Experimental Investigation on the Concrete by Addition of Bamboo Fibers and Partial Replacement of Cement with GGBS

K Bhagya[1], M Shreya[2], K Saraswathi[3], M Suresh[4], S Saikishore[5]
[1]Assistant professor, Department of Civil Engineering, Jyothishmathi Institute of Technology and Science, Karimnagar, Telangana, India-505001
[2,3,4,5] B.Tech students, Department of Civil Engineering, Jyothishmathi Institute of Technology and Science, Karimnagar, Telangana, India-505001

***Abstract*—The main objective of this project is to analyse the behaviour of M25 grade of concrete with mix design 1:1:2 and with water-cement ratio 0.45. Here cement was partially replaced by 10%,20%,30% of GGBS. 1% of bamboo fiber is added to the whole mass of concrete. Aspect ratio of bamboo fiber is 30. Due to addition of bamboo fiber and GGBS the compressive strength, split-tensile strength and flexural strength was increased due to pozzolanic action of GGBS and strong bond formation of bamboo fiber. The maximum strength was achieved at 30% of GGBS and 1% of steel fiber. Due to addition of bamboo fiber and GGBS the work ability results were good. The usage of GGBS and bamboo fiber in concrete is used to develop the concept of green concrete. Bamboo fiber and GGBS based concrete is environmentally safe and economical.**

Work-ability tests, compressive strength test, split tensile strength test, flexural strength test is performed and results are obtained to know the strength properties of the concrete after replacing 10,20,30 percentages of GGBS with cement and addition of 1% of bamboo fiber to whole mass of concrete.

Key words: Bamboo fiber, GGBS, work ability, compressive strength, split tensile strength, flexural strength.

INTRODUCTION

Bamboo belongs to grass family and has been associated with various names such as “poor man’s timber”, “Green Gold”, “Cradle to Coffin” because of its various documented applications. Bamboo is widely recognized as highly renewable, fast growing, economic raw material. Products from bamboo are grouped into industrial use, food products, construction and structural application, wood substitutes and composites, and cottage and handicraft industry. GGBS blended concrete have been used successfully in concrete for many years in many countries throughout the world. From all the available technical literature it is suggested that there are potentially many technical benefits to be gained from using the GGBS. Where structures have to be designed for durability requirements in very aggressive environment GGBS blend mixes are recommended in standards of most developed and developing countries. Many countries have accepted the benefits and have recommended its use in their national standards. Once the user is made aware of the properties of the material and understood the benefits to be gained there is no reason why it should not continue to be used successfully and more often in existing and future project.

BAMBOO AS A BUILDING MATERIAL:

Bamboo as a building material has high compressive strength and low weight has been one of the most used building materials as support for concrete, especially in those locations where it is found in abundance. Bamboo as a building material is used for the construction of scaffolding, bridges and structures, houses. Due to a distinctive rhizome-dependent system, bamboos are one of the fastest-growing plants in the world and their growth is three times faster than most other species of plants. They are renewable and extremely versatile resource with multi-purpose usage. Among many uses of bamboo, Housing is one of the major area’s applications especially in the wake of residential shortages around the globe. Bamboo as a building material is conventionally associated with the region of Southeast Asia and South America where

climate is best suitable for its cultivation. In many of the nations, bamboo is used to hold up suspension bridges or simply make places of dwelling.

PROPERTIES OF BAMBOO FIBER

- TENSILE STRENGTH:

Bamboo is able to resist more tension than compression. The fibers of bamboo run axial. In the outer zone are highly elastic vascular bundle, that have a high tensile strength. The tensile strength of these fibers is higher than that of steel, but it's not possible to construct connections that can transfer this tensile strength. Slimmer tubes are superior in this aspect too. Inside the silicates outer skin, axial parallel elastically fibers with a tensile strength up to 400 N/mm^2 can be found. As a comparison, extremely strong wood fibers can resist a tension up to 50 N /mm^2.

- COMPRESSIVE STRENGTH:

Compared to the bigger tubes, slimmer ones have got, in relation to their cross-section, a higher compressive strength value. The slimmer tubes possess better material properties due to the fact that bigger tubes have got a minor part of the outer skin, which is very resistant in tension. The portion of lignin inside the culms affects compressive strength, whereas the high portion of cellulose influences the buckling and the tensile strength as it represents the building substance of the bamboo fibers.

◆ ELASTIC MODULUS:

The accumulation of highly strong fibers in the outer parts of the tube wall also work positive in connection with the elastic modulus like it does for the tension, shear and bending strength. The higher the elastic modulus, the higher is the quality of the bamboo. Enormous elasticity makes it a very useful building material in areas with very high risks of earthquakes.

