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EXPERIMENTAL STUDY ON CONCRETE WITH SHEET GLASS POWDER AS A PARTIAL REPLACEMENT OF FINE AGGREGATE

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ABSTRACT

Sheet glass powder (SGP) used in concrete making leads to greener environment. In shops, nearby Chennai many sheet glass cuttings go to waste, which are not recycled at present and usually delivered to landfills for disposal. Using SGP in concrete is an interesting possibility for economy on waste disposal sites and conservation of natural resources. This paper examines the possibility of using SGP as a replacement in fine aggregate for a new concrete. Natural sand was partially replaced (10%, 20%, 30%, and 40%) with SGP. Compressive strength, Tensile strength (cubes and cylinders) was compared with those of concrete made with natural fine aggregates. Fineness modulus, specific gravity, moisture content, water absorption, bulk density, %voids, and % porosity (loose and compact) state for sand (S) were also studied. The test results indicate that it is possible to manufacture concrete containing Sheet glass powder (SGP) with characteristics similar to those of natural sand aggregate concrete provided that the percentage of SGP as fine aggregate is limited to 10-20%, respectively.

Keywords: Sheet glass powder, recycle, compressive strength, tensile strength.

1. INTRODUCTION

During recent years here awareness is increased regarding environmental pollution due to domestic and industrial waste. Now pollution control board is formed to regulate environmental degradation due to industrial waste. When once environment is allowed to degrade, it will take huge amount of public exchequers to clean it so in view of this, it is better to present than searching of solution for concrete. Concrete is in general, cement-based concrete, which meets special performance requirement with regard to workability, strength and durability, that cannot always be obtained with techniques and materials adopted for producing conventional cement concrete. Fine aggregate is important construction material, which is widely used, in construction works. Nowadays the cost of concrete is increased since the cost of fine aggregate is increased. To reduce the requirements and cost of concrete some alternative materials are needed to replace the fine aggregate.

2. MATERIALS COLLECTION

2.1 GLASS

The glass has been used as an engineering material since ancient times. But because of the rapid progress made in glass industry in recent times the glass has come out as the most versatile engineering material of the modern times. The first glass object made by man was of natural glass such as obsidian and rock crystal.

2.1.1CLASSIFICATION OF GLASS

1) Soda lime glass
2) Potash lime glass
3) Potash lead glass

2.1.2 COMPOSITION OF GLASS

Soda-lime glass: Na_2O, CaO, $6SiO_2$
Potash-lime glass:K_2O, CaO, $6SiO_2$
Potash -lead glass:K_2O,PbO,$6SiO_2$

2.1.3 WASTE SHEET GLASS POWDER

Glass is a transparent material produced by melting a mixture of materials such as silica, soda ash, and CaCO3 at high temperature followed by cooling during which solidification occurs without crystallization. Glass is widely usedin 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 sheet glass powder is divided in two categories wise:

- SGP particle size less than 90 microns (Fig. No 2)
- SGP particle size from 90 micron to 300 micron (Fig. No 3)

FIGURE:- 2.1 SHEET GLASS POWDER

2.2 CEMENT

The most common cement is used is ordinary Portland cement. Out of the total production, ordinary Portland cement accounts for about 80-90 percent.

2.3 FINE AGGREGATE

Locally available free of debris and nearly riverbed sand is used as fine aggregate. In the present study the sand conforms to zone II as per the Indian standards6. The specific gravity of sand is 2.68. Those fractions from 4.75 mm to 150 micron are termed as fine aggregate, and the bulk density of fine aggregate (loose state) is1393.16kg/m3 and rotted state is 1606.84kg/m3.

2.4 COARSE AGGREGATE

The crushed aggregates used were 20mm nominal maximum size and are tested as per Indian standards 6 and results are within the permissible limit. The specific gravity of coarse aggregate is 2.83; the bulk density of coarse aggregate (loose state) is 1692.31kg/m3 and rotted state is 1940.17kg/m3.

2.5 SHEET GLASS POWDER

The material is collected from Chennai, and the nominal maximum size of SGP is 300 Microns. The specific gravity of SGP is 2.45 fractions from 4.75 mm to 150 microns Sheet Glass Powder are used.

2.6 WATER

Water available in the college campus conforming to the requirements of water for concreting and curing as per IS: 456-2000.

