EXPERIMENTAL STUDY ON HIGH PERFORMANCE CONCRETE USING PARTIAL REPLACEMENT OF WASTE GLASS WITH ADMIXTURES

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ABSTRACT

This experimental study was conducted to investigate the effect of using waste glass powder as partial replacement of fine aggregate for a mix of M60 grade concrete. The demand for aggregate in construction industry is increasing rapidly and so it is becoming more important to seek suitable alternatives for aggregates in the future. The main objective of the project is to find out alternative materials for concrete to meet the demands of natural fine aggregate for the upcoming years, to provide adequate serviceability at minimum cost, to make the eco friendly concrete with safety. In this investigation, an attempt has to be made to determine the feasibility of waste glass powder in high performance concrete. Laboratory work was conducted to determine the performance of control sample and concrete with waste glass powder. The performance of these types of concrete was determined by the density test, compressive strength test, split tensile strength test and Flexural strength test. The compressive strength and Split tensile strength of concrete is found to be greater than control mix. The optimum percentage of replacement for both compressive strength and flexural strength is found to be 10% of replacement.

Keyword: - *Permeable Concrete, Polymer Admixture, Compressive Strength, Flexural Strength, Split Tension Test, and Concrete Pavement etc….*

1.INTRODUCTION

1.1 GENERAL

About 11.5 billion tons of concrete is produced worldwide in this 9 billion tons of aggregate is used, which means 80% of aggregate is used for the production of concrete this leads to the depletion of natural resources. The demand for concrete is expected to grow to approximately 18 billion tons (16 billion tonnes) a year by 2050, hence the alternative is needed for the aggregate. River sand is a scarce material, uncontrolled sand mining from the riverbed leads to the destruction of the entire river system since alternative is needed for river sand.

About 12.5 million tons of waste glass is generated worldwide, in this 77% is used for landfill. Due to the limited landfill space available and stringent environmental regulations, many waste glasses are attempting to develop efficient, economic and environmental sound alternatives for utilizing this waste glass. Therefore, the civil engineers have been challenged to convert this waste glass, in general, to useful building and construction materials. Crushed Waste Glass (CWG) can be effectively used as an alternative for fine aggregate. The waste glass is crushed to the size of fine aggregate and can be used as the partial replacement for river sand.

Utilization of waste glass for construction shall not only solve waste problems, but also provide a new resource for construction purposes. The use of waste glass as a substitute for fine aggregates in concrete is one option that can alleviate waste glass disposal problem and has been studied widely in recent years. Despite of the recent studies, there are still many unknowns with the use of waste glass.

Study is needed to determine the contribution of waste glass to the performance of hardened concrete. There are great concerns on the strength and durability of the concrete being produce with replacement material when used as construction materials in the construction industries. If it is proven that the concrete is durable and strong, this will lead to the use of waste glass to replace part of the fine aggregate in concrete. Finally, this study also aims to determine the most suitable mix proportion that can produce concrete of desirable strength without compromising engineering performance and quality.

1.2 HIGH PERFORMANCE CONCRETE (HPC)

High-strength concrete (>40 Mpa compressive strength) was first used in reinforced concrete frame buildings with 30 or more stories. In tall buildings, the size of column is lower one-third part of the building is quite large when conventional concrete is used. Besides saving in the materials cost, construction engineers have found that the choice of reinforced concrete frame instead of steel frame in high-rise buildings permits additional savings resulting from higher construction speeds. Beginning with 50 Mpa concrete column for the Lake Point Tower in Chicago, constructed in 1965, many tall buildings containing high strength concrete elements have been built in North America and elsewhere. The 79 story Water Tower Place in Chicago contains 60 Mpa concrete columns. The Scotia plaza Building in Toronto and the Two Union Square Building in Seattle have column with 90 and 120 Mpa strength concrete, respectively. To obtain high strength concrete is its low permeability, which is the key to long-term durability in aggressive environments. Consequently, far more high-strength concrete has been used for applications where durability rather than strength was the primary consideration. Marine concrete structures – long span bridges, undersea tunnels and offshore oil platforms.

1.2.1 NEED FOR HIGH PERFORMANCE CONCRETE

Cementitious materials have been in existence for a long time and it is a well known fact that their use in construction activity dates back to the time of Babylonians, Romans and Egyptians. These materials had undergone several changes over the ages and during the past four decades. Changes both in the process and production have established that cement and concrete composites are the most economical construction materials as on today.

In spite of these advancements, the rapid deterioration of concrete structures especially, in coastal regions and in industrial locations having aggressive environments, necessitated enhancing the durability aspects of concrete mixers. As a first step, it has been established that the lower w/c ratio results in HSC that can resist the environment degradation better. But the requirements of workability inhibited the initial attempts in this direction, until super plasticizers or high range water reducers were developed. These materials facilitated the production of reasonably high strength concrete having low w/c ratio; through mostly with higher cement contents. However, it was soon learnt that this approach to improve the performance levels necessitated an increase in cement content, making the concretes much more relative to the environments. These aspects resulted in prescribing norms to the minimum and the maximum cement contents permissible in the different environments.

Also, it was realized that the high strength alone will not be an effective method for achieving high performance and that the durability of these materials in various environments need a better understanding to achieve an appropriate solution. These necessitated the utilization of industrial wastes having pozzolanic properties in concrete and showed the possibilities of obtaining improvements in durability, besides attaining HSC composites. The important milestone of these works is probably the introduction of recycled concrete aggregate, silica fume and fumed silica with the use of both pozzolanic materials and super plasticizers; it is now possible to incorporate both high strength and high performance in concrete composites.

1.3 FLYASH

Fly ash is finely divided residue resulting from the combination of ground or powered coal. They are generally finer then cement and consist mainly of glassy spherical particles as well as residue of hematite and magnetite, char and some crystalline phases formed during cooling.

1.3.1 Classification

There are two major classes of flyash in the basis of chemical composition from the types of coal burned. Class F and Class C fly ash are products of the combustion of coal in large power plant. Fly ash is collected in electrostatic precipitations or bag houses and then transferred to large silos for shipment. When needed, fly ash is classified by precise site requirements, thus assuring a uniform, quality product.

1.3.1.1 Class F Flyash

Class F fly ash is available in the large quantities and is produced when either anthracite, bituminous with pozzolanic properties and Cao content < 5 percent. It contains a greater combination of silica, alumina and iron (greater than 70 per cent) than 5 class C fly ash. Fly ash (Class-F) was obtained from Mettur Thermal Power Plant (MTTP). Most effectively moderates heat gain during concrete curing and is therefore considered an ideal cementious material in weight concrete and high strength mixes. For same reason, Class F is the solution to a wide range of summer concreting problems.

1.3.1.2 Class C Flyash

Class C fly ash obtained from burning sub- bituminous, or lignite coal, possessing pozzolanic and cementitious properties CaO content up to 10 percent. Most useful in "performance" mixes, prestressed applications, and other situations where higher early strengths are important. Especially useful in soil stabilization since class C may, not require the addition of lime.

1.4 GLASS

Glass is an amorphous (non-crystalline) solid material. Glasses are typically brittle and optically transparent. The most familiar type of glass, used for centuries in windows and drinking vessels, is soda-lime glass, composed of about 75% silica (SiO_2) plus Na_2O,CaO, and several minor additives. Often, the term glass is used in a restricted sense to refer to this specific use.

In science, however, the term glass is usually defined in a much wider sense, including every solid that possesses a non-crystalline (i.e., amorphous) structure and that exhibits a glass transition when heated towards the liquid state. In this wider sense, glasses can be made of quite different classes of materials: metallic alloys, ionic melts, aqueous solutions, molecular liquids, and polymers. For many applications (bottles, eyewear) polymer glasses (acrylic glass, polycarbonate, polyethylene terephthalate) are a lighter alternative to traditional silica glasses. Glass, as a substance, plays an essential role in science and industry. Its chemical, physical, and in particular optical properties make it suitable for applications such as flat glass, optics and optoelectronics material, laboratory equipment, thermal insulator (glass wool), reinforcement materials (glass-reinforced plastic, glass fiber reinforced concrete), and glass art (art glass, studio glass).

