PERFORMANCE ANALYSIS OF FIBER REINFORCED CONCRETE USING EXPERIMENTAL METHOD, ETABS AND OPTIMIZATION BY TAGUCHI METHOD

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Abstract - *Concrete is a most widely used construction material around the world. This concrete based materials are very effective and easy to handle in all the ways. Concrete has excellent bonding property with coarse and finer aggregate. Due to the excellent setting property of concrete, the strength of concrete can be achieved even in under water also. When compared to its compressive strength, the tensile strength of concrete is very low. Due to less tensile strength concrete fails in very less tensile loads. This problem of concrete can be overcome by reinforcing suitable materials. Steel rod is one of the commonly used reinforcing material in concrete technology. Reinforced rods in the concrete helps to improve the tensile strength of concrete. However, concrete is extremely brittle, rigid and very stiff, due to this character of concrete it allows the formation of cracks on it. The main weakness of the concrete is their crack formation. The cracks generally propagated on the concrete when it subjected to loads and stress. The cracking behavior of the concrete needs to be overcome.*

Fibre reinforced concrete is a best way to reduce the formation of cracks in concrete. Fibres in the concrete help to prevent the cracks and enhance the mechanical properties of concrete. This project discusses about the effects of adding glass and bamboo fibres in the concrete. The glass and bamboo fibres has high strength and higher potential to control the cracks. The certain percentage of fibres in the concrete greatly improves the strength parameters of the concrete, but excess of fibres in the concrete may cause adverse effects. Bamboo fibre is used to replace the usage of synthetic and glass fibres. Bamboo fibres are easily available, bio degradable and renewable. The combination of glass and bamboo fibres in the concrete improves the concrete property and reduce the overall cost of the construction.

In this study, the concrete of M30 grade with mix proportion of 1: 2 .037: 3.44 is used. The compressive, split tensile and flexural strength tests are conducted to analyze the performance of pure concrete and concrete with glass and bamboo fibres. The volume of fibre is used as 1% to the weight of cement. All the bamboo fibres treated with suitable chemical to prevent the decay and to improve the strength. The cube, cylindrical and beam specimens are casted to conduct the compressive, split tensile and flexural strength tests respectively. All the structures are tested after 28 days of curing.

The experimental result clearly indicates that the strength of fibre reinforced concrete is better than the pure concrete. The maximum strength of concrete is gained in 1% fibre weight content with the mix proportion of 75% glass and 25% bamboo fibres, therefore 1% fibre weight and 75-25 mix proportion of glass and bamboo fibre is taken as optimal. Taguchi optimization method is used to find the optimal variable influence the result. Performance analysis of concrete using Etabs is also conducted.

Key Words: **FRC, Taguchi method, Bamboo fibre reinforced concrete, Glass fibre reinforced concrete, Comparison of PCC and FRC**

1. INTRODUCTION

Concrete is one of the most widely used construction material in the world. Now a day's the Concrete is used widely as construction material for the various types of building and structures due to its well durability. For a long span it was considered to be a durable and sustainable material which requires less maintenance during its life span. Concrete plays a very important role for achieving high strength at early age of time to fulfill the requirement of the structures. The less and endurable life of conventional concrete under the different types of climatic conditions conventional concrete possesses major deficiencies like low bond strength, low tensile strength high permeability and also develop more cracks. Concrete is an adaptable construction material used all around the world.

Fibres are commercially available and it is manufactured from steel, plastic, glass, cores and other natural materials. Steel fibres can be defined as discrete, short length of steel having ratio of its length to diameter is called aspect ratio in the range of 20 to 100 with any of the several cross-sections, and that are sufficiently small to be easily and randomly dispersed in fresh concrete mix using conventional mixing procedure. The random distribution results in a loss of efficiency as compared to conventional rebars, but the closely spaced fibres improve toughness and tensile properties of concrete and help to control cracking. Fibre Reinforced Concrete (FRC) is defined as a composite material essentially consisting of steel fibres, cement, aggregates and water in conventional concrete or mortar. Although reinforcing brittle materials with fibres is an old concept, modern day use of fibres in concrete is only started in the early 1960s onwards. Realizing the improved properties of the fiber reinforced concrete products, further research, development and innovations on fiber reinforced concrete has been initiated since the last three decades.