3. MATERIAL TESTING

3.1 TESTING OF CEMENT

Cement is the important binding material in concrete. Ordinary Portland cement is the common form of cement. It is the basic ingredient of concrete, mortar, and plaster. It consists of mixture of oxides of calcium, silicon and aluminum. Cements of various strengths are available. Depends on the requirement concrete it is to be chosen.

3.2 FINENESS OF CEMENT

Fineness of cement is tested in two ways.

1) By sieve
2) By air permeability method

3.4 SIEVE TEST

IS 2386 (I)-1963 recommended the sieve analysis. This test consists of the simple operation of dividing aggregates into fractions, each consisting of particles of the same size. The sieves used for the test have square openings sieve as are described by the size of their openings as 80 mm, 63 mm, 50 mm, 40 mm, 25 mm, 20 mm, 16 mm, 12.5 mm, 10 mm, 6.3 mm, 4.75 mm, 3.35 mm, 2.36 mm, 1.70 mm, 1.18 mm, 850µm, 600µm, 425µm, 300µm, 212µm, 150µm and 75µm. All the sieves are mounted in frames one above the other in ascending order.

The sieves used for coarse aggregates are of sizes 12mm, 10 mm, 6.3 mm, 4.75mm & pan. All the sieves are mounted on a sieve shaker. Aggregate of known quantity is placed over the top sieve, and after sieving thought the test sieves, the residue in each sieve is weighted the percentage of weight retained to the total weight is calculated, from which the percentage passing is determined.

3.5 STANDARD CONSISTENCY TEST

400gm of cement was weighed and it was first mixed with 25% of water by its weight and filled in mould within five minutes. Now the vicat mould was placed in the glass plate and it was filled with paste and shakes to expel the entrapped air if any. The surface of the paste was leveled on the top of the mould with trowel. Now the plunger was fixed in the moving rod and the mould was kept under the plunger. Now the plunger was made to touch the surface of the paste and then it was allowed to fall under its own weight. When the plunger comes to rest, the depth of penetration was noted. If it was from 33-37mm from top the % of water added was correct and this % of water added was the consistency of cement. If not, the test was repeated by taking the fresh sample and mixed with water content increasing the percentage by 1%.

Normal consistency of cement = 31%

3.6 SETTING TIME TEST

Initial setting time is regarded as the elapsed between the moments that the water is added to the cement, to the time that the paste starts its plasticity. The final setting time is the time when elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure.

1) INITIAL SETTING TIME
2) FINAL SETTING TIME

3.7 SPECIFIC GRAVITY OF CEMENT

- 100 gm of cement is weighed.
- 990 ml of kerosene is filled in a specific gravity bottle.
- Specific gravity of cement=weight of cement (volume of 10ml) weight of kerosene of equal volume of cement.

CALCULATION OF SPECIFIC GRAVITY

Weight of dry cement, Ws $= (W_2 – W_1)$
$= 16g$
Weight of kerosene filling the voids $= (W_3 – W_2)$ $= 74.8g$
Weight of kerosene filling the density bottle
$= (W_4 – W_1)$
$= 80g$
Weight of equal volume of kerosene,
$Wm_w = (W_4 – W_1) - (W_3 – W_2)$
$= 5.2g$
Specific gravity, G $= W_s / W_w$

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= 15/5.2
Specific gravity, G = 2.85

3.8 FINE AGGREGATE

Fine aggregate shall consist of natural sand or manufactured sand or a combination. Fine aggregates should be selected so as to reduce the water demand hence rounded particles are thus preferred to crush rock fines where possible. The finest fractions of fine aggregate are helpful to prevent segregation.

The river sand conforming to zone II as per IS 383-1987 was used. For the fine aggregate river sand conforming to IS 383-1987 was used. It passes through 2.36mm IS sieve with a specific gravity of 2.67 and this was come under zone.

3.9TESTS FOR FINE AGGREGATE

3.9.1 FINENESS MODULUS

Fineness modulus is the weighted average size of a sieve on which the material is retained and it indicates fineness of the fine aggregate it does not indicate the grading i.e. particle size distribution of the fine aggregate.

The fineness modulus of fine aggregate is calculated by following formula.

Fineness modulus = Sum of cumulative percentage /100

3.9.2 SPECIFIC GRAVITY

The absolute specific gravity refers to the volume of the solid material excluding all pores, and can, therefore be defined as the ratio of the weight of the solid to its volume less pores.

