Flexural Strength Behavior of Ceramic Coarse Aggregate Added Bamboo Reinforced Beam

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Abstract: **-The bamboo is generally a giant grass plant having the strength and durability properties comparable with timber and steel. The weight-strength ratio of the bamboo is more than that of timber and steel. Large amount of ceramic wastes are producing from the ceramic industries every year. The ceramic wastes are known to be non bio degradable materials which cause much pollution problems in the environment. These materials can be reused for different purposes including construction will make a way for innovations in sustainable construction development. Here in the project ceramic waste coarse aggregate are partially replaced in percentage for coarse aggregate with bamboo as reinforcement. The optimum replacement value of the ceramic aggregates was obtained from compression tests on ceramic added concrete cubes and flexural strength of optimum % ceramic aggregate added bamboo reinforced beam was found out. Analysis and comparison of the optimum % ceramic aggregate added bamboo reinforced beam was then done with normally reinforced concrete beam.**

Key words: **Ceramic aggregate, Bamboo reinforcement, Flexural strength**

I. INTRODUCTION

The concrete as a construction material has been used in construction from about two centuries. The global production of the ceramic tiles in the world is about 8500 million square meters, this amounts is about 400 million square in Iran. The ceramic wastes are created due to the flows in the production of the ceramic materials. The non-decaying waste materials cause a waste disposal crisis, thereby contributing to the environmental pollution problems. This ceramic waste is used in concrete to improve the strength and durability factors. To achieve different properties of the concrete the ceramic will be used as partial material of replacement for fine and coarse aggregate.

The bamboo is the fast-growing woody plant in the world. The bamboo is used as a construction material for ancient times. Now it is well suited as a replacement material for steel reinforcement, because of its good and comparable mechanical property. Bamboo is characterized as a bio degradable, renewable and energy efficiency natural resource.it is an environmentally sustainable building material and it has been used as a construction material in certain areas for centuries. The bamboo can be used as an alternative material in reinforcement of concrete. The density of then fibres in cross section of the bamboo shell varies with thickness as well as height.In trials of tensile strength of the bamboo, it outperforms most other materials. It achieves this strength through its hollow tubular structure evolved over million years to resist wind forces in its natural habitat. This light weight material makes it easy to harvest and its transport. Due to incredible rapid growth cycle and the varieties of areas in which it is able to grow, bamboo is also extremely cheaper material.

The using of the ceramic waste aggregate concrete with bamboo reinforcement would be good alternative for the normal reinforced concrete because, the materials are locally available and economical since, there are scarcity of the steel and natural aggregates now a days.

Fig 1. Growth of bamboo

II. OBJECTIVE

To study the Flexural strength behavior of ceramic aggregate added bamboo reinforced beam on varying proportions of coarse aggregate being replaced with ceramic aggregates.

III. SCOPE

In this experimental study, ceramic waste aggregate is used only as a replaceable material for coarse aggregate.

IV. EXPERIMENTAL PROGRAM

A. Materials

Concrete

Concrete is a construction material, which is composed of Portland cement and water combined with fine and coarse aggregate. In the concrete the fine aggregate and the coarse aggregate bonded together with cement paste and that hardens over time. The cement reacts chemically with the water and other ingredients to form a harder matrix that will bind the materials together to form a durable strong material that has many uses.The increase in amount of water present inside the concrete will cause it to become more porous and to lose its strength. The proportioning of the ingredients inside the concrete is referred to as the designing of the mixture and it is designed to obtain a compressive strength of 15 to 35 MPa.Ordinary Portland cement (OPC)-(Chettinad cement) was used for the investigation. It was first tested for its physical properties in accordance with Indian Standard specifications. The cement that is most widely used for the construction purpose is Portland cement.

The maximum size of the coarse aggregate was 20 mm and the specific gravity of the coarse aggregate was 2.622. The granite is a coarsely grained igneous rock having an even texture consisting largely of quartz and feldspar with often small amounts of mica and other materials. The granite is a very hard compact material having fine polish showing beauty of crystals. The density of the granite is 2,723 Kg/m3, the specific gravity and crushing strength of the granite stone are 2.622 and 158 to 220 MPa.