- ANISOTROPIC PROPERTIES:

Bamboo is an an-isotropic material. Properties in the longitudinal direction are completely different from those in the transversal direction. There are cellulose fibers in the longitudinal direction, which is strong and stiff and in the transverse direction there is lignin, which is soft and brittle.

- SHRINKAGE:

Bamboo shrinks more than wood when it loses water. The canes can tear apart at the nodes. Bamboo shrinks in a cross section of 10-16 % and a wall thickness of 15-17 %. Therefore, it is necessary to take necessary measures to prevent water loss when used as a building material.

- FIRE RESISTANCE:

The fire resistance is very good because of the high content of silicate acid. Filled up with water, it can stand a temperature of 400° C while the water cooks inside.

➢ Various Structural Shapes of Bamboo as a Building Material:

Bamboos are treated in such a way that they assume desired shapes and structures while they grow:

1. Squared cross-section can be obtained by compressing the growing stalk of bamboo within a square section.
2. Arch shapes of bamboo can also be created by compressing the bamboo's growth into the desired shape. This would cost lesser than it would to get the same form with normal timber.
3. Curved and Flat shapes of bamboo are achieved through traditional techniques like applying heat and pressure.

GGBS AS BUILDING MATERIAL

GGBS (Ground Granulated Blast-furnace Slag) is a cementitious material whose main use is in concrete and is a by-product from the blast-furnaces used to make iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimises the cementitious properties and produces granules similar to a coarse sand. This 'granulated' slag is then dried and ground to a fine powder. Although normally designated as 'GGBS' in the UK, it can also be referred to as 'GGBFS' or 'slag cement'.

The molten slag is lighter and floats on the top of the molten iron. The molten slag comprises mostly silicates and alumina from the original iron ore, combined with some oxides from the limestone. The process of granulating the slag involves cooling of molten slag through high-pressure water jets. This rapidly quenches the slag and forms granular particles generally not bigger than 5 mm. The rapid cooling prevents the formation of larger crystals, and the resulting granular material comprises around 95% non-crystalline calcium-alumina silicates. The

granulated slag is further processed by drying and then grinding in a vertical roller mil or rotating ball mill to a very fine powder, which is GGBS.

HOW TO USE GGBS IN CONCRETE

Ground granulated blast furnace slag (GGBS) is a by-product of the steel industry and is used as a supplementary cementitious material in concrete. Here are the general steps to use GGBS in concrete:

1. Determine the percentage of GGBS to be used: GGBS is usually used as a partial replacement for Portland cement in concrete. The percentage of GGBS used in concrete varies depending on the project's requirements, but it is typically 20-50%.
2. Calculate the mix design: The concrete mix design needs to be adjusted to accommodate the addition of GGBS. The water-cement ratio and the number of other materials, such as aggregates and admixtures, may need to be adjusted to maintain the desired work ability and strength of the concrete.
3. Add GGBS to the concrete mix: GGBS is added to the concrete mix as a powder. It should be added along with the other dry materials, such as cement and aggregates, and mixed thoroughly before the addition of water.
4. Mix the concrete: The concrete should be mixed thoroughly to ensure the GGBS is evenly distributed.

LITERATURE REVIEW

I.BAMBOO FIBER

- WORKABILITY

Thingujam Jackson Singh [2015] have given a critical review of the characterization for natural fiber reinforced composite. The mechanical properties of the natural fiber composites (bamboo, sisal) primarily depend upon the fiber interracial adhesion. Though the natural fibers are superior in properties, but due to its hydrophilic nature, it possesses poor bonding nature with the hydrophobic polymer matrix. This has resulted in the degradation of its mechanical properties. The optimum fiber length, loading and low moisture absorption nature of the fibers have improved the mechanical properties of the composite. The addition of flame retardants has resulted in the increase of thermal stability of the composite. The natural fiber reinforced composites got high potential of replacing the conventional material used in the electrical appliances.

Kavitha. S [2018] has obtained results showing that the slump value decreased from 110 mm for normal concrete to the 60 mm for 1.25% fiber content. The slump values with corresponding fiber content varying from 0.5 -1.25 percentage of cement is 95 – 60 mm which considerably decreases on increasing fiber percentage in concrete mix proportion.

- COMPRESSIVE STRENGTH

Compressive strength of concrete is one of the most important properties of concrete. It is a qualitative measure of concrete. Failure of concrete under compression is a mixture of crushing and shear failure. The compressive strength varies as a function of both cement paste and fibers. Higher binder ratio gives higher compressive strength.

Dr. Shakeel Ahmad [2017] have studied that concrete cube reinforced with 1% bamboo fibre by volume have been tested in compression testing machine and stress -strain curve has been plotted. The results have been compared with plain concrete cubes. He had found that the strength of concrete cubes with fibers doesn't show much improvement up to 28 days but surprisingly strength become double in 50 days testing. Bamboo fibers can be used as replacement with concrete which can save the expensive concrete, 10000cm3 per 1m3 of concrete.