1.1 BAMBOO FIBRE REINFORCED CONCRETE

Bamboo is one of the oldest building materials used by mankind. The bamboo culms or stem has been made into an extended diversity of products ranging from domestic house hold products to industrial applications. In Asia bamboo is quite for bridges scaffolding and housing, but it is usually temporary exterior structural material. In many overly populated regions of the tropics certain bamboo supplies, the one suitable material i.e. sufficiently cheap and plentiful. In response to global warming issues and sustainable society, the manufacturing using natural material has become actively in developing countries. Bamboo is low cost, fast growing and broad distribution of growth is expected to contribute significantly in earthquake-resistant construction and seismic retrofit technology.

These fibres will provides the various mechanical properties and design applications. Different parameters such as water–cement ratio, porosity, composite density, inter filler content, orientation and length, type of cure influence properties and behaviour of FRC as well as accuracy of production method. The use of fibre in the High-Performance Concrete (HPC) class, being a class with extremely high mechanical performance, durability, workability and aesthetics, has gained momentum in recent years.

Fig 1.1 Bamboo Fibre

1.2 GLASS FIBRE REINFORCED CONCRETE

Glass fibre reinforced concrete (GFRC) is a material that is making a significant contribution to the economics, technology and aesthetics of the construction industry worldwide for over 40 years. GFRC is one of the most versatile building materials available to architects and engineers. Compared to traditional concrete, it has complex properties because of its special structure. Different parameters such as water–cement ratio, porosity, composite density, inter filler content, fibre content, orientation and length, type of cure influence properties and behaviour of GFRC as well as accuracy of production method [2–4]. GFRC can be produced as thin as 6 mm so their İskender, M., Karasu, B. ECJSE 2018 (1) 136-162 137 weight is much less than traditional pre–cast concrete products. Progressing of 3D–printing technology with glass fibre reinforced ink can build a whole building and complex architecture forms with high reliability as well as the use of premix, spray–up, hybrid methods of GFRC. Self– cleaning environmentally friendly panels for industrial construction have been contributing to the GFRC both in terms of cost and popularity. The use of glass fibre in the High-Performance Concrete (HPC) class, being a class with extremely high mechanical performance, durability, workability and aesthetics, has gained momentum in recent years. The design and manufacture of GFRC products is covered by international standards, which have been developed in Europe, America, Asia and Australasia. GFRC is manufactured in over 100 countries.

Fig 1.2 Glass Fibre

1.3. **OBJECTIVES**

- To study the effect of glass fibre and bamboo fibre in concrete.
- To analyse the comparative performance of Fibre Reinforced Concrete (FRC) using experimental method and Taguchi method.
- Quality improvement of FRC.

1.4. SCOPE OF STUDY

- Experimental studies have to be conducted for developing newer type of concrete which is having desirable properties, sustainable as well as cost effective.

- Bamboo and Glass Fibre improve toughness and tensile properties of concrete and help to control cracking
- Addition of mineral admixtures like NaOH makes the concrete more durable and also improves the mechanical properties of hardened concrete.