1.4.1 WASTE GLASS POWDER (WGP)

Waste glass is a major component of the solid waste stream in many countries and is generally used in landfills. As an alternative, however, waste glass would be used as a concrete aggregate, either as a direct replacement for normal concrete aggregate (low value) or as an exposed ,decorative aggregate in architectural concrete products (high value). Expansive alkali silica reactions (ASR) can occur between glass particles and cement paste, particularly in most condition and high alkali cements. This reaction can occur whenever aggregates contain reactive silica. However it is now well known that by controlling cement alkali level and moisture, the reaction can be mitigated. Research has shown that the waste glass can be effectively used in concrete either as aggregate or as pozzolana.

1.4.2 IMPORTANCE OF WASTE GLASS UTILIZATION

Currently India has taken a major initiative on developing the infrastructures such as express highways, power projects and industrial structures etc., to meet the requirements of globalization, in the construction of buildings and other structures. Concrete plays the rightful role and a large quantum of concrete is being utilized. River sand, which is one of the constituents used in the production of conventional concrete, has become highly expensive and also scarce. The utilization of glass powder which can be called as manufactured sand has been accepted as a building material in the industrially advanced countries. As a result of sustained research and developmental works undertaken with respect to increasing application of this industrial waste, the level of utilization of glass powder in the industrialized nations has been reached more than 60% of its total production.

1.5 NEED FOR STUDY

Glass is a solid waste produced in different forms. Disposing of solid waste is a cumbersome process. Hence, Crushed waste glass if used in concrete saves some percentage of sand. Thus, this is a Cost effective process.

1.6 OBJECTIVE

- To evaluate and understand the effectiveness of glass powder in strength enhancement of High performance concrete by partially replacing fine aggregate by WGP.

- To study and compare the performance of conventional concrete and glass powder concrete.

1.7 SCOPE

The scope of this research is to determine the usefulness of economical and conservative by product Waste Glass Powder (WGP) in High performance Concrete. The cost of materials will be decreased by reducing the sand content by using waste material like waste glass powder instead of river sand.

2. Materials Used

2.1 CEMENT

Ordinary Portland cement 53 grade (ultratech cement) complying with IS 269, 1976 was used. The cement was kept in an airtight container and stored in the humidity controlled room to prevent cement from being exposed to moisture. The grade 53 is known for its rich quality and is highly durable. Hence it is used for constructing bigger structures like building foundations, bridges, tall buildings, and structures designed to withstand heavy pressure.

Table 2.1 Properties of Cement

S. No.	Chemical Ingredients	Range %	Common Proportion
1	Lime	60-70	63
2	Silica	17-25	22
3	Alumina	3-8	6
4	Iron Oxide	0.5-6	3
5	Magnesium Oxide	0.4-4	2.5
6	Sulphur Trioxide	1-3	1.75
7	Alkalies such as soda & potash	0.2-1	0.25

2.2 FINE AGGREGATE

Sand used for the experimental program was locally procured and conformed to Indian Standard Specifications IS: 383-1970. The sand was first sieved through BIS 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. Fine aggregate was tested as per IS 2386-1963.

Table 2.2 Properties of fine aggregate

S. No	Properties	Observed Value
1	Specific gravity	2.67
2	Water absorption	1.703%
3	Dry bulk density	1754.25 Kg/m^3
4	Fineness modulus	3.02

2.3 COARSE AGGREGATE

The material which was retained on BIS test sieve 4.75mm was termed as coarse aggregate. The broken stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 12.5 mm was used in the work. The aggregate was washed to remove dust and dirt and was dried to surface dry condition. The aggregate was tested as per Indian Standard Specifications IS: 2386-1963.

Table 2.3 Properties of Coarse Aggregate

S. No	Properties	Observed value
1	Specific gravity	2.6
2	Water absorption	0.214%

3	Dry bulk density	1630.814 Kg/m^3
4	Fineness modulus	6.9

2.4 MINERAL ADMIXTURE

In this project the fly ash used belongs to class F shown in fig 3.2 and was brought from Ennore Thermal Power Station, Chennai.

Fig 2.1 Fly ash

2.5 WASTE GLASS POWDER

Waste glass powder is used in this project is collected from various glass shops at parry's, Chennai. The waste glass powder is used as a partial replacement for river sand which is shown in fig 3.2

Table 2.4 Properties of Waste Glass Powder

S.NO	Properties	Waste glass powder (WGP)
1	SiO_2	70.22
2	CaO	11.13
3	MgO	-
4	Al_2O_3	1.64
5	Fe_2O_3	0.52
6	SO_3	-
7	Na_2O	15.29
8	K_2O	-
9	Cl	-
10	Loss on ignition	0.80

Fig 2.2 Waste Glass Powder

2.6 CHEMICAL ADMIXTURE

Super plasticizers, also known as high range water reducers, are chemicals used as admixtures where well-dispersed particle suspensions are required. These polymers are used as dispersants to avoid particle aggregation, and to improve the flow characteristics of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste.

GLENEIUM B233 admixture is used in this project based on polycarboxylic ether. This super plasticizer is free from of chloride and it is compatible with all types of cements. The properties of super plasticizers is shown in table 3.4

Table 2.5 Properties of Super plasticizers

S. No	Properties	Observed value
1.	Colour	Light Brown Liquid
2	Specific gravity	1.08
3	Ph	>6

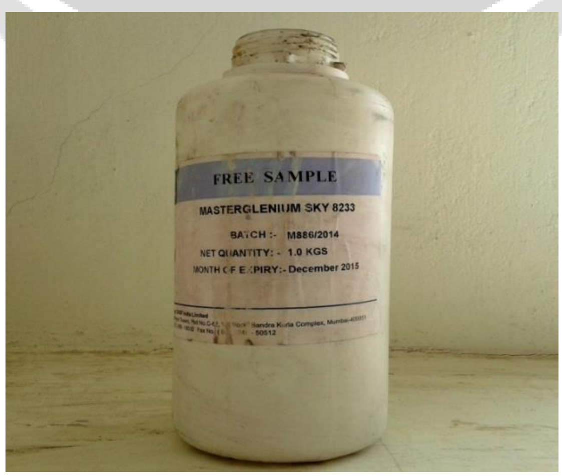


Fig 2.3 Super plasticizer (Glenium B-233)

2.7 WATER

Portable tap water available in the laboratory with pH value of 7.0 and conforming to the requirements of IS 456-2000 is used for making concrete and curing the specimen as well.

3. METHODOLOGY

The literature related to the project is collected and reviewed. The initial for the coarse and fine aggregate is conducted, from that initial test results the mix ratio is arrived. The cubes, cylinders and beams were casted for both conventional and replacement of fine aggregate for various proportion. Hardened concrete Tests such as Compressive strength, Split tensile strength and flexural strength is conducted cylinders and beams. From the above data result and discussion is analysed and final conclusion is arrived using that test results.