Thus in order to eliminate the effect of totally enclosed impermeable pores, the material has to be pulverized sand the test is both laborious and sensitive, and further more it is not normally required in concrete technology works. Hence what we actually find is the apparent specific gravity, which is the ratio of the weight of the aggregate dried in oven, at approximately 100’c for 24 hours to the weight of water occupying a volume equal to that of the solid including the impermeable pores. The specific gravity of sand is found to be more than that of quarry dust.

Calculation of specific gravity

Specific gravity can be

Cal. by using this formula $= \dfrac{(W_2 - W_1)}{(W_2-W_1) - (W_3-W_4)}$

Where ,

W_1 = Empty weight of pycnometer.

W_2 = Weight of pycnometer + oven dry soil

W_3 = Weight of pycnometer + oven dry soil+ water

W_4 = Weight of pycnometer + water

TABLE: 3.2 SPECIFIC GRAVITY OF FINE AGGREGATE

Sample	**I**	**II**	**III**
Empty wt of pycnometer (W_1)	635g	635g	635g
Wt of pycnometer +sand (W_2)	835g	835g	835g
Wt of pycnometer +sand+ water(W_3)	1655g	1645 g	1645g
Wt of pycnometer +water(W_4)	1525g	1520 g	1520g
Specific gravity of sand	2.73	2.7	2.7

WATER ABSORPTION OF FINE AGGREGATE
CALCULATIONS:

Weight of dry sample of fine aggregate, W1=1000g = 1000 g
Weight of saturated specimen, W2=45g = 45 g
Weight of water absorbed,

W3 = (W2-W1) = 45 g

Percentage of water absorption= (W2-W1 / W1) x100
=4.5%

= 4.5%

3.9.3 SIEVE ANALYSIS

Sieve analysis is carried out to determine the fineness modulus and drawing the grading curve of fine aggregates by sieving as per is code. The sieve analysis is carried out for sand, crushed sand as available.

3.10 COARSE AGGREGATE

A maximum size of 20mm is usually selected as coarse aggregates used in concrete. Aggregates should be strong and free of internal flaws or fractures. Aggregates should be strong and free of internal flaws or fractures. Aggregates of high intrinsic strength are generally preferred. Granites, basalt, lime stones and sandstones are being successfully used in concrete.

3.10.1 TEST FOR COARSE AGGREGATE

SPECIFIC GRAVITY

Indian standard specification IS: 2386(PART III) of 1963 gives various procedures to find out the specific gravity of different size of aggregates. A sample of aggregates nit less than 1kg is taken. It is thoroughly washed to remove the finer particle and dust adhering to the aggregates.They are kept in water for a period of 24 hours afterwards. The basket and aggregates are then jolted and weighed [weight a1] in water and allowed to drain for a few minutes and then the aggregates is taken out from the basket and placed on dry cloth and surface is gently dried with the cloth. The aggregates is transferred to the second dry cloth and further dried. The empty basket again immersed in water, jolted 25times and weighted in water [weight a2].

The aggregate is exposed to atmosphere away from direct sun light for not less than 10monutes until it appears completely surface dry. Then the aggregates are weighted in air [weight b]. Then aggregates is kept in the oven at the temperatures of 100 to 100c and maintained at this temperature for 24 hours. It is then cooled of the air tight container and weighed as [weight c].

Specific gravity = (C/B-A)

Apparent Specific Gravity = (C/C-A)

Water Absorption = ((B-C) X 100 / C)

Where,

A= weight in g of the saturated aggregate in water (A1-A2),

B = weight in g of the saturated surface–dry aggregate in air and

C = weight in g of oven dried aggregate in air.

3.10.2 SIEVE ANALYSIS FOR COARSE AGGREGATE

TABLE NO: 3.4 SIEVE ANALYSIS FOR COARSE AGGREGATE

S.NO	Sieve size (mm)	Weight retained(g)	Mass retained(g)	Cumulative % retained	Cumulative % finer
01.	26.5	0	0	0	0
02.	20	340	34	34	66
03.	11.2	650	65	99	1
04.	10	0	0	99	1
05	6.7	10	1	1	0

.					
06.	4.75	0	0	100	0
07.	Pan	0	0	100	0

3.10.3: WATER ABSORPTION OF COARSE AGGREGATE

CALCULATIONS:

Weight of dry sample of coarse aggregate,
W1 = 1000 g
Weight of saturated specimen, W2 = 1010 g
Weight of water absorbed, W3 = (W2-W1)
=(1004-1000) = 10 g
Percentage of water absorption, = (W2-W1/W1) x100
= 1 %

3.11 SHEET GLASS POWDER

3.11.1SPECIFIC GRAVITY

The absolute specific gravity refers to the volume of the solid material excluding all pores, and can, therefore be defined as the ratio of the weight of the solid to its volume less pores.Thus in order to eliminate the effect of totally enclosed impermeable pores, the material has to be pulverized sand the test is both laborious and sensitive, and further more it is not normally required in concrete technology works. Hence what we actually find is the apparent specific gravity, which is the ratio of the weight of the waste sheet glass powder to the weight of water occupying a volume equal to that of the solid including the impermeable pores.