Kavitha. S[2018] The compressive strength increases from 32.8 N/mm2 with 0% fiber content to a maximum of 41N/mm2 with 1% of fiber content and then starts decreasing with an increase in fiber content. The compressive strength values in M Pa obtained in range of 20-25, 28.2 – 30.6, 33.7-38.9 after 7, 14 and 28 days of curing.

- SPLIT TENSILE STRENGTH

Humberto C. Lima [2016] have concluded that the experimental tests on the bamboo species Dendrocalamus giganteus showed that the bamboo tensile strength is comparable with the best woods used in constructions and even with steel. The tensile stress vs. strain curve of the bamboo is linear up to failure. Bamboo average tensile strength is approximately 280 M Pa in the specimens without node and 100 M Pa in the specimens with node. Finally, 60 cycles of wetting and drying in solution of

calcium hydroxide and tap water did not decrease the bamboo tensile strength neither the Young's Modulus. Ade Sri Wahyuni [2017] have concluded that in general the tensile strength of bamboo fibre reinforced concrete is comparable to that of Normal Concrete. Despite the strange result of a few samples which decrease at the later age, the bigger picture shows the addition of rice husk ash, sea shell ash and bamboo fiber, increase the tensile strength of concrete.

M.Brindha[2019] concluded that the bamboo fiber reinforced concrete fabricated by initially chopped fibers of 6cm length shows split tensile strength for M40 grade concrete as 3.15 at 1% and 3.31 at 1.5% fiber induction under test. The split tensile strength of cylinder is increased with the addition of bamboo fiber up to 1.5% and addition of bamboo fiber up to 1.5 % exhibits an increase of 37.91% in case of split tensile strength when compared to nominal mix.

- FLEXURAL STRENGTH

R. S. P. Coutts [2015] have studied that fiber loading of 14% by mass, the autoclave bamboo fiber reinforced cement composites have a flexural strength greater than 18 M Pa and a density of about 1.3 g cm-². However, the fracture toughness value is low, being less than 0.50kJ rn-² due to short fiber length and high fines' content of the Bamboo pulp. By screening out fines contained in the original bamboo pulp the flexural strength values can be improved to greater than 20 M Pa while fracture toughness exceeds I+0 kJ n--l.

Dr. Shakeel Ahmad [2018] found that modulus of elasticity of concrete increases by addition of bamboo fibers. The flexural strength of bamboo reinforced beam increases as high as nearly doubled, so bamboo reinforced beam can be used in low-cost buildings.

H. Raghavendra Rao [2019] have studied that the hybrid composites are found to have good Flexural properties. In the case of maximum strength, the values vary between 60 to 213 M Pa. The Flexural strength of these composites is found to be enhanced when alkali treated bamboo fibers were used in the hybrid composites.

Kavitha. S [2019] concluded that the addition of bamboo fibers makes the concrete very resistive in flexural and improvement in 28 days strength was observed to be 7.5 N/mm. Hence addition of fiber content increases the flexural strength, for nominal mix 28 days compressive strength is 32.8 N/mm2 up to 1% there will be a increase in strength from 1.25 % there will be decrease in strength.

W. Yao [2014] the flexural tests were carried out at a loading rate of 0.5 mm/min on a computer controlled MTS810 universal-testing machine with a maximum load of 100 kn. The span for specimens was set as 300 mm. The average flexural strengths are 90.4 and 91.1 M Pa. The results of this investigation show that for the laminates with reformed bamboo plate on the bottom as tension layer and the fiber reinforced mortar sheet on the top as compressive layer, the flexural strength values can be improved to greater than 90MPa.

Ajinkya Kaware[2013] water absorption of bamboo is quite high to reduce this effect seasoning or other suitable treatment should be given tensile strength of bamboo is good for M20 grade 0% of slag 0% of steel fiber compressive strength is 26.33N/mm2. .For 20%slag 1%steel fiber strength will be decreases for M40 grade nominal mix strength is 44.59%.for 20% slag&1.5% of steel fibers 45.67N/mm2 .For M30 grade nominal mix flexural strength is 6.07N/mm2 .for 20% slag 1.5% of steel fibers flexural strength will be increases 7.61N/mm2. Our paper investigated that the compressive strength increases up to 1% more than 1% there will be decreases. Split tensile strength increases step by step adding the bamboo fibre.