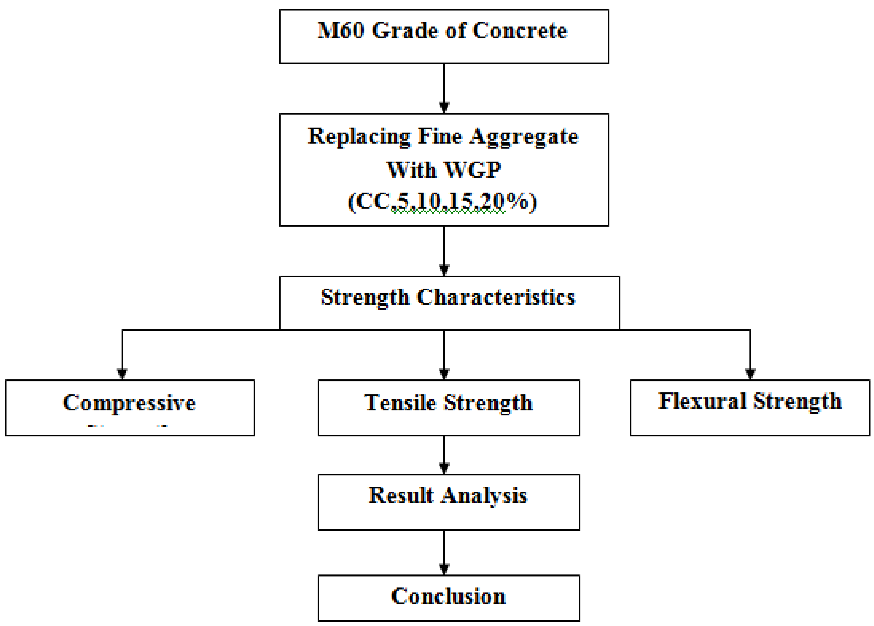


Fig 3.1 Methodology for High Performance Concrete

3.1 MIX PROPORTION

3.1.1 GENERAL

The concrete used in this study was proportioned to attain strength of **60 MPa**. ACI committee recommendation has been used for M60 design. The mixes were obtained for conventional concrete and by replacing 5, 10, 15and 20 percent of the mass of fine aggregate by Waste glass powder. The water cement ratio (w/c) is taken as 0.29**.** The mix design has been adopted as per, ACI 211.4R-93. The initial test have been done for aggregate based on IS: 2386 (Part III) – 1963.

3.1.2 MIX DESIGN

Collected Data for Coarse Aggregate,

Specific gravity = 2.74
Bulk Density = 101.795 lb/ft^3
Fineness Modulus = 6.9

Water Absorption = 0.214%

Collected Data for Fine Aggregate,

Specific gravity = 2.67
Bulk Density = 109.5 lb/ft^3
Fineness Modulus = 3.02
Water Absorption = 2.6%

Step 1: Slump and Required Concrete Strength Section

Required average strength (f_{cr}) $= \frac{fc+1400}{100}$
f_{cr} = 11224.736 psi

Step 2: Maximum Size of Coarse Aggregate Selection

As per Codal provision ACI 211.4R-1993 table 4.3.3
The maximum size of Coarse Aggregate = ½ inch

Step 3: Selection of Optimum Coarse Aggregate Content

Volume of oven dry rodded coarse aggregate = 0.68
Oven dry weight of coarse aggregate / yd^3 of concrete = dry unit weight × 27
= 69.221× 27
= 1868.956 lb

Step 4: Estimate Mixing Water and Air Content

Maximum size of coarse aggregate = ½ inch
Water content = 295 lb/yd^3
Entrapped air = 2%
Void content of fine aggregate, % (V) = 34.24 ≠ 35
Water adjustment = 295lb/yd^3

Step 5: Selection of Low Water to Cementitious Material Ratio (w/c + p)

For ½ inch coarse aggregate and f_{cr} (11224.736 psi) from table 4.3.5 (b)
w/c + p = 0.283

Step 6: Calculation of Cementitious Material

Weight of cementitious material $= \frac{water\ content}{w/c + 100}$
=1042.4

Step 7: Proportion of Basic Material with Mixture Cement

Cement concrete per yd^3 = 1042.4 lb/yd^3
Volume per yd^{3}of all material except fine aggregate,
Cement $= \frac{1042.4}{(3.15 \times 62.4)}$
= 5.3
Coarse aggregate $= \frac{1979.171}{2.6027\ x\ 62.4}$
= 12.186
Water $= \frac{295}{62.4}$

= 4.727

Air (2%) = 0.02×27

= 0.54 ft^3

Total = 22.753 ft^3

Required volume of sand per yd^3 of concrete = 27 – 22.753

= 4.247 ft^3

Wt of sand dry per yd^3 of concrete = 4.247 x 62.4 x 2.673

= 708.432 lb/ft^3

Step 8: Material content

Cement = 1042.4 lb/ft^3

Coarse aggregate = 1979.171 lb/ft^3

Fine aggregate = 708.432 lb/ft^3

Water = 295 lb/ft^3

Step 9: Adjustment

Cement = 1042.4 lb/yd^3

Coarse aggregate = 1979.171 x [$1+\frac{0.2149}{100}$]

= 1983.42 lb/yd^3

Fine aggregate =708.432 x [$1+\frac{1.7034}{100}$]

= 720.4994 lb/yd^3

Water =309.2146 lb/yd^3

Cement =1042.4lb/ft^3= 615.016 kg/m^3

Fine aggregate =762.343lb/ft^3=425.095kg/m^3

Coarse aggregate =1983.424lb/ft^3

=1170.22kg/m^3

Water =309.214lb/ft^3=182.436kg/m^3

Table 3.1 Mix Proportion

Cement	Fine aggregate	Coarse aggregate	Water
615.016	425.095	1170.22	182.436
1	0.69	1.9	0.29

4. TESTING OF SPECIMEN

4.1 Compressive Strength

For cube compression testing of concrete, 100mm diameter and 200mm height size cylinders were used. All the cylinders were tested in saturated condition, after wiping out the surface moisture. The cubes were tested at the age of 7 and 28 days of curing using compression testing machine of 1000 kN capacity.

The tests were carried out at a uniform stress of 10 kg/cm^2/minute after the specimen has been centred in the testing machine. Loading was continued till the readings were reversed from the incremented values. The reversal in the reading value indicates that the specimen has failed. The Machine was stopped and the reading at that instant was noted which was the ultimate load.

