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# REPAIR AND REHABILITATION OF FRP CONCRETE BEAM WITH SILICA FUME

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**Abstract:**
The main purpose of this project is to gain the practical understanding of the repair and rehabilitation of the FRP concrete beams by using different repair methods. Although the concrete is designed as per codes/standards due to some conditions they are failure as a result of various factors such as soil condition, environment, and other factors before their life span. Due to the higher cost of reconstruction, we go through the repair and rehabilitation of the beams using various methods based on the failure condition e.g.: failure due to less tensile strength, high shear stresses, due to compressive forces etc., In this project we taken a deformed beam with the dimensions of 1000*112*240 mm. The beam are treated with two different methods one is CONCRETING WITH SILICA FUME METHOD to modify their mechanical properties. The silica fume repair method is used for increasing the bond between the particles which increases more strength. Also, it helps to reduce the cracks.

***Keywords:*** Silica fume, Rehabilitation, FRP Concrete beams, Tensile strength

## 1.INTRODUCTION

Concrete is one of the most usage materials in the construction industry due to its mouldability and ease of construction. Generally concrete is a heterogenous material of cement, fine aggregate (sand), coarse aggregate (gravel) and water if needed admixtures are also used to improve the properties of the concrete, some are used based on the environmental conditions. Due to some certain limitations of concrete like less flexural strength, low resistance to chemicals, porosity and permeability etc., leads to distress the concrete, occurrence of cracks, delamination, corrosion etc., expect these limitations some of the natural disasters like earthquakes, hurricanes, cyclones also lead to the damage and deterioration of the entire structure in such conditions we have to repair the structure or members. As we taken two concrete beams which are casted by adding rubber and using fibre reinforced polymers instead of steel reinforcement to improve the properties of the concrete. Those members were failure due to compression stress which were used for research purpose, now we are taking that beams and doing repair and rehabilitation to regain the strength. The dimensions of the concrete beams are 1000*112*240 mm with the reinforcement of 4bars, 2 no's at the bottom and 2 no's at the top of concrete generally represented as hanger bars. Repair and rehabilitation of FRP concrete beams typically involve the use of various methods to strengthen, reinforce, and restore them to their original state. Common techniques used for repair include resin injection, post-tensioning, bolting, and metal lamination. Fibre Reinforced Polymer (FRP) strengthening systems are often employed to add flexural strength to the beam or enhance post-tension integrity. When necessary, localized removal of sections of concrete may be used in order to provide access for FRP installation or tensioning devices. If a beam is beyond repairing or restoring it must be replaced with a new one. Here we are repairing two beams with two different methods one is concreting with silica fume and another one is concreting with steel fibres. Using silica fume 15% of the total volume of the concrete because 15% of silica fume only gives the maximum increase in the strength and mechanical properties more than that leads to decrease in the mechanical properties and increases the setting time as well. Silica fume increases the bonding between the concrete by filling the voids due to its smaller in size and makes the concrete stiff hence it helps to increase in strength.

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## 2.MATERIALS USED

### *A. Cement*

Cement is a binder, a chemical substance used for construction that sets, hardens and adheres to other materials to bind them together. It is most widely used and very important ingredient in construction. These are characterized as Hydraulic (OPC) and Non-Hydraulic based on the ability of setting in the presence of water.

1) *Portland pozzolana cement:* It is one type of blended cement. It consists of 15-35% of pozzolanic material, 4% of gypsum and the remaining is clinker. PPC is available only in one grade which is equivalent to 33grade.The pozzolana material is available in 2 types:

   Artificial pozzolana

   It includes fly ash, silica fume. rice husk, blast furnace slag.

   Natural pozzolana

   It includes burnt clay, pumicite, diatomaceous earth.

It is eco-friendly cement because it is made by natural and industrial waste and also it reduces the emission of carbon monoxide from the concrete at the time of mixing and casting. It has slower rate of heat of hydration i.e., less affected to cracks and reduced the shrinkage. PPC contains the silica, makes cement very fine due to its smaller in size increases the workability, reduces the honeycomb formation and bleeding.

### *B. Silica fume*

It is one of the mineral admixtures. It also known as micro silica, which is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete. Due to its fineness, it can completely fill the pores which increases the strength, durability, flexural strength etc., and also forms good bonding in concrete decreases the permeability and porosity of concrete. The average percentage of 7 to 10% and maximum 15% enhances the concrete properties but beyond that 15% leads to decrease in strength and takes more setting time. Adding silica fume increases the water quantity also due to its large surface area, to avoid this water content we need to add water-reducing admixtures these all are leads to higher cost effective. In repair methods silica fume helps to make good bonding of newly poured concrete with old concrete and also fill the gaps in the existing beams. By adding silica fume up to 15% by the total weight of concrete, increases the compressive strength of concrete from 30 to 40%.