2. RELEVANCE OF THE TOPIC

Fibre-reinforced concrete has more tensile strength when compared to non-reinforced concrete. It increases the concrete's durability. It reduces crack growth and increases impact strength. Fibre-reinforced concrete improves resistance against freezing and thawing. Fibres are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce the bleeding of water. Some types of fibres produce greater impact, abrasion and shatter resistance in concrete. Reinforced concrete itself is a composite material, where the reinforcement acts as the strengthening fibre and the concrete as the matrix. It is therefore imperative that the behaviour under thermal stresses for the two materials be similar so that the differential deformations of concrete and the reinforcement are minimized. The uniform dispersion of fibres throughout the concrete mix provides isotropic properties not common to conventionally reinforced concrete. The applications of fibres in concrete industries depend on the designer and builder in taking advantage of the static and dynamic characteristics of this new material. The main area of FRC applications are runway, aircraft parking and pavements, tunnel lining and slope stabilization, dams hydraulic structures etc.

Fig 2.1 Cracking of Non- Reinforced Concrete

3. EXPERIMENTAL SETUP

3.1. EXPERIMENTAL DESIGN

The preparation of concrete and preparation of various fiber materials are discussed in the experimental design phase. The bamboo fibers are extracted from bamboo and glass fibers from glass. After collecting the bamboo fibers this fireside treated with Noah (Khan et al 2017) to improve basic properties and limits their action with other substances. To attain high tensile property weak, amorphous, Hemi cellulose components are eliminated. Glass fibers are created with the combination of materials such as SiO, ALLO, CaO. B, O, etc. These glass fibres have high density and cost than bamboo fibers. These materials are non-recyclable and non-renewable.

3.2. MIX DESIGN

Concrete mix is created by utilizing ordinary Portland cement with 53grade and designation of M30 grade. Maximum size of 20mm stone chips is used as coarse aggregate and local sand materials are used as the fine aggregate. Water cement ratio of concrete mix is 0.40 and mix proportion is 1:2.037:3.44 by volume the glass and bamboo fiber ratio of 75:25 with 1% fiber content by weight of cement fraction were used. Usage of water reduced by adding the super plasticizer materials. These concrete mixes are casted in various molds for developing the concrete structures. Cylindrical, cubic and beam shaped structures are created for testing. The ratio between water, cement, fine aggregate, and coarse aggregates taken are 0.4:1:2.037:3.44. The cement and water are taken as 350,140 Kg/m respectively. Different structure shapes are molded using the prepared concrete mix.

3.3. CASTING OF CONCRETE SPECIMENS

3.3.1 Cylindrical specimen

The cylindrical shaped specimens are mainly created for split tensile testing. The concrete mix poured in to a cylindrical molds of 150 mm diameter and500 mm height. The molded cylindrical concrete structures are kept in wet place and de-molded after 24 hours. These concrete structures are submerged in open water tank for curing up to 28 days.

3.3.2 Cubical specimen

The concrete mix poured in to a cubical mold of 150mmxI50mmx150mm. After the creation process, the concrete structures are de-molded at 24 hours of curing. The cubic specimens are then submerged in to the water for a curing of 28 days.

3.3.3 Beam Specimen

The concrete mix is poured into a beam shaped mold. After the creation process. The concrete structures are de-molded at 24 hours of curing. In this experimentation, mainly three dimensions of concrete beams are created. The beam BI, B2, B3 are casted with the dimensions of 230mmx300mx 1200 mm, 230mmx350mx 1200mmand 230mmx400mmx 1200 mm respectively. The beam shaped structures are mainly created for flexural strength test.

Fig 3.1 Concrete Specimens

3.4. CURING OF SPECIMEN

After 24 hours of casting, the samples were demoulded and placed in the curing tank for 28 days. Figure shows curing tank and demoulded specimens for 28 day curing.

4. TESTING OF SPECIMEN

4.1. Compressive Strength on Concrete Cubes

Compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength. The test was conducted to find compressive strength of concrete as per IS 516: 1959. The curing specimen were taken out and surface was cleaned and dry for 6 hours. The strength is expressed in N/mm^2. The specimen (150X150X150) were tested by using compression testing machine of 2000KN capacity. The testing of cubes in the compression testing machine are shown in fig 4.5. The compressive strength at failure is calculated using the following equation.

$$\text{Compressive strength } N/mm^2 = \frac{\text{Ultimate compressive load (N)}}{\text{Area of cross section of specimen mm2}}$$

Fig 4.5 Compression testing machine

4.2. Splitting Tensile Strength of Concrete Cylinders

The splitting tensile strength test are conducted to determine Splitting tensile strength of concrete as per IS 516: 1959. For different percentage replacements of clinker bricks of 10% .15% and 20% concretes of three cylinders were casted and splitting tensile strength test was carried out.