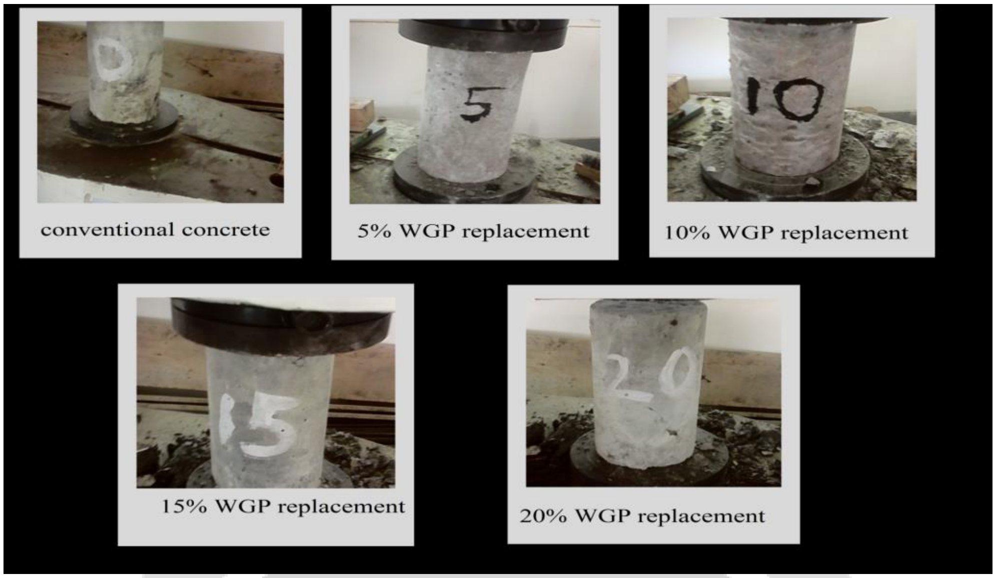


Fig 4.1.1 Compressive Strength Test before testing

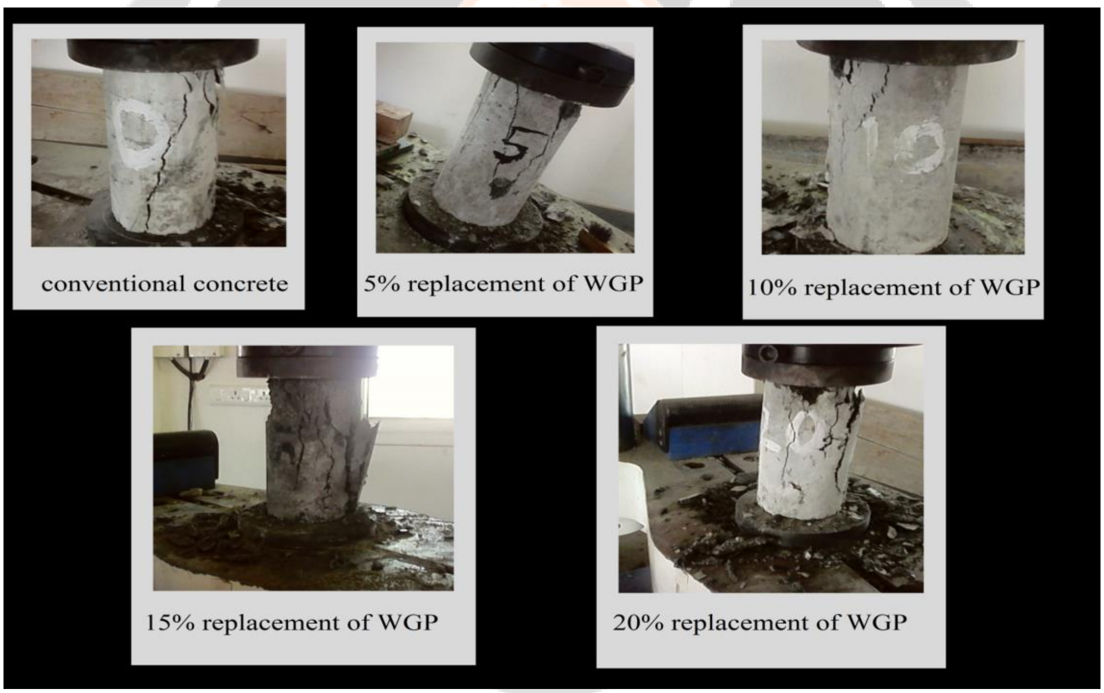


Fig 4.1.2 compressive strength test after testing

4.2 Split tensile strength

For split tensile strength of concrete, 100 mm dia x 200mm height cylinders were used. The split tensile strength on cylinder were conducted on a computerised compressive testing machine of capacity 1000KN.The method covers the determination of the splitting tensile strength of cylindrical concrete specimens. This method consists of applying a diametric compressive force along the length of a cylindrical specimen. This loading induces tensile stresses on the plane containing the applied load. Tensile failure occurs rather than compressive failure. Plywood strips are used so that the load is applied uniformly along the length of the cylinder. The maximum load is divided by appropriate geometrical factors to obtain the splitting tensile strength.

Split tensile strength = $\frac{2P}{\pi ld}$

P = maximum load in Newton's applied to the specimen
l = length of the specimen (mm)
d = cross sectional dimension of the specimen

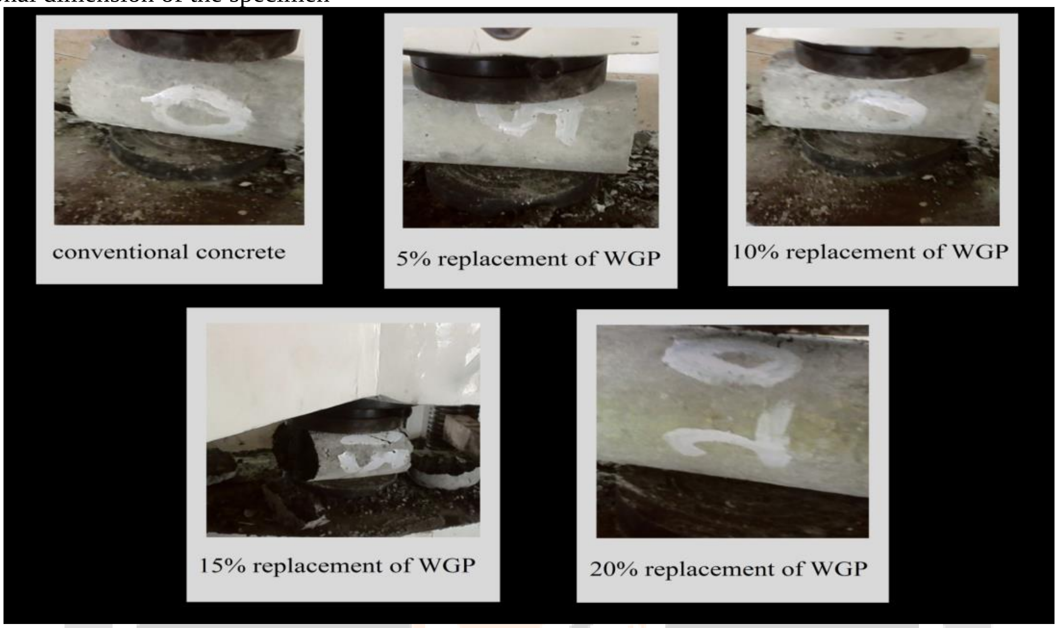


Fig 4.2.1 split tensile strength for cylinders before testing

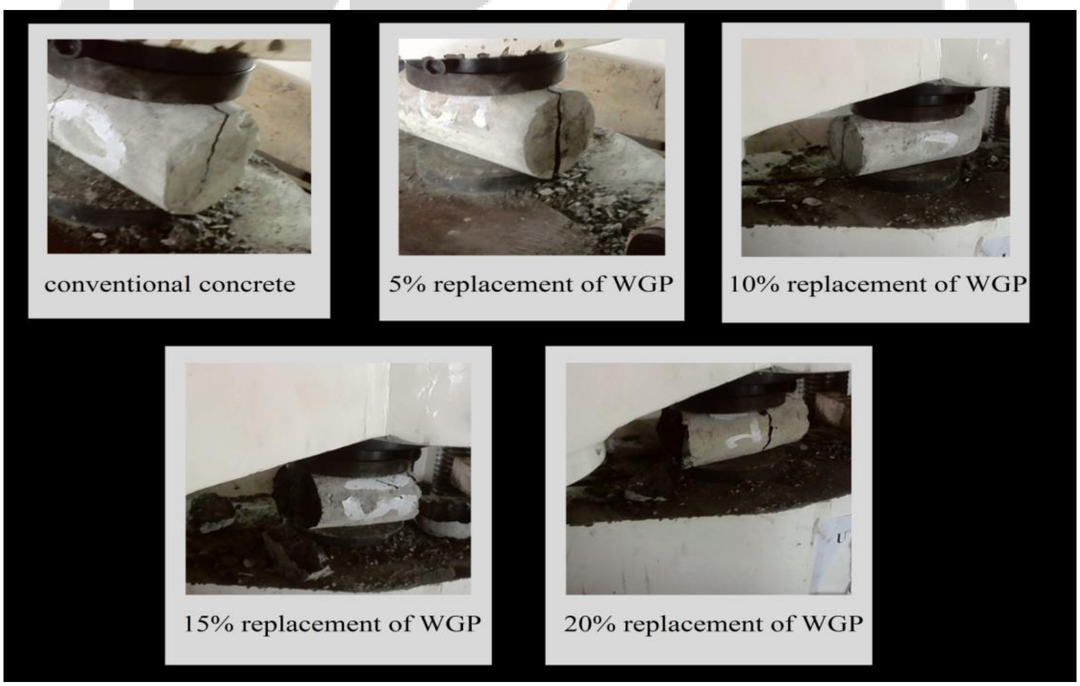


Fig 4.2.2 split tensile strength for cylinders after testing

4.3 Flexural strength

For prism flexural testing of concrete, 150 x 150 x 700mm size is used. All the prisms were tested in saturated condition, after wiping out the surface moisture. They were tested at the age of 28 days of curing using compression testing machine of 1000 kN capacity. Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load.