II.GGBS

SANTOSH KUMAR KARRI, G. V. RAMA RAO, P. MARKANDEYA RAJU (10 OCT 2015) This present paper focuses on investigating characteristics of M20 and M40 grade concrete with partial replacement of cement with ground granulated blast furnace slag (GGBS) by replacing cement via 30%,40%,50%. The cubes, cylinder and prism are tested for compressive strength, split tensile strength, flexural strength, durability studies with sulfuric acid and hydrochloride acid were also conducted. from this paper work ability of concrete increases with the increasing GGBS replacement level. the compressive strength of concrete increased when cement is replaced by GGBS for both M20 and M40 grade concrete. at 40% replacement of cement by GGBS the concrete attained maximum compressive strength. the split tensile strength of concrete is increased when cement is replaced with GGBS the split tensile strength is maximum at 40% of replacement. the flexural strength of concrete is also increased when the cement is

replaced by GGBS. At 40% replacement the flexural strength is maximum. The compressive strength values of acid effected concrete decreases on comparison with of normal concrete, but the effect of acid on concrete decreases with the increase of percentage of GGBS. at 40% replacement of GGBS the resistance power of concrete is more. The compressive strength values of GGBS concrete effected to HCL were greater than the GGBS concrete effected to H2SO4. the effect of HCL on strength of the concrete is lower than the effect of H2SO4 on strength of the cement.

DR. SURESH AND K. NAGARAJU (2015) Investigating characteristics of concrete with partial replacement of cement with GGBS. This paper deals with GGBS, its advantages and disadvantages in using it in a concrete. Author carried out experiment on GGBS concrete by replacing it with OPC by 50%, 60%, 80% and 90%. It is observed that GGBS is good replacement to cement in some cases but it cannot replace cement completely but even though it replaces partially it gives very good result. HOGAN AND MEUSEL [3]: AT 40%,50% found that up to 3 days of age strength contribution of slag mortar was low. However, strength similar to reference Portland cement was achieved in 7 days and higher strength thereafter.

A. ONER AND AKYUZ (JAN 2007) Calculated the optimum GGBS content to maximize the strength as 40%. When the curing period is extended the strength increases the reason is that the Pozzolanic reaction is slow and the formation of calcium hydro oxide requires time. The compressive strength of GGBS concrete increases as GGBS content increases at optimum point after which the compressive strength decreases. The optimum level of GGBS content maximizing the strength is at about 55-59% of total binder content.

HUIWEN WAN (17 JULY 2003) Geometric characteristics of different GGBS including particle size distribution, shape and their influence on cement properties GGBS with same surface area but made by different grinding techniques can have different performance. Even though the surface area of GGBS is same the geometric characteristics and the PDS (particle Distribution size) can be different due to different grinding techniques.

K. GANESH BABU&V. SREE RAMA KUMAR (30 MARCH 2000) This paper attempts to assess the cementation efficiency of GGBS in concrete at the various replacements in percentage at 28 days. In this paper the replacement levels in the concrete studied varied from 10% to 80% and the strength efficiencies at 28 days are calculated. The earlier proposed method for evaluating the efficiency of pozzolan like Fly ash and Silica fume was also found to be appropriate for the evaluation of GGBS. The overall strength efficiency factor (K) varied from 1.29 to 0.70 for percentage replacement levels varying from 10% to 80%. General efficiency factor (Ke) with a value of 0.9 at 28 days and percentage efficiency factor (KP) varying from +0.39 to -0.20 for the replacement levels varying from 10% to 80% studied. The strength of concrete varying from 20 to 100 M pa with GGBS level varying from 10% to 80%. For obtaining equal strength I concrete it will be required that and additional 8.5% and 19.5% in total cementitious material at 50% and 65% cement replacement.

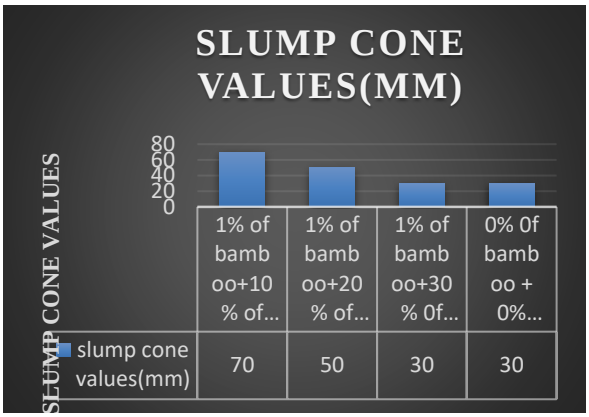
RESULTS AND DISCUSSION

1.SLUMP CONE TEST

The test was conducted on the fresh concrete before casting of the specimens or mould. A total 3 different concrete mix ratios are prepared and are tested. The test results obtained for the M25 grade of concrete are listed in the table.