### *C. Fine aggregate*

Usually, sand is used as fine aggregate. It varies in different sizes from 70 microns to 4.75mm, the most common mineral in the sand is quartz–also known as silicon dioxide and it possesses highly resistant to weather. This is formed when silicon and oxygen combine. Feldspar is the most found group of minerals on the earth's surface and forms about 65% of the terrestrial rocks. When the wind and sea whip up on the shores, they transport these teeny-tiny granules to the beach and make up the sand with this combination. Sand is a non-renewable resource which never happens twice. It is available through various sources desert sand, river sand, lake sand, sea sand, volcanic sand, olivine sand etc., with different colours like white, black, red-orange colour, white-grey colour, light-brown colour etc.,

Sand which is used for construction should in inert and does not reactive with other constitutes because of that sea sand is not used for concrete mainly river sand and lake sand are used. Also, sand makes the concrete in uniform mixture and fills the gaps between the concrete which increases the strength of concrete. By using sand in concrete prevents the shrinkage and it gives better texture and gives smooth finishing. It increases the volume of concrete thereby reduces the cost of construction. Sand decreases the porosity in concrete. This decreases the volume of voids hence reduces the development of cracks in it. Sand increases the permeability in concrete, helps in escape of gases and heat out from the concrete uniformly without development of build up pressure, thereby reduces the tendency of development of cracks in it.

D. *Coarse aggregate*

Gravel is the most used coarse aggregate. The size varies from 4.75 to 37.5mm. There are 2 types of aggregates are there rounded and angular, Rounded aggregates require less w/c ratio and by using these aggregates it improves the workability of concrete but this type of aggregates are not preferred when strength is the primary requirement due to its less interlocking mechanism and weak bond strength. Whereas by using angular aggregates increases cement content they increase the strength of the concrete. Coarse aggregates increase the density, strength, hardness, durability, toughness etc., the size of aggregates has also impact on these properties. So, the size of aggregates will vary based on the design mix, place of construction, requirements like strength, durability etc., And decreasing the voids in concrete by using different sizes of aggregates instead of using single size makes concrete more effective. The coarser the aggregate, the more economical the mix. Larger pieces offer less surface area of the particles than an equivalent volume of small pieces. Use of the largest permissible maximum size of coarse aggregate permits a reduction in cement and water requirements. Using aggregates larger than the maximum size of coarse aggregates permitted can result in interlock and form arches or obstructions within a concrete form. That allows the area below to become a void, or at best, to become filled with finer particles of sand and cement only and results in a weakened area.

## 3. MIX CALCULATION

A. *Design mix (M40 for 1m³)*

1) *Calculation of target mean strength*

$f'_{ck} = f_{ck} + 1.65x$ (from IS 10262-2009 table-1 x=5)

$= 40 + 1.65*5$

$= 48.25\ N/mm^2$

2) *Water-cement ratio*

(From IS 10262, table-5, severe)

Adopted water-cement ratio = 0.45

3) *Size of aggregates*

Coarse aggregate = 20mm

Fine aggregate = 4.75mmm

4) *Selection of water content*

Maximum water content for 20mm aggregate (from table 2, IS 10262)

with slump value of 25 to 50 = 186 litres

But considered slump value is 110mm

Estimated water content = 186 + 7/100*186

= 199.02 litres

5) *Calculation of cement content*

(From table 5, IS 456:2000)

Cement content = 199.02/0.45

$= 442.267\ Kg/m^3$

6) *Calculation of aggregate content*

(From table-3 of IS 10262)

20mm size aggregates considering zone-1 = 0.6

0.5 = 0.6

Now,

Actual water-cement ratio = 0.45

It is less by (0.5-0.45) = 0.05

The coarse aggregate in increased at the rate of 0.01 for every decrease in w/c ratio of 0.05

So, for decrease of every 0.05 w/c ratio = coarse aggregate increased by 0.01

Corrected proportion of volume of coarse aggregate = 0.6 + 0.01

= 0.61

Volume of fine aggregate = 1-0.61
= 0.39

7) *Mix proportion*

Volume of concrete = $1m^3$

Volume of cement = mass of cement / specific gravity of cement*1000
= 442.267 / 3.15*1000
= 0.1404 $m^3$