The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture.

The flexural strength of concrete prism was determined based on IS: 516 – 1959. Place the specimen in the machine in such a manner that the load is applied to the upper most surface as cast in the mould along two lines spaced 13.3cm a part. Apply load without shock and increase continuously at a rate of 180 kg/min and it is increased until the sample fails. Measure the distance between the line of fracture and nearest support.

If $a > 13.3$cm then

Modulus of rupture $fb = Pl/bd^2$

If $a < 13.3$

$fb = (3P\times a)/bd^2$

If $a < 11$, discard the specimen

Where,
P = Maximum load applied to the specimen in kN.
L= Supported Length in mm.
d = Depth of the specimen mm, and
a = Distance of the crack from the nearest support.

Fig 4.3.1 prism before testing

Fig 4.3.2 Prism after testing

4.4 DESIGN OF REINFORCED CONCRETE BEAMS

4.4.1 Theoretical Prediction

In this section, the ultimate moment of resistance of the series of the beam to be tested were predicted. These results will be compared with the experimental results. The method used to determine the theoretical bending strength is presented first, and then experimental results are shown and discussed.

4.4.2 Theoretical Bending Strength

The RC beams externally strengthened with GFRP sheets, is designed, based on the requirements of IS: 456-2000. The following assumptions are made for calculations:

a) Transverse beam sections are plane before and after the loading
b) The bond between all constituent materials of the section is perfect
c) The distribution of strain is linear along the section.
d) The actual parabolic concrete stress-strain curve can be replaced by an equivalent rectangular distribution.
e) The maximum compressive strain of concrete is 0.0035.
f) The tensile strength of concrete is negligible.
g) The compressive strength in the steel is not taken into account.

In the Limit State Design approach, the potential failure modes are identified.

1) Failure of the concrete in compression
2) Steel yielding followed by failure of the concrete in compression.

4.4.3 DESIGN OF BEAM SECTION

In the present study RCC beam is designed by limit state method. M60 grade concrete and Fe 415 steel is used in design and the beam is considered to be an under reinforced section. Based on the design results two steel bars of 8mm diameter at compression face and two bars of 8mm diameter at tension face is provided. The stirrups used are 6mm diameter at 100mm which is more than the minimum required spacing, so that the beam should behave as a shear deficient beam.

4.4.4 Design Details of Beam Element (IS 456 -2000)

Breadth of beam = 150mm
Depth of beam = 150mm
f_{ck} = 60 N/mm^2
f_y = 415 N/mm^2
Diameter of bar = 8 mm

Clear cover = 20 mm

Effective depth of beam = 150-20- 8/2

= 126 mm

For balanced X^n

X_{umax} = 0.48d

= 0.48 x 126

= 60.48 mm

Ast = $2 \times \pi/4 \times 8^2$

= $100.53\ mm^2$

Depth of neutral axis = 11.26 mm

$X_u < X_{umax}$ .It is an under reinforced section.

M = $0.87F_y \times Ast \times d \times (1 - \frac{f_y A_{st}}{b\ d\ F_{ck}})$

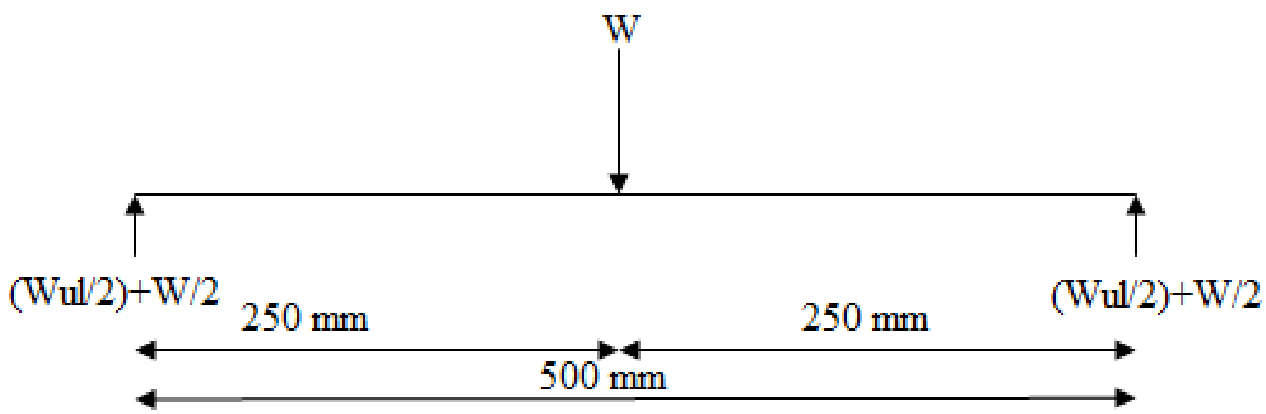
= 4.405 KNm

S_w = 0.15×0.15×25×1

= 0.563 KN/m

= 1.5×0.563

= 0.843 KN/m



Taking Moment about at Centre,

$(W_u L/2 + W_u/2) \times (0.24)$ = 4.405

W_u = 36.26 kN

Check for Stresses:

Nominal shear stress, τ_v = $\frac{V}{bd}$

= [(0.843 x 0.48) / 2 + (36.26)] / [150 x 126]

= $1.86\ N/mm^2$

p_t = [(100 x 100.53) / (150 x 126)]

= 0.53 %

From IS 456 – 2000 table 19

τ_c = $0.52\ N/mm^2$

τ_{cmax} = $4\ N/mm^2$

τ_v = $1.86\ N/mm^2$

Shear reinforcement is necessary

Design of shear reinforcement

Shear taken by concrete = τ_c x b x d

= 0.52 x 150 x 126

= 9.83 KN.

Shear taken by stirrups = 36.26 – 9.83

= 26.45 KN

Using 6 mm diameter 2 legged vertical stirrups

$A_{sv} = \frac{2 \times \pi \times 6^2}{4}$ = 56.52 mm^2

$V_s = \frac{0.87 \times fy \times Asv \times d}{Sv}$

$S_v = \frac{0.87 \times 415 \times 56.52 \times 126}{26.45 \times 10^3}$

= 102.23mm.

Minimum Shear reinforcement $= \frac{Asv}{bsv} \geq \frac{0.4}{0.87fy}$

$S_v = \frac{56.55 \times 0.87 \times 415}{0.4 \times 126}$ = 404.35 mm.

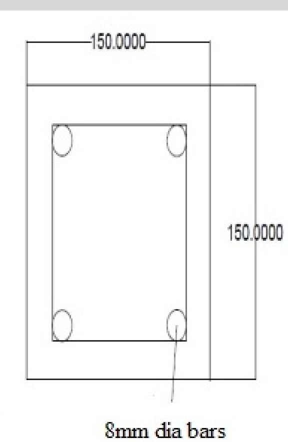
(or) 0.75×d

0.75×126 = 94.75mmc/c

Provide 6mm dia 2 legged stirrups @ 100mm c/c.

