beam of size 500mm x 100mm x 100mm the flexural strength was determined as per IS 516-2021 for 7 and 28 days. The Maximum capacity of flexural testing machine was 100 KN. The load applied was gradually

increasing until the specimen failed. The

3. Result and discussions



Figure 3 Testing of Beams samples

Load at which specimen failed were noted along with average length of fracture from nearer support.

Modulus of rupture (f_b) = PL/BD^2 if a is greater than 133mm

$f_b = 3Pa/BD^2$ if a is less than 133mm but greater than 110mm

Where, P = maximum load applied in (KN),
 L = length between support (mm), B = width of the specimen in mm, D = measured depth of the specimen in mm, a = length of fracture from nearest support in mm

3.1.Slump test

Level of concrete now a day not only determined by its constituents but also by its flowability of concrete mixture during the transportation from ready mix site to final placing. It is concrete's property that tends to show that effort necessary to easily work on freshly prepared concrete without deteriorating the consistency of concrete. Adding of Coconut fibre gradually decreases the slump value of mixture.

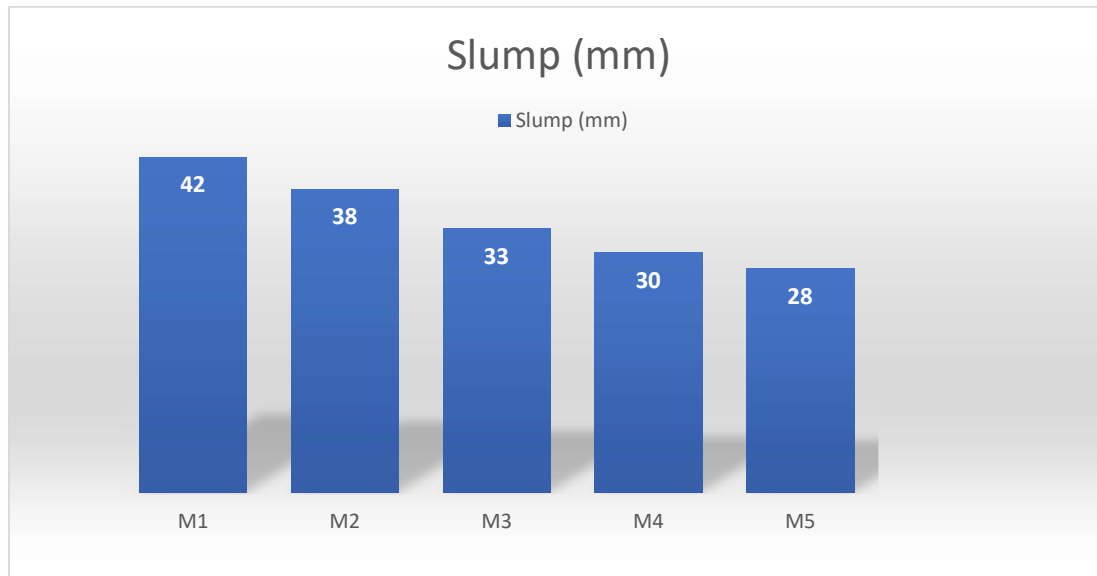


Figure 4 Slump value with addition of coconut fibre



Figure 5 a) Slump test b) Measurement of slump value

3.2.Flexural Test

Concrete is weak in tension and however very strong in compression as compared to tension, and in reinforced concrete member the dependence is on steel reinforcing bars. However, concrete develops tensile stresses due to drying shrinkage, rusting of steel reinforcement and many other reason also. Therefore, it is necessary to have knowledge of tensile strength of concrete. Flexural Strength gives us direct idea about tensile strength. It tests the ability of plain concrete beam to withstand the failure in bending. Also, the main aim of this research is to study the flexural behaviour of concrete beam using coconut shell and coconut fibre.

Addition of coconut fibre increases the flexural strength of beam. As the the percentage of fibre increases in concrete mixture the flexural strength kept

increasing upto a certain limit but after that onwards its starts decreasing. The Finding from this research shows that the optimum

content of coconut the must be used to get optimum result is somewhere between 1% to 1.5% coconut fibre of cement's weight.

