Experimental Investigation on Flexural Strength of RCC Beams by Using GFRP MAT and Steel Fibre with Waste Glass Powder

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Abstract— The modern trend in the design field is going towards the seismic design of buildings. The important parts of the buildings are foundation, column, beam and slab. In any structure the load carrying capacity is very important for resisting any kind of load. The load carrying capacity of the structure is depends on the strength of the beam-column joint. As we know that the load on the structure first acts on the slab then the load is distributed to the beam and then to column. The column is a compressive member and the beam and slabs are flexural members. From this we know that the flexural strength of the beam is more important to the structure. So that we preferred to do the practical study on the flexural strength of the beam. We are planning to do comparative study on the flexural strength of the Ordinary RCC beam and Ordinary RCC beam with GFRP mat and Ordinary RCC beam with glass powder and steel fibre. First we prepared the cubes for constant percentage of steel fibre and different percentage of glass powder as partial replacement of cement. After the 28 days curing period cubes are tested from the test result for maximum strength we prepared the beams also we casted the ordinary RCC beams. After 28 days curing three beams are rapt using GFRP mat then tested in the laboratory. Finally test results are reported for future reference.

Keywords: Comparative Study on the Flexural Strength of the Ordinary RCC Beam and Ordinary RCC Beam with GFRP Mat, Ordinary RCC Beam with Glass Powder and Steel Fibre

I. INTRODUCTION

There is a huge need for repair and strengthening of deteriorated, damaged structures. There can be many reasons for the deterioration of structures, it can be due to environmental influences, inadequate design and construction or need for structural up-gradation so as to meet new seismic design requirements because of new design standards, deterioration due to corrosion in steel caused by exposure to an aggressive environment and accident events such as earthquakes, excessive deflections, and poor concrete quality, etc. or sometimes even to solve execution errors caused at the time of construction. For these purposes, various strengthening techniques have been developed to satisfy these strengthening requirements. The advanced composite material such as fibre reinforced polymer (FRP) composites, concrete member can now be easily and effectively strengthened using externally bonded FRP composites. Retrofitting of concrete structures with wrapping FRP sheets provide a more economical and technically superior alternative to the traditional techniques in many situations because it offers high strength, low weight, corrosion resistance, high fatigue resistance, easy and rapid installation and minimal change in structural geometry. Although the fibres and resins used in FRP system are relatively expensive compared with traditional strengthening materials, labour and equipment cost to install FRP system are often lower. FRP system can be used in areas with limited access where traditional techniques would be impractical. However, the use of these materials for retrofitting the existing concrete structure cannot reach up to the expectation due to lack of the proper knowledge on structural behaviour of concrete structure retrofitted by fibre reinforced polymers (FRP) composites. Encasement of these girders not only increases design life, but also protects the member from surface attacks. FRP is a versatile material. FRP can be applied to wide range of structures. FRP sheet can be cut and easily bonded to any concrete members. It is highly cost effect method of maintaining or upgrading to accommodate higher load (such as traffics), loss of pre-stress in existing reinforcement, or degradation of structures (e.g. corrosion of reinforcement). The technique may allow continued usage of structures or facility during strengthening works. Higher material cost of glass fibre is outweighed by numerous advantages over steel such as low self-weight and less requirement for plate surface preparation. Glass or Aramid fibre offer lower cost alternative to other forms of strengthening such as use of steel plates, or provision of additional support member. Column wrapping with FRP can be an alternative to jacketing additional reinforced concrete, or complete replacement of structures, with obvious saving in materials energy. It increases the capacity with minimal addition of dead load to the structure.

II. MATERIALS USED AND PROPERTIES

A. Steel Fibre

Steel fibre-reinforced concrete is basically a cheaper and easier to use form of rebar reinforced concrete. Rebar reinforced concrete uses steel bars that are laid within the liquid cement, which requires a great deal of preparation work but make for a much stronger concrete. Steel fibre-reinforced concrete uses thin steel wires mixed in with the cement. This imparts the concrete with greater structural strength, reduces cracking and helps protect against extreme cold. Steel fibre is often used in conjunction with rebar or one of the other fibre types.