4.4.5 Beam Detailing

The reinforcement detailing for the beams to be tested for flexural behaviour is shown below,



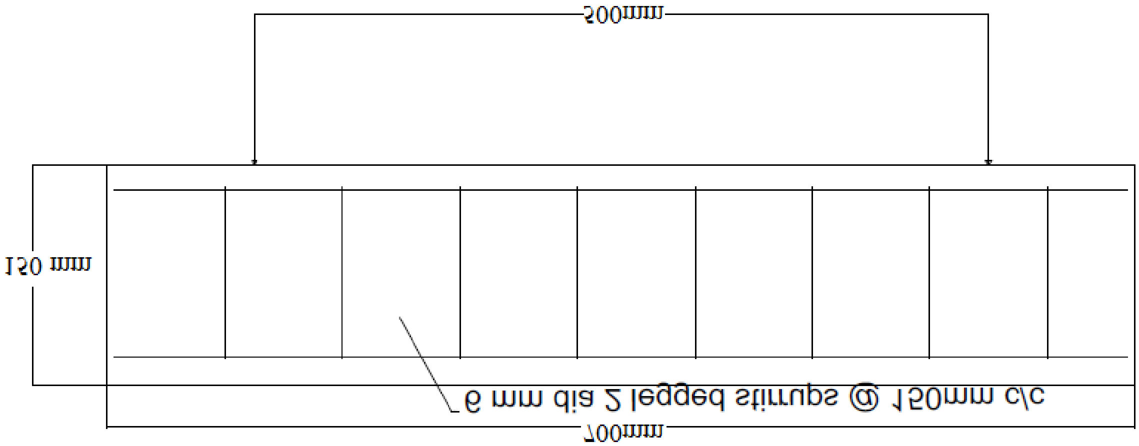


Fig 4.4 Cross Section and Longitudinal Section of Flexural Member

5. RESULT AND DISCUSSION

5.1 5.1 DENSITY OF CONCRETE

Density of concrete is calculated for each percentage of replacement of Waste glass powder and conventional concrete. The density of the concrete is reduced in addition of the waste glass powder in concrete. Replacement of waste glass powder in concrete reduces about 10.7% weight of concrete. Density of concrete is shown in table 5.1

$$\text{Density of concrete} = \frac{weight}{volume}$$

Table 5.1 Density of Concrete for Cylinders

S. NO	Replacement of waste glass powder %	Weight of concrete	Density (Kg/m^3)
1	0	4.20	2675.159
2	5	4.10	2611.475
3	10	4.05	2579.618
4	15	3.85	2452.229
5	20	3.75	2388.535

From the above table the density of concrete is reduced for each percentage of replacement. The decrease in density provides the light weight concrete.

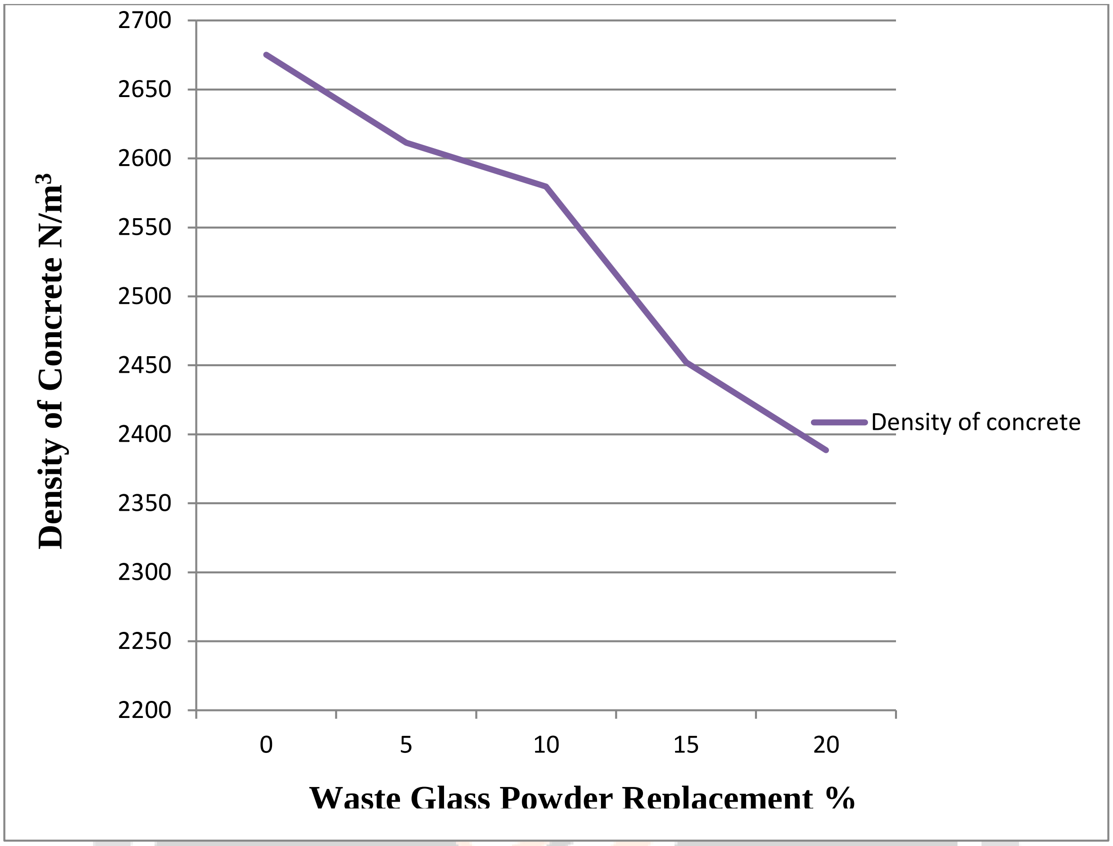


Fig5.1 Graphical representation of Density of concrete at 28 days

From the above fig 5.2 it is clear that the density of concrete reduces for each percentage of increase in waste glass powder.

5.2 COMPRESSIVE STRENGTH

The compressive strength test results are shown in table 5.3. Compression test is done on cylinders at 7th and 28th days of curing for conventional and each percentage of replacement from 5-10%. Totally 30 cylinders were casted to determine the compressive strength of the concrete. The size of the cylinder 200mm height and 100mm diameter is used for this experimental work. From the compressive test results the optimum dosage is found to be 10%. The replacement strength is greater than the conventional concrete.

From the below 7 days compressive test results the strength of the replaced concrete is 9.65% greater than the conventional concrete. At 7 days curing the conventional concrete achieves 72% strength and the optimum Waste glass replaced achieves 79% strength.

Table 5.2 Compressive Strength for 7 days

S. No	Replacement of waste glass powder %	Loads KN			Mean KN	Strength N/mm^2
		Trail 1	Trail 2	Trail 3		
1	0	342.55	335.65	339.25	339.15	43.18
2	5	358.90	352.25	350.45	353.87	45.06
3	**10**	**371.05**	**365.15**	**379.45**	**371.88**	**47.35**
4	15	259.55	262.85	271.60	264.67	35.39
5	20	247.90	242.95	251.30	247.38	31.49