The cylinder of size 150X300 mm was casted and cured for 14 days and specimen was tested after surface drying. The specimen were placed in the compression testing machine and place packing strips made up of plywood along with specimen on both top and bottom. The load was applied and increase continuously, till the specimen breaks without shock. Until failure the applied load was noted.

The splitting tensile strength of the specimen was calculated using the following formula:

$$T = \frac{2P}{\pi D L}$$

Where,

T= Splitting tensile strength
P= maximum applied load
D=Diameter of cylinder
L=Length of Cylinder

4.3. Flexural Strength Test of Beams

The standard size of beams used here was 150X150X500mm. The specimens was casted and cured for 28 days and swipe out water before testing. The specimen were placed in the machine such a way that the load applied along two lines spaced 200 mm apart. The beams are supported over an effective span of 400 mm and tested in load testing machine by applying two point load along its length. The load was applied and increase continuously until failure and the maximum load applied to the specimen during the test were noted. The following equation is used to calculate the flexural strength of the specimen:

$$F=\frac{PL}{BD2}$$

F= Modulus of rupture
P= Maximum load applied
L= Length of specimen
B= Width of specimen
D=Depth of specimen

Fig 4.6 Flexural strength test machine setup

4.4. RESULTS AND DISCUSSION

The compressive tests are carried out for all specimens with a total of twenty-eight days and which are given in table 4.1 and 2. In the complete concrete, the fibre contents are added as 1% . In this, the fibre-reinforced concrete cubes are designed for glass to bamboo ratio of 75:25 . For pure concrete (without reinforcement), the maximum compressive strength of 34.08 N/mm^2 is attained after 2 8 days. Besides, the compressive strength is minimum for the without reinforcement in concrete. When using 1% of fibre content in the overall concrete the maximum compressive strength is gained with a rate of 42.08 N/mm^2.

Specimens	Weight (Kg)	Compressive Strength(N/mm^2)
Cube - 1	7.56	32.57
Cube - 2	8.10	34.08
Cube - 3	8.2	32.16

Table 4.1

Specimens	Weight (Kg)	Strength(N/mm^2)
Cube - 1	8.59	40.36
Cube - 2	8.7	42.08
Cube - 3	8.46	41.01

Table 4.2

The results of Split Tensile Strength are given in Table 4.3 and 4.4 . In this, the fibre-reinforced concrete cylinders are casted with glass to bamboo ratio of 75:25 with 1 % of fibre content. Besides, the tensile strength is minimum for the without reinforcement in concrete. When using 0% of fibre content (pure concrete) in the overall concrete the split tensile strength is gained with a rate of 3.41N/mm^2. The maximum tensile rate is gained for 75% of glass and 25% of bamboo as 4.13 N/mm^2.

Specimens	Weight (Kg)	Compressive Strength(N/mm^2)
Cylinder - 1	12.89	3.36
Cylinder - 2	12.98	3.41
Cylinder - 3	13.01	3.45

Table 4.3

Specimens	Weight (Kg)	Tensile Strength(N/mm^2)
Cylinder - 1	13.27	4.26
Cylinder - 2	13.66	4.13
Cylinder - 3	13.17	4.19

Table 4.4

Table 4.5 and 4.6 shows the Flexural Strength of M30 Grade HFRC prisms. The analysis of flexural strength, a concrete beam with the absence of reinforcement provides the minimal value of flexural strength when compared to the glass and bamboo fibre reinforced concrete. The maximum flexural strength achieved from the concrete without reinforcement is 6.7. At the same time, 7.28 of flexural strength is gained from the reinforced concrete with 75% of glass fibres and 25% of bamboo fibres at 1% by weight of cement.