The amount of water in concrete controls many fresh and hardened properties in concrete including workability, compressive strengths, permeability, water tightness, durability, weathering, drying shrinkage etc.The water using for construction purposes should be free from acids, alkali's, oils and other organic impurities.. The two main functions of the water are to react chemically with water to form a cement paste that get hardened by the setting time and to act as a vehicle or lubricant in the mixture of fine aggregates and cement.

The ceramic aggregates are the materials that were obtained as a waste from the tile industries. The ceramic materials are Non-Biodegradable materials that will cause pollutions in the environment. The ceramic materials also have the mechanical properties comparable to that of the natural aggregates. The water absorption capacity of the ceramic aggregates is more than natural stone aggregates.The addition of the ceramic aggregates increases the compressive strength and split tensile strength of the concrete specimen. The ceramic waste is a durable, hard and highly resistant material to chemical and physical degradation forces.

Fig 2. Ceramic Aggregates

Reinforcement

The steel reinforcement was the high yield strength (HYSD) bars having yield strength of 415 N/mm2 was used as reinforcement in the concrete. The longitudinal tension reinforcement used was high-yield strength bars of 8 mm diameter and the hanger bars were high yield strength bars of 6 mm diameter. The stirrups were made from mild steel bars with 6mm diameter.

Fig 3. Steel Reinforcement

The bamboo reinforcement was made using Bambusa bamboo species having yield strength of 117.9 MPa. The bamboo were then placed in a tank filled with a solution of 45 litre water, 2 Kg boron and 2 litre boric acid for 2 days and then placed under sunlight for maximum drying. The longitudinal reinforcement was made with 4 splints of ¾ inch width and thickness. The stirrups were made with 9 splints of ¾ inch width and ¼ inch thickness with 15 cm c/c spacing.

Fig 4. Bamboo Reinforcement

The wood enamel paint was used in order as an adhesive material to bind the sand particle to bamboo reinforcement. This was done for providing maximum bonding for the bamboo reinforcement with the concrete matrix. The wood enamel paint used was 'Berger luxol Hi-Gloss Enamel' of green color.

Material Test Results

Sl.No	Materials	Property	Value Obtained
1	Cement	Specific gravity	3.12
		Fineness modulus	2.50 %
		Standard Consistency	28.9 %
		Initial setting time	210 min
		Final setting time	475 min
2	Fine Aggregate	Specific gravity	2.68
		Fineness modulus	2.93
		Grading zone	Zone I
3	Coarse Aggregate	Specific gravity	2.622
4	Ceramic Aggregate	Specific gravity	2.56
5	Bamboo	Tensile strength	248.23 N/mm^2

B. Mix Design

M20 grade concrete mix is designed as per standard design procedures using the properties of the materials used. The M20 mix is the lowest design mix and is designed as per IS-10262-2009 procedure using the properties of the materials selected and from the calculations. The ratio is found as 1: 1.746: 2.78.

C. Beam Design

In this study the RCC beams were designed using M20 grade concrete and Fe 415 steel. The dimensions of the beams were designed with the standard design procedure in Limit state method. From the beam design, rectangular beams are provided with 2 steel bars of 8 mm diameter at the tension zone and 2 steel bars of 6 mm diameter as hanger bars. The stirrups used are of 6mm diameter for beams. The dimension of the beams is fixed to 150 mm x 300 mm with a span of 1.2 m.