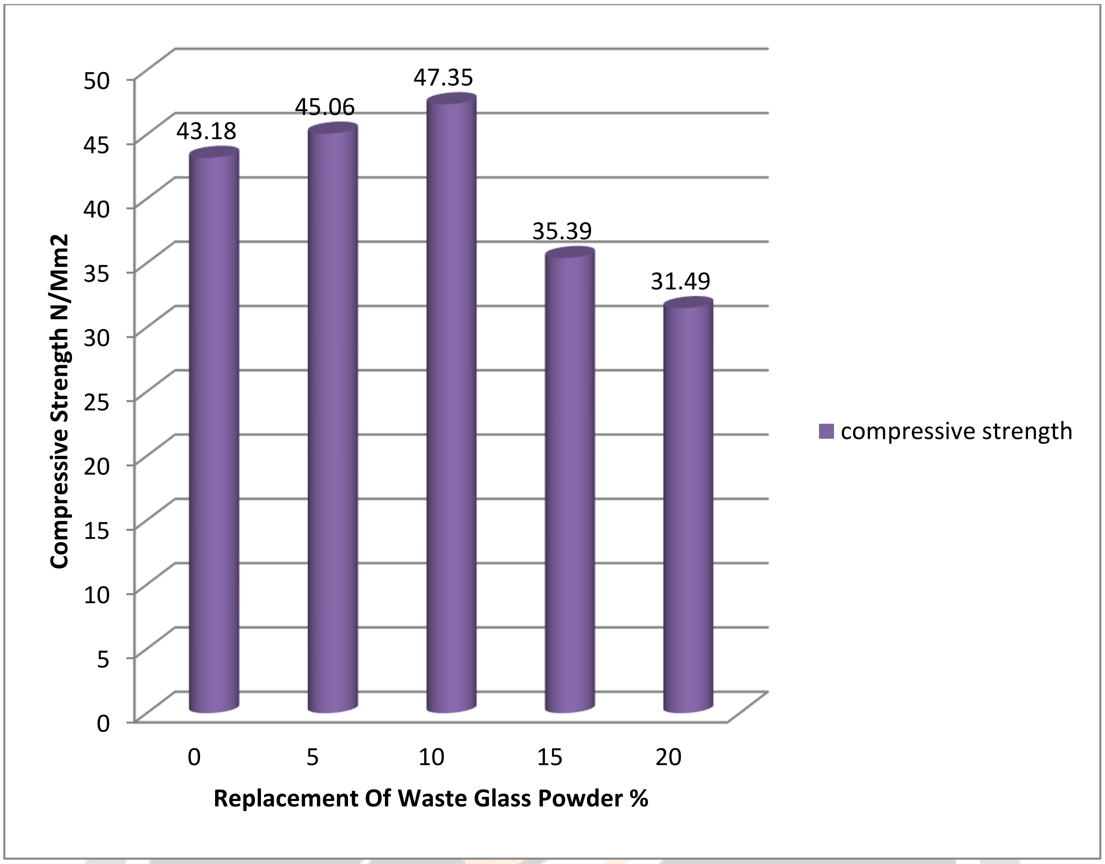


Fig 5.2 Graphical Representation of Compressive Strength of cylinders at 7 Days

From the above graph it is clear that the compressive strength of cylinder increase up to optimum level of replacement after that starts decreases. The compressive strength of replaced cylinders is greater than the conventional concrete. The optimum percentage of replacement of waste glass powder in concrete is found to be 10%.

Table 5.3 Compressive Strength for 28 days

S. No	Replacement of waste glass powder %	Loads KN			Mean KN	Strength N/mm^2
		Trail 1	Trail 2	Trail 3		
1	0	504.20	489.45	499.85	497.833	63.39
2	5	512.05	526.50	509.70	516.083	65.71
3	**10**	**536.05**	**538.15**	**547.80**	**540.667**	**68.84**
4	15	412.25	435.85	425.15	424.417	54.04
5	20	383.70	394.80	389.45	389.317	49.57

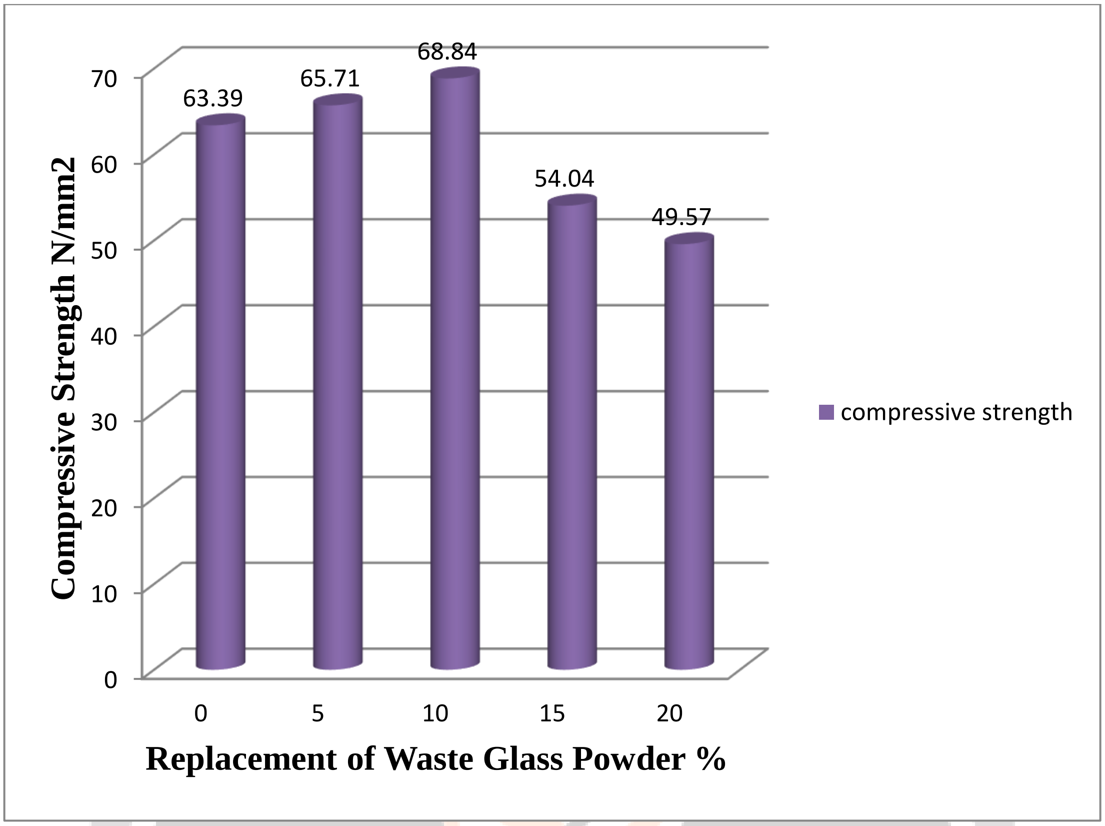


Fig 5.3 Graphical representation of Compressive Strength of cylinder at 28 Days

From the above graph the maximum strength of the concrete achieved is found to be in 10% replacement of WGP.

5.3 Split Tensile Strength

The tensile strength test results for cylinders at 28th days curing are presented in table 5.4. The test is conducted for both conventional and each percentage of replaced cylinders. From the test results the optimum dosage is found to be 10%. The split tensile strength value increases and gradually decreases after the optimum percentage. Strength of the 5 and 10% replacement is greater than the conventional concrete. Totally 15 cylinders of size 100mm diameter and 200mm height are casted and after 28 days curing.

Table 5.4 split tensile strength at 28 days

S. No	Replacement of waste glass powder %	Loads KN			Mean KN	Tensile Strength N/mm^2
		Trail 1	Trail 2	Trail 3		
1	0	165.50	169.55	164.85	166.63	5.3
2	5	172.65	169.05	173.15	171.62	5.46
3	**10**	**179.05**	**182.65**	**185.95**	**182.55**	**5.81**
4	15	130.40	127.30	132.85	130.18	4.14
5	20	118.85	122.35	116.25	119.15	3.79