TABLE 1.1 SLUMP CONE VALUES

S. NO	Grade of concrete	% of bam boo fiber	% of ggbs	Slump values for control mix in mm	slump values in mm
1	M25	1	10	30	70
2	M25	1	20	30	50
3	M25	1	30	30	30



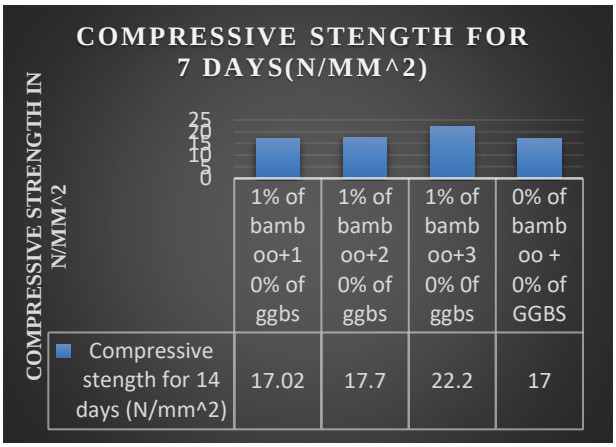
GRAPH 1.1 SIUMP CONE VALUES

2.COMPRESSIVE STRENGTH

The test was conducted on the fresh concrete before casting of the specimens or mould. A total 3 different concrete mix ratios are prepared and are tested. The test results obtained for the M25 grade of concrete are listed in the table.

TABLE 1.2 COMPRESSIVE STRENGTH FOR 7 DAYS IN N/mm^2

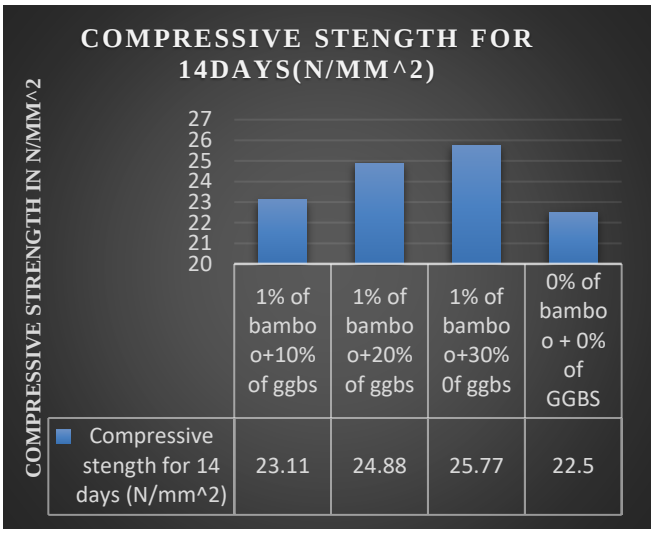
S.no	Grade of concrete	% of bamboo	% of GGBS	For control mix	For conventional mix
1	M25	1	10	17	17.02
2	M25	1	20		17.7
3	M25	1	30		22.2



GRAPH 1.2 COMPRESSIVE STRENGTH FOR 7 DAYS

TABLE 1.3 COMPRESSIVE STRENGTH FOR 14 DAYS IN N/mm^2

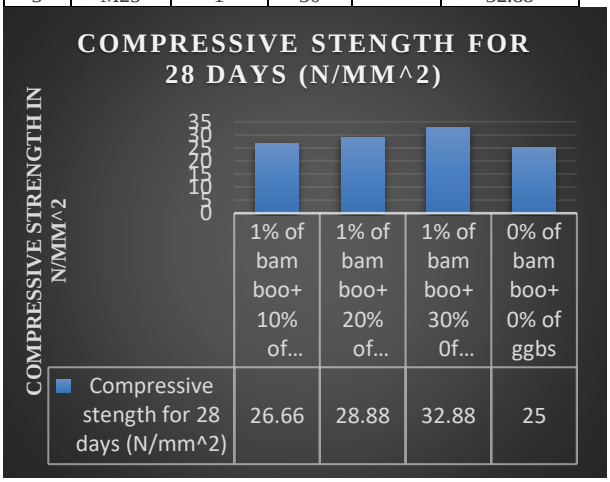
S.no	Grade of concrete	% of bamboo	% of GGBS	For control mix	For conventional mix
1	M25	1	10	22.5	23.11
2	M25	1	20		24.88
3	M25	1	30		25.77



GRAPH 1.3 COMPRESSIVE STRENGTH FOR 14 DAYS

TABLE 1.4 COMPRESSIVE STRENGTH FOR 28 DAYS IN N/mm^2

S.no	Grade of concrete	% of bamboo	% of GGBS	For control mix	For conventional mix
1	M25	1	10	25	26.66
2	M25	1	20		28.88
3	M25	1	30		32.88