Fig. 1: Steel Fibre

B. GFRP

Glass fiber reincforced polymer also known as glass fiber reinforced plastic is a composite material weaving fiber E-glass and polyester material together. It can range from a tensile strength of 44-2358MPa, and a compressive strength from 140-350Mpa while only weighing a quarter of the weight of steel. The woven material can be hardened with a thermosetting polymers such as epoxy, resin or thermoplastics.

Fig. 2: GFRP mat

C. Waste Glass Powder

Glass is a transparent material produced by melting a mixture of materials such as silica, soda ash, and $CaCO_3$ at high temperature followed by cooling during which solidification occurs without crystallization. Glass is widely used in our lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing. The amount of waste glass is gradually increased over the recent years due to an ever-growing use of glass products. Most waste glasses have been dumped into landfill sites. The Land filling of waste glasses is undesirable because they are not biodegradable, which makes them environmentally less friendly. So we use the waste glass in concrete to become the construction economical as well as eco-friendly. Glass waste is very hard material. Before adding glass powder in the concrete it has to be powdered to desired size. In this studies glass powder ground in ball/ pulverized for a period of 30 to 6o minutes resulted in particle sizes less than size 300 µm and sieved in 150 µm. The glass powder having following properties,

- The specific gravity of WGP is 2.6.
- P^H of WGP is 10.25.
- It is Greyish white in colour.
- Most of the glass has strong covalent bond of Si-O bonds (435 kJ/mole).
- The manufactured glass yields theoretical strength of 17 GPa.

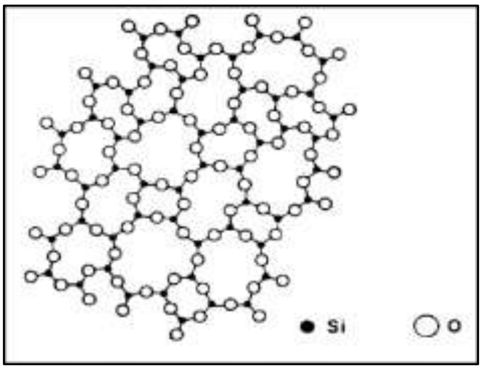

Fig. 3: Covalent Bond of Si-O Bonds

D. Mechanism Of Portland Cement And Glass Powder:

Glass wastes as a cullet are used in the production of building materials mainly as an inert aggregate. However, finely grained glass powder with its well developed surface cannot be regarded as passive toward cement solutions which has actually been proven in practice. Literary sources provide no information about chemical influence of finely grained glass on the process of hardening, especially in its early pre-induction hydration period – the period which considerably conditions the cement stone structure formation and its properties. It is well known that glass is a material with an amorphous structure, characterized by a large supply of free energy. The glass that has been used in our investigations–contains approximately 14% of Na2O and K2O. In the glass structure the ions of these metals have considerably less binding energy as compared to covalent bond of Si-O in the structural fragment of Si-O-+Na or Si-O-+K. In water solution Na+ and K+ ions are easily diffused from glass to the solution and form sodium and potassium hydroxides in the solution, correspondingly. They are displaced by H+ ions from water and thus hydrate the surfaces of glass grains. This is a so called ion-exchange mechanism of interaction between glass and water. Since the area of glass grain surface is very large, comparable to the area of cement grain surface, ionic exchange is very active. Titration analyses show that alkalinity of cement solution without glass additives is near 6 ml of 0.1N HCl. Separate glass powder in water under normal conditions has alkalinity in the range from0.15 (colourless glass) to 0.55 ml of 0.1N HCl (green glass). Thus, the total alkalinity has to increase, however alkalinity of cement mixture with glass additives is 35-40 % less. In our opinion, it is connected with high content of SiO2 in the glass (near 70 %), which results in the formation of calcium hydro silicate (CSH), as shown in chemical reaction:

$$2(3CaO.SiO2) + 6H2O = 3CaO.2SiO2.3H2O + 3Ca\,(OH)_2$$

(Tri-calcium Silicate) (Calcium Silicate Hydrate) (Calcium Hydroxide) …. (1)

$$3Ca\,(OH)_2 + SiO2 + (n-1)\,H2O = CaO.SiO2.nH2O$$

(Calcium hydroxide) (Glass) (Calcium Silicate Hydrate) …. (2)

As a result of reaction (1) the amount of calcium hydroxide in the cement solution decreases. Consequently, the alkalinity of solution with glass powder additives decreases as well and additional amount of Calcium Silicate Hydrate crystal phase in a cement stone is formed. It has been established that addition of finely grained glass to Portland cement or to Portland cement based concrete accelerates the binding process during pre-induction period of hydration (2–4 min.) but retards it during after-induction period. However, this does not affect the mechanical strength of the concrete samples after the first day of hardening. The strength of samples with glass is as higher as compared to the control samples, because, has been stated above; glass additives modify cement stone structure.