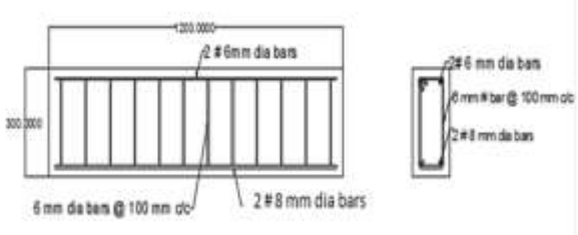

Fig 5. Design of steel Reinforcement

The bamboo reinforced beams are provided with 4 numbers of bamboo splints with ¾ inch width and thickness. The stirrups used are of bamboo splints of ¾ inch width and ¼ inch thickness with spacing of 15 cm c/c.

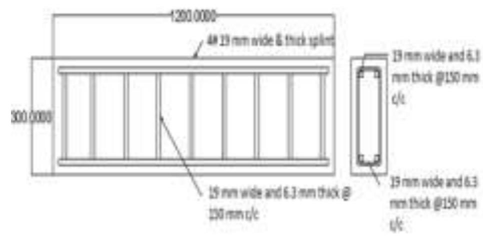

Fig 6. Design of Bamboo Reinforcement

D. Tests For Compression

For the compression test, a total of 24 concrete cubes were casted with 4 batches of 6 cubes. Materials were taken with respect to the mix proportion. The casting was done for 4 ratios namely 0%, 10%, 20% and 30% of replacement of coarse aggregate with ceramic aggregate, which is also having the material property same as that of the natural stone. In each casting mixing was done for single batch of 6 cubes in a 150 kg capacity mixer available in the laboratory.The compression tests for concrete cubes were done for 7 days and 28 days of curing. The compression tests were done using compressive testing machine on a loading rate of .14 to .32 MPa. On the 7 days of curing the cubes will acquire 66 % of total strength and on the 28 days of curing the cubes will gain 99% of total strength.

E. Tests For Flexure

Treatment of bamboo

The bamboo used for bamboo reinforcement was treated with chemical treatment methods. In this method 2 kg boron and 2 kg boric acid were mixed with 45 liters of water in a tank. Hole was put on each node of the bamboo and was allowed for kept inside the tank for 2 days. After 2 days bamboo was taken out of the tank and kept under sunlight for the complete draining of chemical solution. The treatment were done in order to increase the mechanical properties of the bamboo and to fight against the fungal and insect attacks on the bamboo.

Fig 7. Treatment of Bamboo

Making of bamboo reinforcement

The bamboo splints of 19.1 cm width and thickness were used for longitudinal bamboo reinforcement. The splints of 19.1 cm width and 6.3 cm thickness were selected for the making of stirrups. The stirrups were bended using applying fire gun to the bend area by applying some hand pressure. Frequently after bending, the splints were put under water for not to lean again. The stirrups were then tied with the longitudinal reinforcement at spacing of 15 cm.

Fig 8. Making of bamboo reinforcement

The coating was done over the bamboo for two reasons. The first reason was to prevent the bulging of the bamboo after the completion of the casting. The second reason was to bind the sand particles to the reinforcement to provide bonding between bamboo reinforcement and concrete matrix. The coating was done with 'Berger wood enamel paint' and the reinforcement was bind with 'M-Sand'. The paint was applied on the reinforcement with the use of a brush and then it was placed inside a prepared sand bed of M-Sand. The reinforcement was then kept without any movement in a sheet for a day for the reinforcement to become dry. After the process the longitudinal reinforcement was tied with stirrups for the casting of the beam.

Fig 9. Coated bamboo reinforcement

Casting of beam

The casting of the beam was done in a single stage with 4 set of mix. The moulds were prepared with 1.5 cm thick mongo wood planks. The casting was done for 4 set of totally 8 beams and was classified as 'normal concrete with steel reinforcement, normal concrete with bamboo reinforcement, optimum percentage ceramic aggregate replaced concrete with steel reinforcement and optimum percentage ceramic replaced concrete with bamboo reinforcement.The mixing of the concrete was done in 4 set of mix with the use of a mixer of about 400 kg capacity available in the work area. . The reinforcement was then placed in the position as per the design. The concrete mix was then poured into the mould and the vibrations were done given with the help of a needle vibrator. Then the beams were finished at the top level of the mould. The beams were removed from the mould after 24 hours. After the de-Moulding the beams were cured for 28 days of curing inside a water tank.