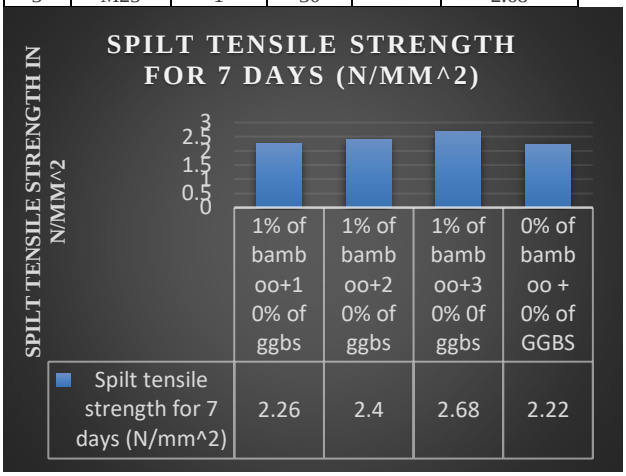
GRAPH 1.4 COMPRESSIVE STRENGTH FOR 28 DAYS

3.SPILT TENSILE STRENGTH

The test was conducted on the fresh concrete before casting of the specimens or mould. A total 3 different concrete mix ratios are prepared and are tested. The test results obtained for the M25 grade of concrete are listed in the table.

TABLE 1.5 SPLIT TENSILE STRENGTH FOR 7 DAYS IN N/mm^2

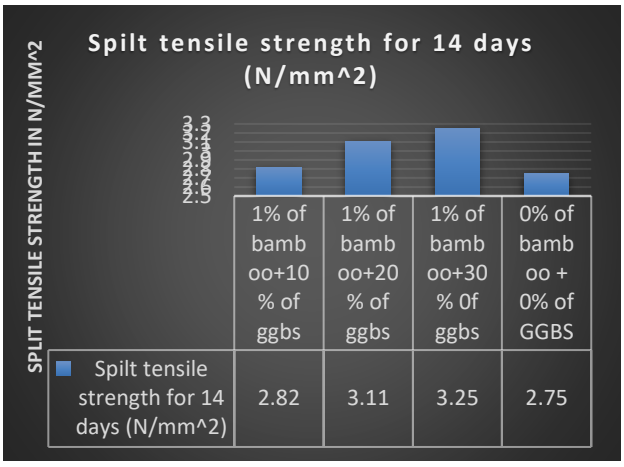
S.no	Grade of concrete	% of bamboo	% of GGBS	For control mix	For conventional mix
1	M25	1	10	2.22	2.26
2	M25	1	20		2.40
3	M25	1	30		2.68



GRAPH 1.5 SPLIT TENSILE STRENGTH FOR 7 DAYS

TABLE 1.6 SPLIT TENSILE STRENGTH FOR 14 DAYS IN N/mm^2

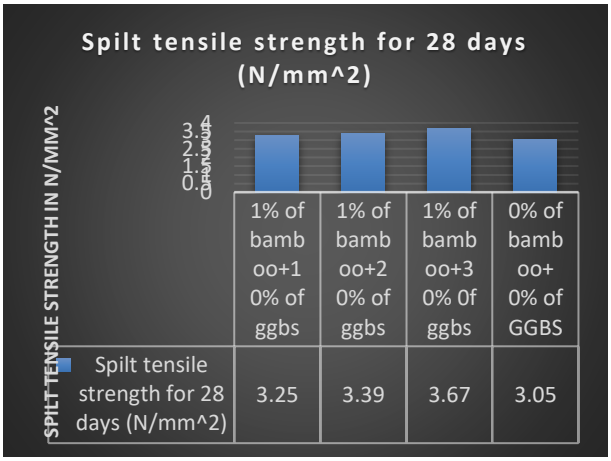
S.no	Grade of concrete	% of bamboo	% of GGBS	For control mix	For conventional mix
1	M25	1	10	2.75	2.82
2	M25	1	20		3.11
3	M25	1	30		3.25



GRAPH 1.5 SPLIT TENSILE STRENGTH FOR 14 DAYS

TABLE 1.7 SPLIT TENSILE STRENGTH FOR 28 DAYS IN N/mm^2

S.no	Grade of concrete	% of bamboo	% of GGBS	For control mix	For conventional mix
1	M25	1	10	3.05	3.25
2	M25	1	20		3.39
3	M25	1	30		3.67



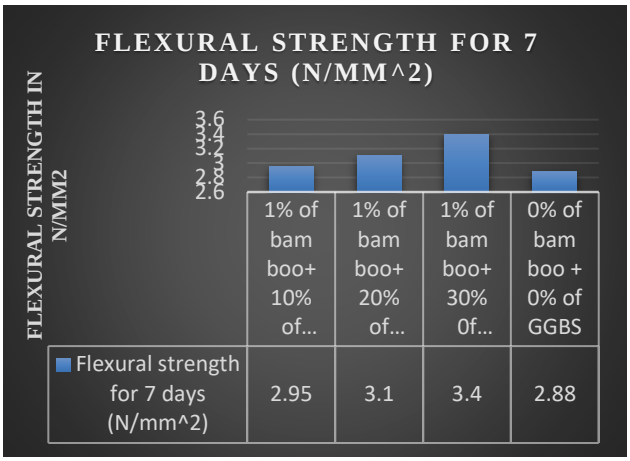
GRAPH 1.6 SPLIT TENSILE STRENGTH FOR 28 DAYS