Volume of water = mass of water / specific gravity of water*1000
= 199.02 / 1*1000
= 0.1990 $m^3$

Volume of entrapped air= 2% for 20mm coarse aggregate
= 2/100
= 0.02 $m^3$

Volume of all in aggregates (coarse + fine)
= volume of concrete – (volume of cement + volume of water + volume of entrapped air)
= 1 – (0.1404+0.1990+0.02)
= 0.6406 $m^3$

Mass of coarse aggregates = volume of all aggregates*volume of coarse aggregates*specific gravity*1000
= 0.6404*0.549*2.82*1000
= 991.764 Kg

Mass of fine aggregates = volume of all aggregates*volume of fine aggregates*specific gravity*1000
= 0.6404*0.451*2.65*1000
= 765.613 Kg

8) *Mix proportions*

Cement = 442.267 $Kg/m^3$
Water =199.02 litres
Coarse aggregate = 991.764 Kg
Fine aggregate = 765.613 Kg

*B. Weight of ingredients*

From the above mix design obtained mix ratio is 1:1.7:2.2

1) *Volume of beam* = length*breadth*height
= 1*0.24*0.112
= 0.0268 $m^3$
2) *Weight of concrete* = volume of beam*density of concrete in kgs
= 0.0268*24000
= 64.32 Kg
3) *Weight of cement* = 1/4.9 *64.32 (1+1.7+2.2=4.9)
= 13.12 Kg
4) *Weight of fine aggregate* = 1.7/4.9*64.32
= 22.31 Kg
5) *Weight of coarse aggregate* = 2.2/4.9*64.32

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= 28.87 Kg

6) *Weight of silica fume* = 15% of cement weight
= 15/100*1
= 1.96 Kg

## 4. METHODOLOGY

A. *Materials and grade of mix*

- For this mix required materials are silica fume, steel fibres, cement, fine aggregates, coarse aggregates.
- Select the appropriate design mix and calculate the proportioning of materials in the form of ratios.
- In this mixing M40 grade should be taken and the mix proportions are mentioned in the above calculations.

B. *Preparing the surface of beams*

- First, place the beams in a clean place then remove the clay and soil from it.
- Remove the loose concrete at the place of deformation by chipping of the concrete using hammer.
- Clean the reinforcement, tighten and straighten the reinforcement in the beams.
- Apply the epoxy coating to the beams for improving bond between the old, existed concrete and newly pouring concrete.

C. *Measuring of materials*

- Calculate the required quantity of materials for the beams as per design mix ratio.
- Next measure the materials quantity by using weigh batching because it is more accurate than volumetric batching.

D. *Mixing of concrete*

1) *Dry mix: -*

- First dry mixing should be done by placing and mixing all the ingredients without pouring water.
- Dry mix makes the ingredients uniform.

2) *Wet mix: -*

- After dry mixing place the water as per the w/c ratio and mix the ingredients within 5mins of pouring the water.
- Fast mixing makes good strength and taking long time for mixing reduces the slump also.

E. *Placing of concrete*

- Then place the concrete in the moulds of which are previously prepared within 30mins of mixing and fixed the moulds tightly to avoid the leakage of water before placing of concrete.
- Delay in placing makes the concrete harden and reduces the properties of concrete like workability, strength, durability, resistance to weather etc.,

F. *Compaction and finishing*

- Compaction should be done to makes the mix dense, to avoid pores and good compaction improves the strength of concrete, it should be done with machine compaction.
- For smooth finishing of surface, finishing should be done by using trowels and removing access concrete to make even surface.

G. *Demoulding and curing*

- After 24hrs demould the moulds and remove the beams.
- Then curing takes place, here curing should be done by covering the beams with burlaps and make the burlaps wets during curing period of 28days.

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- Proper curing should be maintained throughout the entire time because proper curing leads to increase in strength, reduces shrinkage cracks, improves good hydration process.

## 5. EXPERIMENTATION

*A. Flexure test*

Flexural test is used to measure the force required to flex or bend the material. This test is done in two ways by three-point loading or four-point loading. Flexural strength is the strength to resist the bending effect. It is also known as Bending strength.

*B. Apparatus*

Specimen (concrete beam), UTM (Universal testing machine)

*C. Procedure*

1) Clean the beam with dry cloth to remove water content on the surface of beam after curing.
2) Remove excess concrete on the surface by trowel and make the beam even.
3) Lift the beam carefully and place it on the support span on the UTM.
4) Set the bearing plates and make plunger in contact with the surface.
5) After contact is made set the loading degree to 0.
6) Then apply the load gradually not suddenly.
7) Note the readings when the first break (crack) formed and final breakage (ultimate load) was.
8) After deformation again release the plunger and bearing plates remove the specimen.