E. Epoxide Resins

The reaction between epichlorohydrin and bisphenol A yields a large class of resins known as epoxy. These resins can be cross linked to create strong adhesiveness.

1) Epoxy

This is the main group and is characterized by having the epoxide group at each end of the molecule. The grouse can be cross linked with amines and amides. The resultant adhesive is used in bonding metal, concrete, ceramics etc.

F. Cement

Ordinary Portland cement (OPC) is used for the experiment. It is tested for its physical properties in accordance with Indian standard specifications. It is having a specific gravity of 3.15.

G. Fine Aggregate

The fine aggregates passing through 4.75 mm sieve and having a specific gravity of 2.60 are used. The grading zone of fine aggregate is zone III as per Indian standard specifications.

H. Coarse Aggregate

The coarse aggregate of two grades are used one retained on 10 mm size sieve and another grade contained aggregates retained on 20 mm sieve. It is having a specific gravity of 2.65

I. Water

Ordinary tap water is used for concrete mixing in all the mix.

J. Steel Reinforcement

HYSD bar of 10mm diameter is used as main reinforcement. 6mm diameter HYSD steel bars are used for shear reinforcement.

III. EXPERIMENTAL INVESTIGATION

The experimental study consists of casting of nine reinforced concrete rectangular beams. All the nine beam weak in flexure are casted. Out of eight beams six beams are casted using normal concrete without any additions. Out of six normal beams three beams are wrapped using GFRP mat after 28 days curing epoxy as a adhesive. Three more beams are casted by using steel fibre and glass powder in combination. Before casting the beam four cubes are casted using steel fibre of 3% in total volume of concrete and glass powder as partial replacement of cement at four various proportions (10%, 20%, 25%, 30%). After the 28 days curing of cubes they are tested in laboratory for the maximum strength composition the three more beams are casted. After the 28 days curing these beams are tested for flexural strength, from this result we can know that the beam which has more flexural strength.

IV. RESULTS AND DISSCUSSION

Initially we casted six R.C.C beam's using ordinary concrete and then we need to cast three R.C.C beam's using steel fibre with waste glass powder as a partial replacement of cement. For that we casted four cubes with constant percentage of steel fibre (3%) with different percentage of waste glass powder (10%, 20%, 25%, and 30%)

After 28 days of curing period the cubes are tested in laboratory. The test results are,

Sl. No:	% of steel fibre	% of waste glass powder	Load (KN)	Compressive stress (Mpa)
1	3	10	1020	45.2
2	3	20	925	41.1
3	3	25	745	33.1
4	3	30	905	40.2

Table 1: Test Results

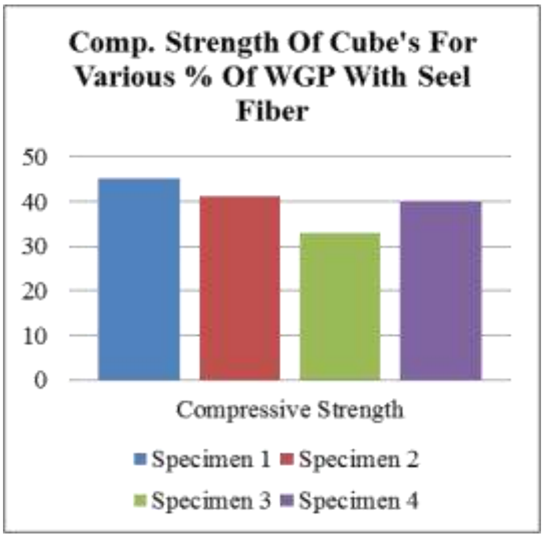

Fig. 4: Compressive Strength of Cube's For Various % of WGP With 3% of Steel Fibre

Fig. 5: Concrete Cube Testing In CTM

Fig. 6: Concrete Cube at Ultimate Loading Point

From this test result we are getting maximum strength at 10% of waste glass powder as a partial replacement of cement with 3% of steel fibre. The beams are casted after getting the result.