Flexural loading on beams

The test covers the flexural strength determination of the concrete beam using two points loading. The simply supported concrete beam was loaded by two point loads placed .33 m from clear span of the beam as per design. Initially the load is applied using a hand pump to obtain the initial cracking load. Loading was done such that the load was increased until flexural failure took place. The flexural peak stress in the beam was calculated on the basis of the peak load on failure obtained**.**The flexural strength testing method is referred to as modulus of rupture. The loading was done using a hydraulic loading frame of capacity about 50 tons.

Fig 10. Test setup of flexural loading beam

Deflection measurement

The deflections of the beam during the flexural bending were calculated using a deflection gauge set at the bottom middle point of the beam. The max deflection of the beam is obtained from the center of the beam. The gauge was placed such that, it was supported by a stand placed at the bottom of the beam supported from ground. The gauge is fixed to the stand by providing magnetic base at the bottom of the gauge. Deflection was shown soon after the increase in the load acting in the beam. Deflection was noted for every increase in 10 kN up to the formation of the initial crack on the beam.

V. RESULTS AND DISCUSSION

Compression strength results

The compressive tests for the specimens were done and the compression yield load after failure was obtained from the dial gauge. The compressive tests were done for 4 sets of concrete cubes with 0%, 10%, 20% and 30% of replacement of coarse aggregates with ceramic aggregate. The specimens were loaded at a rate of .14 to .32 MPa per second.

Sl. No	% Replacement	Compressive Strength
1	0 %	30.21 N/mm^2
2	10 %	39.97 N/mm^2
3	20 %	37.47 N/mm^2
4	30 %	27.55 N/mm^2

Discussion

When the replacement was 10 %, the excess water in the concrete was absorbed by the ceramic aggregates. The water absorption of the ceramic aggregates make the water content in the concrete as optimum water content and it increased the strength. But the increase in the percentage of the ceramic aggregates in concrete caused to increased water absorption. The water absorption is more due to porosity of ceramic aggregates (Anderson et al. 2016). The increase in the water absorption thus caused to form wide capillary cracks and specimen fails in compression. This caused in the reduction of the strength in compressive test specimen with the percentage increase in addition of ceramic aggregates.

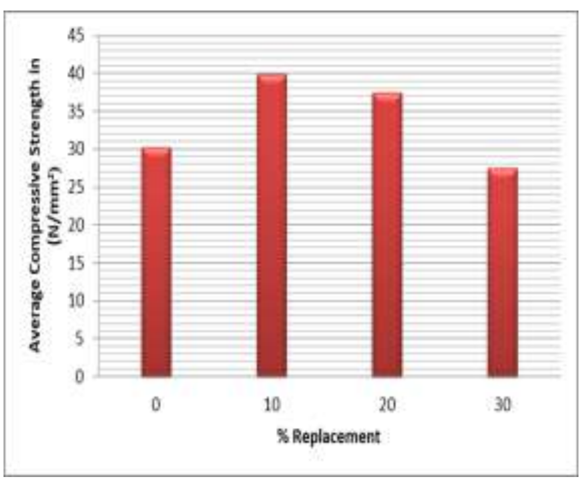

Fig 11. Analysis on compressive strength results

Flexural strength results

The flexural loading was done on the loading frame and the flexural yield load was obtained from the obtained from the dial gauge. The flexural loading was done for 4 set of totally 8 beams namely normal concrete with steel reinforcement, normal concrete with bamboo reinforcement, optimum % ceramic aggregate replaced concrete with steel reinforcement and optimum % ceramic aggregate replaced concrete with bamboo reinforcement**.**

Sl. No	Type of beam	Flexural strength
1	Normal concrete with steel reinforcement	12.56 N/mm^2
2	Normal concrete with bamboo reinforcement	7.795 N/mm^2
3	Optimum % ceramic aggregate concrete with steel reinforcement	13.44 N/mm^2
4	Optimum % ceramic aggregate concrete with bamboo reinforcement	8.59 N/mm^2