## 6. RESULT

The beam with silica fume has first crack at 10kn and failure at 60kn.

TABLE 1[STEEL + RUBBER + SILICA FUME]

| Load (KN) | Deflection (mm) |
|---|---|
| 10 | 0 |
| 20 | 0 |
| 30 | 2 |
| 40 | 2 |
| 50 | 3 |
| 60 | 4 |
| 70 | 4 |

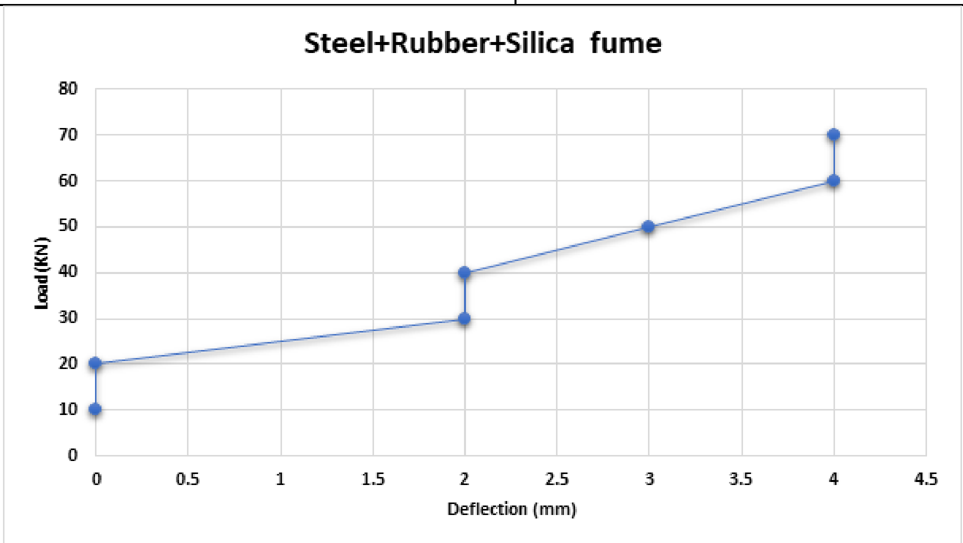


Fig.1

COMPARISION BETWEEN STEEL+RUBBER CONCRETE BEAM vs STEEL+RUBBER+SILICA FUME CONCRETE BEAM

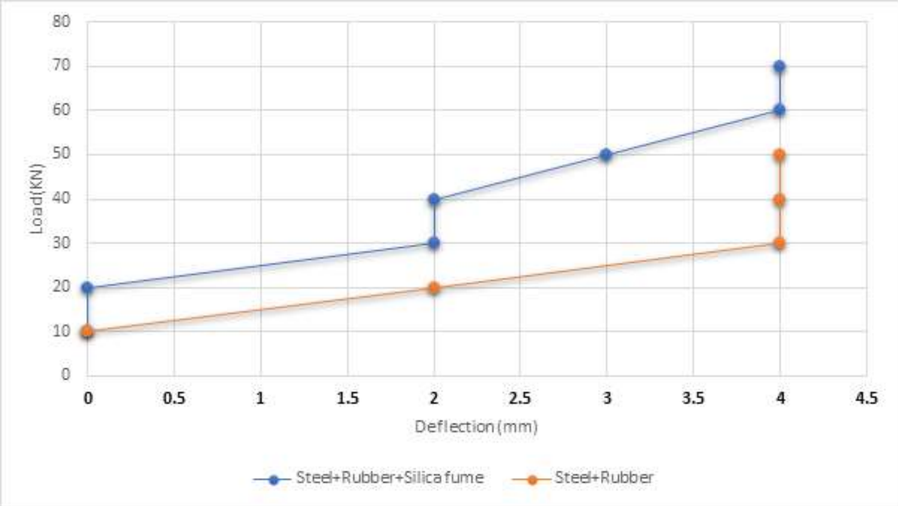


Fig.2

## 7.CONCLUSION

The beam which was previously prepared with STEEL REINFORCEMENT + RUBBER has first crack at 20kn with 2mm deflection failure at 50kn load with 4mm deflection after repairing the failure beam by replacing 15% of cement with silica fume has first crack at 30kn with 2mm deflection failure at 80kn load with 4mm deflection.

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