After 28 days curing beam's are taken out from the curing tank and dried in sunlight for a day. There after three normal beams are kept separately and another three beams are wrapped using GFRP-mat with Epoxy resin. After wrapping the beam's are dried in sunlight for 24 hrs then the beams are tested in the laboratory. The test results are,

Normal Beams:

The normal R.C.C beams (M25) are casted by using available moulds of size 150mm x 150mm x 700mm. After 24 hours of casting moulds are removed and then cured in curing tank for 28 days then beams are tested in laboratory. The test results are,

Sl. No	Load (KN)	Flexural strength (Mpa)
1	67.4	12
2	71.2	12.7
3	70.5	12.4

Table 2: Normal Beams Result

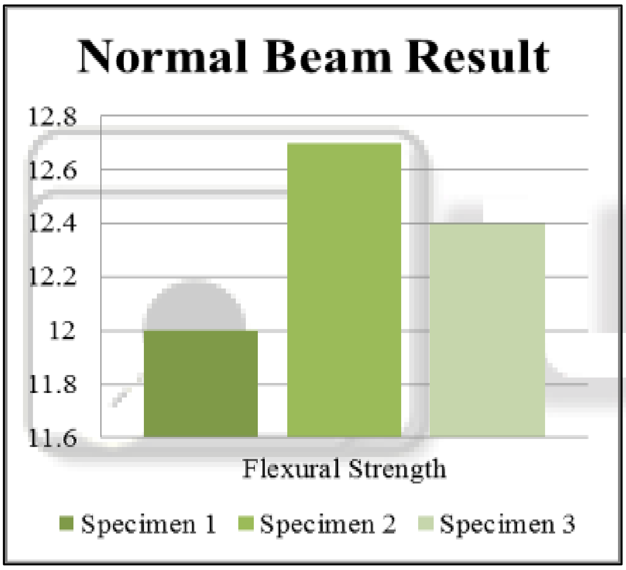

Fig. 7: Normal Beam Results

Fig. 8: Ordinary R.C.C. Beam in UTM

Fig. 9: Cracking of Ordinary R.C.C. Beam in UTM

Waste Glass Powder (WGP) With Steel Fibre Reinforced Concrete Beams:

The beams are casted for the maximum strength giving cube proportion of 10% of WGP and 3% of steel fibre. After 28 days curing the beams are tested in the laboratory. The test results are,

Sl. No	Load (KN)	Flexural strength (Mpa)
1	144.46	26.57
2	144.64	25.70
3	143	25.42

Table 3: Waste Glass Powder (WGP) With Steel Fibre Reinforced Concrete Beams

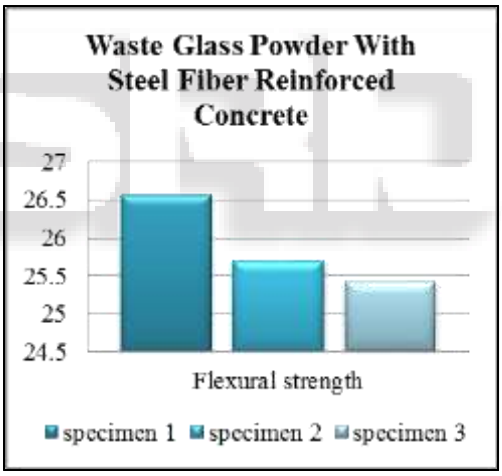

Fig. 10: Waste Glass Powder with Steel Fibre Reinforced Concrete

Fig. 16: Testing Of WGP with Steel Fibre R.C.C Beams

Fig. 11: Ultimate Loading Point of R.C.C Beams WGP with Steel Fibre

A. *Wrapped Beams:*

The normal R.C.C beams are casted and cured for 28 days then the beams are dried at room temperature for 24 hours. Then the beams are cleaned and then epoxy is coated followed by GFRP mat is wrapped. After wrapping beams are dried in sunlight for getting good bond with concrete.