3.FLEXURAL STRENGTH

The test was conducted on the fresh concrete before casting of the specimens or mould. A total 3 different concrete mix ratios are prepared and are tested. The test results obtained for the M25 grade of concrete are listed in the table.

TABLE 1.7 FLEXURAL STRENGTH FOR 7 DAYS IN N/mm^2

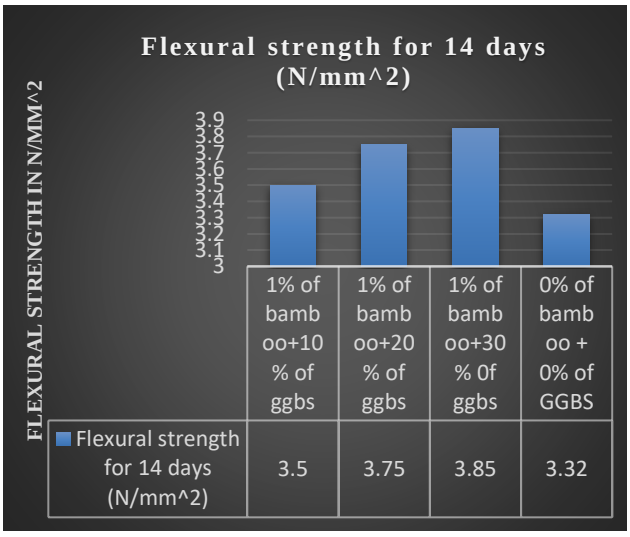
S.no	Grade of concrete	% of bamboo	% of GGBS	For control mix	For conventional mix
1	M25	1	10	2.88	2.95
2	M25	1	20		3.1
3	M25	1	30		3.4



GRAPH 1.8 FLEXURAL STRENGTH FOR 7 DAYS

TABLE 1.9 FLEXURAL STRENGTH FOR 14 DAYS IN N/mm^2

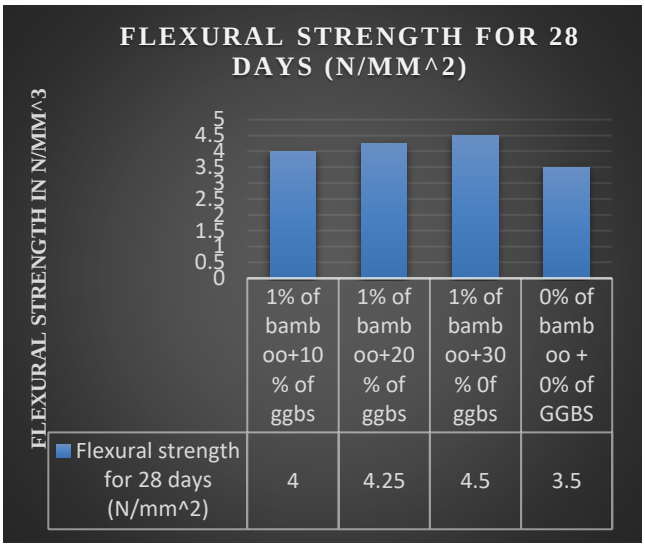
S.no	Grade of concrete	% of bamboo	% of GGBS	For control mix	For conventional mix
1	M25	1	10	3.32	3.5
2	M25	1	20		3.75
3	M25	1	30		3.85



GRAPH 1.9 FLEXURAL STRENGTH FOR 14 DAYS

TABLE 1.10 FLEXURAL STRENGTH FOR 28 DAYS IN N/mm^2

S.no	Grade of concrete	% of bamboo	% of GGBS	For control mix	For conventional mix
1	M25	1	10	3.5	4
2	M25	1	20		4.25
3	M25	1	30		4.5



GRAPH 1.10 FLEXURAL STRENGTH FOR 28 DAYS

CONCLUSION

The experimental investigation is carried out on the development of green concrete with 1% of bamboo fibre and GGBS. The M25 grade of concrete is used for this study. Based on the test results the following conclusions are drawn:

- In this investigation we found that addition of bamboo to the concrete decreased the work ability of concrete. So, to avoid this drawback GGBS played the main role. By replacing 30% of GGBS and adding 1% of bamboo fiber to the concrete gave good result in slump i.e., 30mm which indicates true slump and according to IS-456:2000 the standard value for slump is 25-50mm.
- The compressive strength test, split-tensile strength test, flexural strength test was done for 7,14,28 days. For every test 30% of GGBS replacement and addition of 1% of bamboo fiber gave good results.
- For 28days the compressive strength was observed as 32.88 N/mm^2 for 1% of bamboo and 30% of GGBS. According to IS-456:2000 the compressive strength for M25 grade of concrete for 28 days is 25N/mm^2. Therefore, the percentage increase in strength is 23.42%.
- For 28days the split-tensile strength was observed as 3.67 N/mm^2 for 1% of bamboo and 30% of GGBS. The split-tensile strength standard value for M25 grade of concrete for 28

days is 2.50 N/mm^2. Therefore, the percentage increase in strength is 16.89%.

- ✧ For 28days the flexural strength was observed as 4.5 N/mm^2 for 1% of bamboo and 30% of GGBS. The flexural strength standard value for M25 grade of concrete for 28 days is 3.50 N/mm^2. Therefore, the percentage increase in strength is 22.22%.
- ✧ The main intention of using GGBS and bamboo fiber in our project is to reduce the pollution, to develop greenhouse concept, to make the construction more effective and by using these natural materials the strength will increase and if strength increases the life span of construction also increases.

REFERENCE

[1] IS: 456 (2000) "Plain and reinforced concrete code of practice".

[2] IS: 10262 (2009) Guidelines for concrete mix design proportioning.

[3] IS 4031 (Part-1) 1996 Fineness of cement by dry sieving.

[4] IS 4031 (Part-4) 1988 Determination of consistency of standard cement paste.

[5] IS 4031 (part-5) Determination of initial and final setting times.

[6] IS 2720 part-3 Determination of specific gravity of cement.

[7] As per BS 6349 Determination of water absorption of fine aggregate.

[8] Duggal.S.K Building Materials

[9] Kenneth H., Long man, 1972, Building Materials

[10] Jambal N, Gambhir.M.L., Tata McGraw–Hill Education (2011), Building Materials: Products, properties and Systems 1st Edition

[11] Varghese.P.C., Building Materials (Google eBook)

[12] En.wikipedia.org/wiki/Bamboo

[13] Anagal, V., Darvekar, G., & Gokhale, V. A. (2010). Bamboo Construction: Learning Through Experience. ARCHITECTURE - Time Space & People

[14] Bystriakova, N., Kapos, V., Stapleton, C., & Lysenko, I. (2003). Bamboo Biodiversity: Information for Planning Conservation and Management in the Asia-Pacific Region. Beijing: UNEP-WCMC/INBAR.

[15] Cruz, C. A. (2012). Wright's Organic Architecture: From Form Follows Function to Form and Function are One. Wolkenkuckucksheim Issue 32. Vol. 17. 2012.

[16] Jansen, J.J.A. (2000). Designing and Building with Bamboo. Technical Report No. 20. International Network for Bamboo and Rattan (INBAR).

[17] Liese, W. (1998). The Anatomy of Bamboo Culm. Beijing: International Network for Bamboo and Rattan.

[18] Lobokivov, M., Lou, Y., Schoene, D., Widenoja, R. (2009). The Poor Man's Carbon Sink: Bamboo in Climate Change and Poverty Alleviation. Rome: FAO.

[19] Maurina, A., Sari, W.E., Krisanti, J., Adhisaksana, J. (2014). Komparasi Penggunaan Material Bambu dalam Struktur 'Form Active' dan 'Semi Form Active' pada Bangunan Lengkung Berbentang Lebar. Bandung: Universitas Katolik Parahyangan.

[20] Maurina, A. (2015). Curved Bamboo Structural Element. Proceeding of International Construction Workshop and Conference Parahyangan Bamboo Nation 2. Page 81-92. Bandung: Unpar Press.

[21] Macdonald, A. (2001). Structure and Architecture - 2nd ed. Oxford: Architectural Press.

[22] Purwito. (2015). Laminated Bamboo: The Future Wood. Proceeding of International Construction Workshop and Conference Parahyangan

[23] Bamboo Nation 2. Page 19-58. Bandung: Unpar Press.

[24] Sarkisian, M., Lee, P., Long, E., Shook, D. (2008). Organic and Natural Forms in Building Design. CTBUH Technical Paper.

[25] Sandaker, B. N.)2008). On Span and Space: Exploring Structure in Architecture. New York: Routledge.

[26] Veltkam, M. (2007). Free Form Structural Design: Schemes, Systems, Prototypes of Structures for Irregular Buildings. Delft: Delft University

[27] Widyowijatnoko, A. (2012). Traditional and Innovative Joints in Bamboo Construction. Aachen: RWTH Aachen University.