Specimens	Flexural Strength(N/mm^2)
Beam – 1	6.4
Beam – 2	6.7
Beam – 3	6.6

Table 4.5

Specimens	Flexural Strength(N/mm^2)
Beam – 1	7.22
Beam – 2	7.28
Beam – 3	7.26

Table 4.6

It has been noticed from the above laboratory experiments that the highest compressive intensity is achieved with 1 percent glass fibre content: 75:25 % bamboo fibre. The intensity is observed to decrease more in the fibre material. And the optimal quality of fibres is found as 1 percent among which 75 percent of glass and 25 percent of bamboo are contained. Since glass and bamboo hybridization (75-25 percent), the blend gives an improved solution to arrest micro and macro fractures, thereby increasing the concrete's compressive strength relative to pure concrete and every other variation of hybridization ratio.

The average split tensile strength is achieved by weight of 1% cement material, in which 75% glass fibre and 25% bamboo fibre are produced. The split tensile strength of the managed experiment is observed to be smaller than for strengthened concrete constructed from synthetic material. The improvement in resistance to break tensile due to glass fibre integration is higher than bamboo fibre. Large glass fibre elasticity module renders concrete more ductile. Ductile content friction strength is stronger than brittle substances.

Concrete flexural power improves with the application of fibre to material. The flexural intensity of all managed experiments of hybridized concrete was found to be smaller than that.

5. TAGUCHI METHOD

Taguchi method was developed by Dr.Taguchi of Nippon Telephones and Telegraph Company, Japan based on orthogonal array which gives much reduced variance for the experiment with optimum setting of control parameters. Taguchi experiment minimize the variations in output even though noise is present. Through the Taguchi optimization methods, the optimum factors are affecting the performance can be easily determined. Taguchi method treats optimization problems in two categories.

5.1 STATIC PROBLEMS

Generally, a process to be optimized has several control factors which directly decide the target or desired value of the output. The optimization then involves determining the best control factor levels so that the output is at the target value. Such a problem is called as a "STATIC PROBLEM".

This is best explained using a P-Diagram which is shown ("P" stands for Process or Product). Noise is shown to be present in the process but should have no effect on the output! This is the primary aim of the Taguchi experiments - to minimize variations in output even though noise is present in the process. The process is then said to have become ROBUST.

There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems:

(I) SMALLER-THE-BETTER :

$n = -10 \, Log_{10}$ [mean of sum of squares of measured data]

(II) LARGER-THE-BETTER :

$n = -10 \, Log_{10}$ [mean of sum squares of reciprocal of measured data]

(III) NOMINAL-THE-BEST :

$$n = 10 \, Log_{10} \frac{\text{square of mean}}{\text{variance}}$$

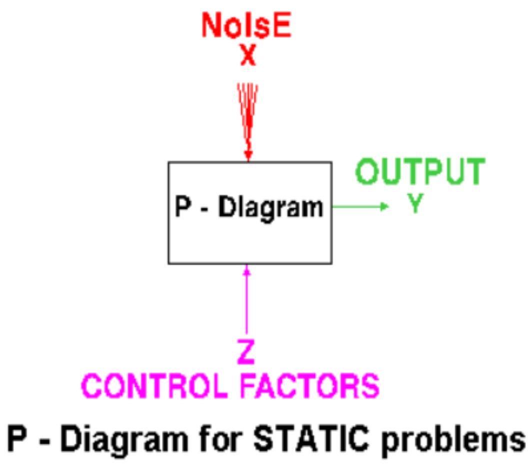


Figure 5.1: Diagram for Static Problems

5.2. DYNAMIC PROBLEMS

In these problems signal input directly decides the output. The desired value is obtained by input/output ratio. Such a problem is called Dynamic problem.