Sl. No	Load (KN)	Flexural strength (Mpa)
1	154.0	27.4
2	146.2	26
3	157	28

Table 4: Wrapped Beams Result

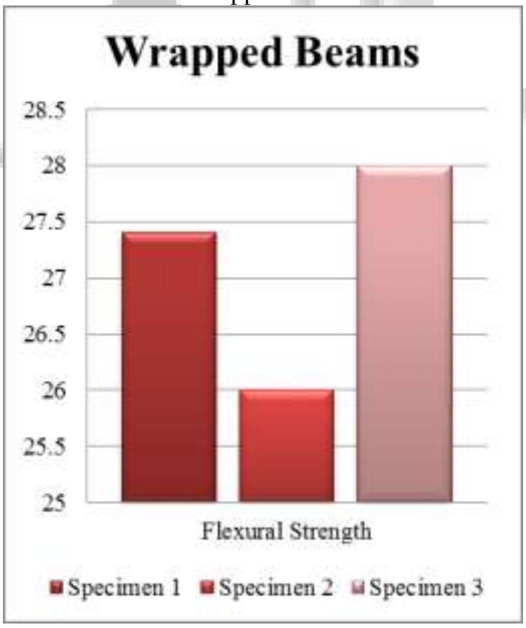

Fig. 12: Wrapped Beams Result

Fig. 13: Wrapping Process

Fig. 14: Wrapped Beam Testing in UTM

Fig. 15: Ultimate Loading Point of Wrapped Beam

B. Comparison of Flexural Strength with R.C.C Beams:

From the above results we took the maximum strength out of three beams. We compared the maximum results.

Sl. No.	Types	Flexural Strength(Mpa)
1	Normal R.C.C. Beam	12.7
2	Waste Glass Powder (WGP) With Steel Fibre Reinforced Concrete Beam's	26.57
3	Wrapped Beam	28

Table 5: Comparison of Flexural Strength with R.C.C Beams

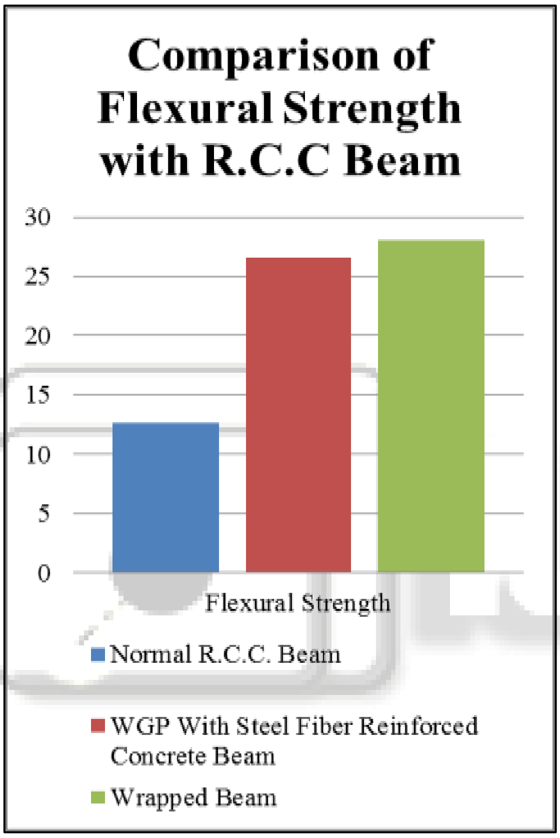

Fig. 16: Comparison of Flexural Strength with R.C.C Beam

Thus, we done the comparison of flexural strength of normal R.C.C beams, WGP with steel fibre combined R.C.C beams and normal R.C.C beams wrapped with GFRP mat.

From these result's we are studied that use of GFRP mat provides good flexural strength than others. Also WGP with steel fibre combined R.C.C beams provides good flexural strength than normal R.C.C beams.

V. CONCLUSION

Thus the comparative practical studies on the flexural strength of the reinforced cement concrete beams were done by casting the beams and testing them in laboratory. From the test results we studied that the flexural strength of the RCC beam is much increased when normal RCC beam is wrapped with GFRP mat by using epoxy resin. Next to the GFRP mat good strength was obtained by using ten percentage of the waste glass powder with three percentages of steel fibres. The normal RCC beams giving minimum flexural strength as compared to the other beams.

From these results we are concluding that for safety consideration alone use of GFRP mat will provide good flexural strength also WGP with steel fibre provides good flexural strength. In safety and economical consideration WGP with steel fibre provides good flexural strength.

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