Discussion

From the flexural loading on the beams, the optimum ceramic content steel reinforced beam has the maximum flexural strength than other beams including the normal concrete steel reinforced beam. From the bamboo reinforced beams, the optimum ceramic content bamboo reinforced beam has higher strength than the normal concrete bamboo reinforced beam. The maximum strength for the optimum ceramic content concrete beams is due to the water absorption property of the ceramic aggregate. It makes the beam to yield for the maximum flexural load. Comparing to the steel beams, the bamboo beams are also having the comparable mechanical property to yield maximum at the flexural load application. Since the bamboo is a low cost and easily available construction material, it can be used as an economical replacement material for steel in its unavailability.

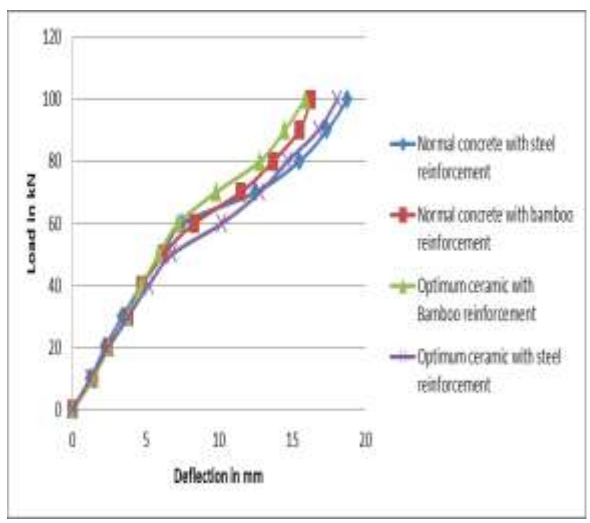

Fig 12. Analysis on flexural strength of beams

The cracks were formed by the flexural loading on the beams and the cracks were generated on the flexural span of the beams having the maximum deflection and the beams were failed in flexure.

VI. CONCLUSION

The experimental investigation was done in order to find the strength variations in adding ceramic coarse aggregate to the concrete and to find the possibility of using bamboo reinforcement as a replacement material for the steel. The strength variations were studied using replacement of natural coarse aggregate with ceramic coarse aggregate in 4ratios namely 0%, 10%, 20% and 30%. The strength variations were calculated using the compressive strength test on concrete cubes. The viability of using bamboo reinforcement instead of steel reinforcement was found out using flexural bending tests of beams.

1. Compressive strength test on concrete cubes were done with 0%, 10%, 20%, 30% and the optimum replacement ratio was found as 10%.
2. Since the water absorption of the ceramic aggregates is 5.1 % , the strength increases in the concrete cubes due to the water absorption capacity of ceramic aggregates in the specimen. The water absorption of ceramic aggregates for 10 % replacement was optimum to increase the compressive strength. But more increase in the water absorption will cause to form wide capillary cracks in the specimen and their bye cause to the reduction in strength.
3. Flexural loading were done for 4 cases of beams namely normal concrete steel reinforced beam, normal concrete bamboo reinforced beam, optimum ceramic aggregate steel reinforced beams and optimum ceramic content bamboo reinforced beams.
4. From the flexural loading on the beams, the optimum ceramic concrete bamboo with steel reinforced beam is having maximum strength. Strength increases due to the optimum water absorption of the beams, which allows for the maximum bending capacity of the beams.
5. Cracks on the beams due to the flexural loading were all developed in the flexural span of the beams inside the 2 point load acting area and all the beams are having comparatively similar load deflection curve pattern.
6. The treated bamboo reinforced beams are also having flexural strength comparable to the steel reinforced beams. Since the bamboo reinforced beams are low cost and easily available construction material, it can be used as an economic replaceable material for steel reinforcement in its present unavailability conditions.

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