The application of Taguchi is extended in various designs such as tolerance design, parameter design, and system design. The Taguchi optimization is performed by means of the SN ratio, which provides the optimal control points. The SN ratio is known as Signal to Noise ratio. The SN ratio can be calculated using three formulas, which are selected based on the objective. The formulas used on three characteristics like smaller is better (12), larger is better (13) and nominal the best (14) (Pradhan *et al* 2019).

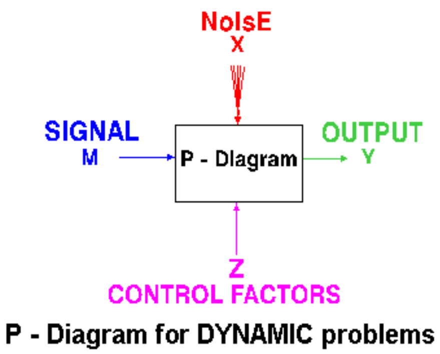


Figure 5.2: Diagram for Dynamic Problems

5.3 RESULT AND DISCUSSION

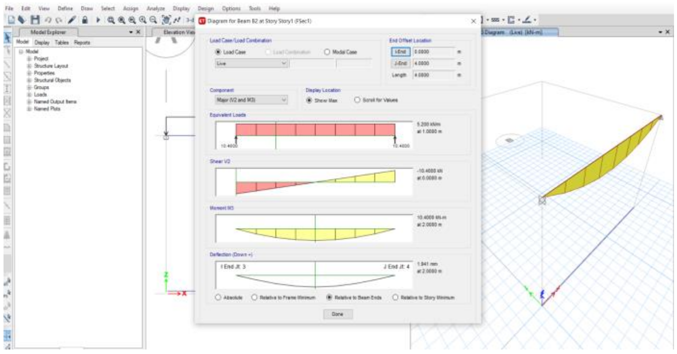
	SN ratio for Compressive Strength of concrete with 7 days curing		SN ratio for Compressive Strength of concrete with 28 days curing		Split Tensile Strength	
Level	**Glass**	**Bamboo**	**Glass**	**Bamboo**	**Glass**	**Bamboo**
1	25.93	25.93	34.08	34.08	34.10	34.10
2	26.15	26.53	36.93	42.08	36.60	41.30
3	25.71	25.39	34.30	41.21	38.30	38.30
4	25.92	25.95	35.10	38.64	41.30	36.60
5	26.14	25.95	39.67	37.10		
6	26.14	25.58	36.40	36.40		
7	25.39	25.71	41.21	34.40		
8	25.58	25.53	39.20	32.12		
Delta	0.76	1.14	7.13	996	0.720	0.720
Rank	2	1	2	1	15	15

6. ETABS

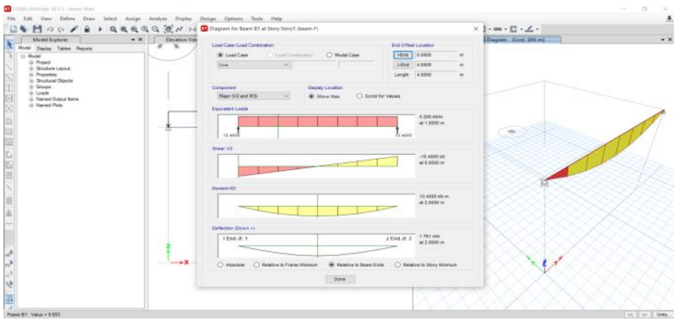
ETABS **is** an engineering software product that caters to multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure. Basic or advanced systems under static or dynamic conditions may be evaluated using ETABS.

ETABS software is used for the analysis of beams and columns. It is highly acclaimed for static and dynamic analysis of multi- storey frame and shear wall buildings.

6.1. PCC



6.2.FRC



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