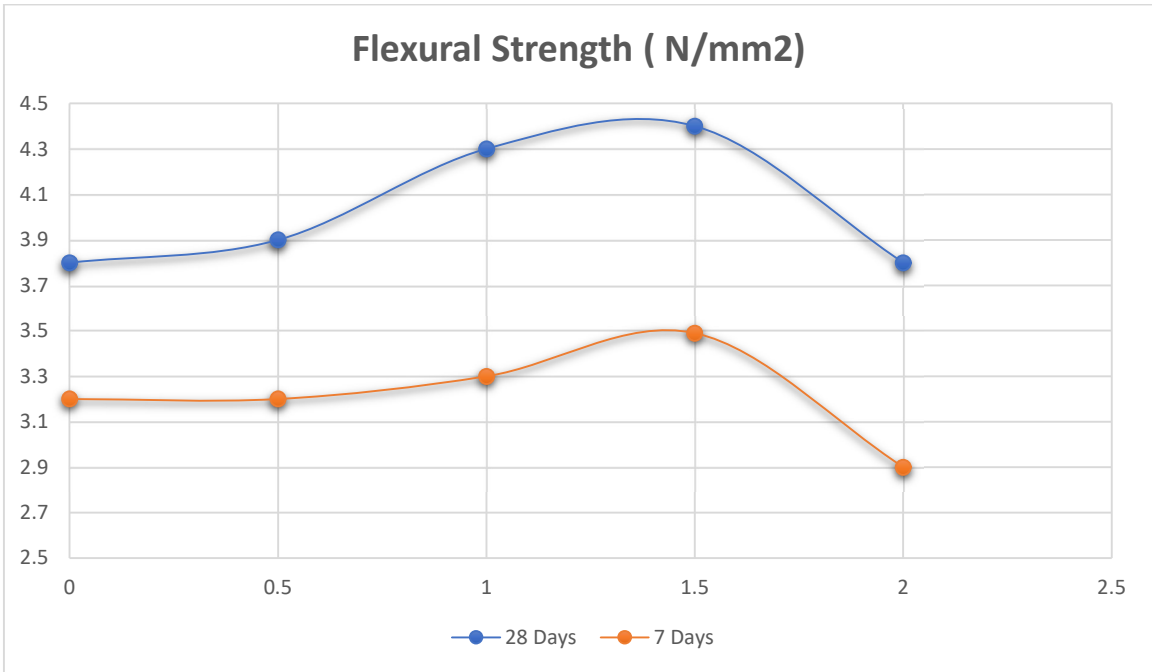


Fig.10. Flexural Strength with addition of coconut fibre in percentage.

3.3.Density of Concrete

Density is defined as mass per unit volume.
Density is kept on decreasing as cement is

replaced with lower density material which eventually decreases the overall density of concrete, below is the variation of density with increase in percentage of fibre.

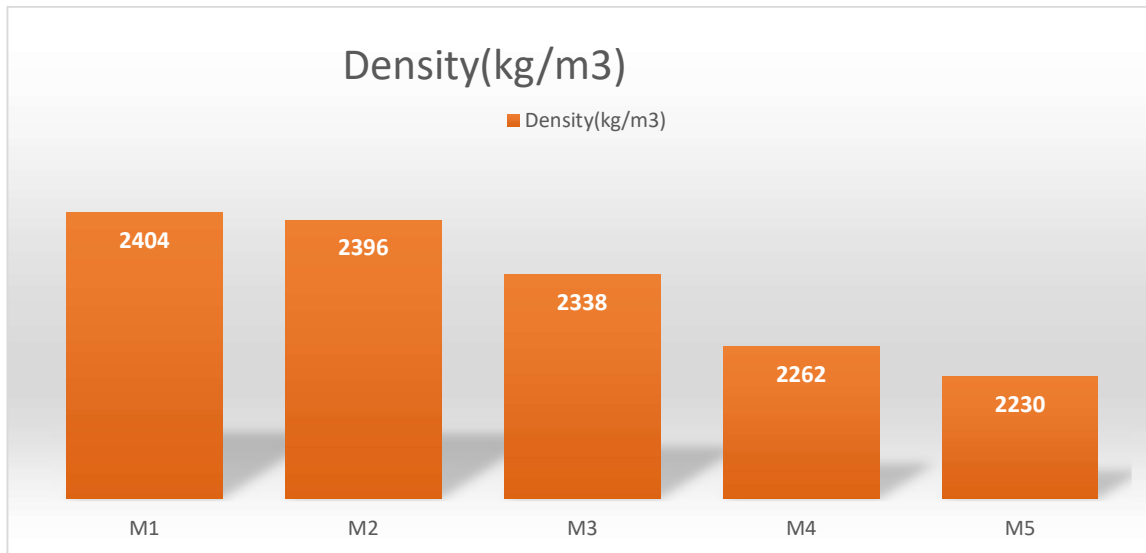


Fig. 11. Density with the addition of coconut fibre

4. Conclusions

In this study, a forward step is taken toward the utilization of coconut shell (10% of coarse aggregate's weight) along with coconut fibre (0% to 2.0 % of cement's weight with interval of 0.5%) in making of sustainable concrete mixture.

Based on the above experimental results, following conclusion can be drawn:

- When the percentage of coconut fibre was increased, the flowing ability of concrete decreases hence the slump value also decreases. The Mix M1 shows the slump near to the control set but other's slump decreases as the fibre percentage increases.
- Above Experiment's data also shows that the density of concrete keeps on decreasing with increase in percentage of coconut fibre.
- Experimental data also suggest that when we increase the coconut fibre content in concrete the flexural strength of concrete mix increases initially to 1.0 % and it remains the same till 1.5% but eventually started to decrease afterwards. The Data when plotted on the graph suggest that the optimum coconut fibre content must lies in between 1.0% to 1.5% coconut fibre of cement's weight.
- The flexural strength of concrete mix can be increased further if surface of coconut shell is treated before use, because when we analyse the failure surface, it's very

much evident that failure plane propagates through surface of coconut shell.

Overall, it can be concluded that coconut shell concrete mixed with coconut fibre is suitable to use in construction industry with sustainable approach and eco-friendly material. It ultimately helps in sustainable development which help in reducing the coconut shell and coconut fibre waste.

Future scope

Coconut shell and coconut fibre is waste material and using this in concrete not only reduce this waste material but also fulfil the goal of sustainable development. Coconut shell and coconut fibre possesses the physical properties that can reduce the dependency on coarse aggregates and also helps in increasing the flexural strength of concrete respectively. Coconut is abundantly available across the world so use of coconut shell and fibre reduces the waste from all over the world.

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