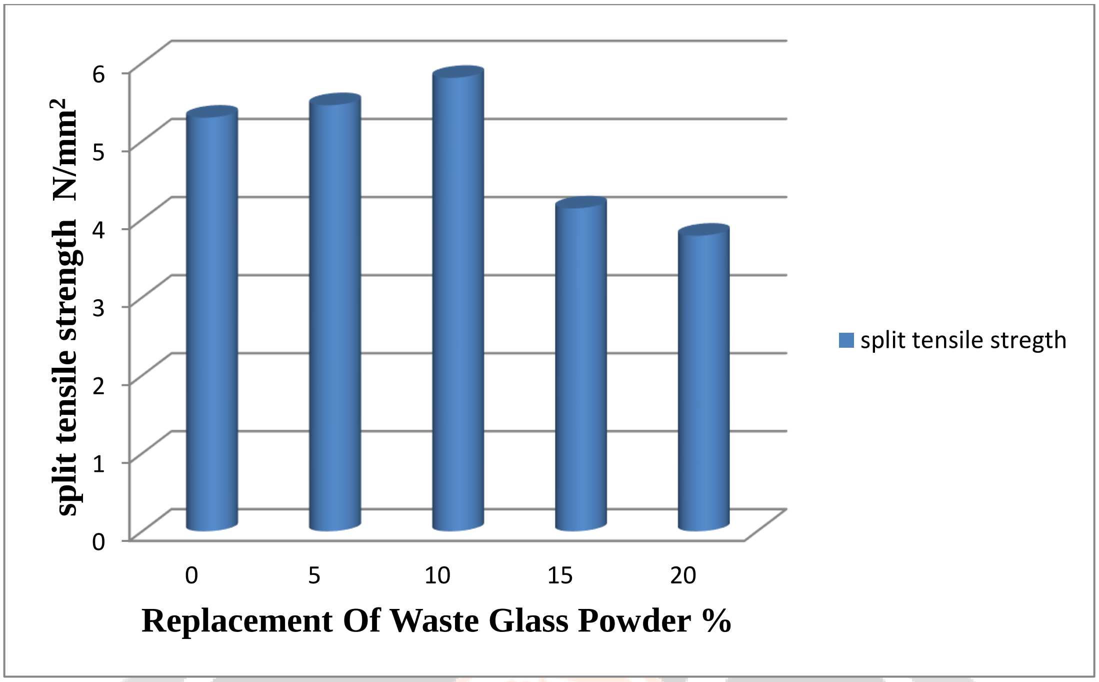


Fig 5.4 Graphical Representation of Split Tensile Strength of Cylinder at 28 Days

From the above graphical representation it is clear that the Split tensile strength of cylinder increase up to optimum level of replacement after that starts decreases. The split tensile strength of replaced cylinders is greater than the conventional concrete. The optimum percentage of replacement of waste glass powder in concrete is found to be 10%.

5.4 Flexural Strength of RCC Beam

The size of beam specimen is 700×150×150mm. Totally 5 beams were casted for each percentage of replacement of Waste glass powder. Mostly the flexural strength of conventional and 5% replacement is almost equal. The flexural strength also increases upto the optimum percentage of replacement i.e 10% of waste glass replacement for fine aggregate. After that the flexural strength starts decreases gradually. The bending moment also increases up to 10% of waste glass replacement.

Table 5.5 Flexural strength of prism at 28 days

S. No	Replacement of WGP %	Ultimate load KN	Maximum Bending Moment KNm	Flexural strength N/mm^2
1	0	102.45	11.95	21.25
2	5	104.95	12.24	21.77
3	10	107.85	12.58	22.37
4	15	96.25	11.23	19.96
5	20	86.90	10.14	18.02

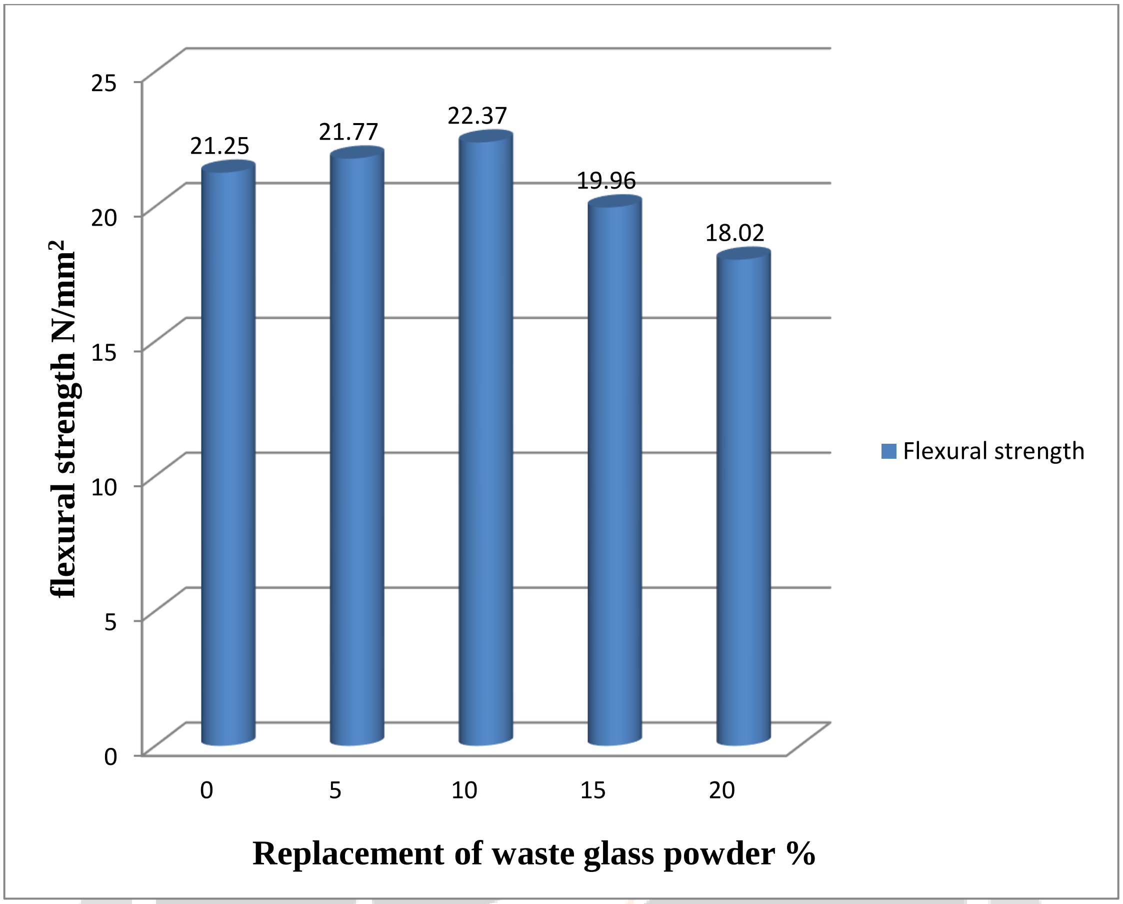


Fig 5.5 Graphical Representation of Flexural Strength of Prism at 28 Days

From the above figure it is found that the flexural strength increases up to 10% and starts decreases beyond that. When the flexural strength of the prism increases the bending moment also increases.

6. Conclusion and Scope for Future Work

6.1: GENERAL

Based on the experimental investigation effect of Waste glass powder in concrete was studied and carried out by partially replacing fine aggregate. The waste glass powder is partially replaced for fine aggregate by 5-20%. From this study the following conclusion were made.

6.2 CONCLUSIONS

- The results of the present investigation indicate that other mix design parameters remaining constant, WGP incorporation in concrete results in significant improvements in compressive strengths.
- The optimum 28-day compressive strength has been obtained in the range of 10% WGP replacement level and adoption of constant w/c ratio
- The compressive Strength of optimum replacement is 8.5% higher than that of the conventional mix.
- The optimum 28-day split tensile strength has been obtained in the range of 10% Waste glass powder replacement level.
- The split tensile strength of 10% replacement of WGP is 9.6% higher than that of the conventional mix.

- The optimum 28-day flexural strength has been obtained in the range of 10% Waste glass powder replacement level.
- The flexural strength is 5.27% higher than that of the conventional mix.
- As the age of concrete increases, the compressive strength also increases. WGP concrete attains high strength.
- It is proved that the high strength concrete can be obtained by lowering the water-cement ratio and the workability can be maintained by the use of super plasticizers even for very low water-cement ratio.
- Density of concrete is reduced as the percentage of waste glass powder increase.
- Since WGP is finer it act as a good filler material in concrete hence it has no voids.
- In flexural behaviour of beam the ultimate load is increased upto 5.27% hence it resist the deformation under load.

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