Calculation of specific gravity

Specific gravity can be
Cal by using this formula $= \dfrac{(W2-W1)}{(W2-W1)-(W3-W4)}$

Specific gravity of fine aggregate, G = 2.45

3.11.2SIEVE ANALYSIS

Sieve analysis is carried out to determine the fineness modulus and drawing the grading curve of fine aggregates by sieving as per is code. The sieve analysis is carried out for sand, crushed sand as available.

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TABLE:-3.11 SIEVE ANALYSIS TEST ON SHEET GLASS POWDER

Sieve size (mm)	**Mass Retained (Kg)**	**Percentage Retained**	**Cumulative Percentage Retained**	**Cumulative Percentage finer**
1.18	0	0	0	0
600(Micron)	0	0	0	0
300(Micron)	0.885	88.5	88.5	11.5
75(Micron)	0.115	11.5	100	0
Pan	0	0	100	0

4.0 MIX DESIGN FOR M_{25} GRADE CONCRETE
STEP1: DESIGN STIPULATIONS FOR PROPORTIONING

Grade designation : M_{25}
Type of cement : OPC 53 Grade
Maximum nominal size of aggregate: 20 mm.
Minimum cement content : 340kg/m^3
Maximum cement content : 450 kg/m^3
Maximum water content ratio : 0.43
Workability :100mm
Exposure condition : mild
Degree of supervision : Good
Type of aggregate :Crushed Angular Aggregate

STEP 2: TEST DATA FOR MATERIALS
Cement used OPC 53 grade conforming to IS 8112

SPECIFIC GRAVITY
1. Cement : 2.85
2. Fine aggregate : 2.7
3. Coarse aggregate : 2.7

WATER ABSORPTION
1. Fine aggregate : 1 %

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2. Coarse aggregate : 4.5 %

FREE MOISTURE

1. Fine aggregate : Nil
2. Coarse aggregate : Nil

SIEVE ANALYSIS

Fine aggregate : Conforming to zone-II of IS-383
Coarse aggregate : Conforming of table2 of IS-383.

STEP 3: TARGET STRENGTH FOR MIX PROPORTIONING

Refer clause 2.2 in IS 10262-1982

$F_{ck}' = F_{ck} + 1.65\ s$

Where

,$\overline{F}_{ck}$= Target average compressive strength at 28 days.
Fck= Characteristic compressive strength at 28 days.
S = Standard deviation(from IS-456-2000)
= 5.3N/mm²
Fck'= 35 + (1.65 + 5.3)
Fck' = 33.74 N/mm².

STEP 4: SELECTION OF WATER CEMENT RATIO

(From Fig 1in IS-10262-1892)
Maximum water cement ratio =0.43
Based on experience adept water cement ratio = 0.4
0.4 < 0.43 **Hence ok.**

STEP 5: SELECTION OF WATER CONTENT

(From table 4 of IS-10262-1982)
Maximum water content =186 kg
Estimate water content for 100 mm slump
(25-50mm slump =186kg add 25 mm =3 % increase so,100 mm =3%) =186 + (3/100×186)=191.6 kg.

STEP 6: CALCULATION FOR CEMENT CONTENT

W/c ratio = 0.43
Cement content =191.6/0.43
=445.58 kg/m³
450 kg/m³ < 445.58 kg /m³
Hence ok.

STEP 7: PROPORTION OF VOLUME OF COARSE AGGREGATE& FINE AGGREGATE CONTENT

From table 3 volume of coarse aggregate corresponding to 20 mm size aggregate & fine aggregate for w/c of 0.40 =0.60

In the present case w/c =0.43. The volume of coarse aggregate is required to be increased to decrease the fine aggregate content .as w/c ratio is lower by 0.13, increase the coarse aggregate volume by 0.02 (at the rate of (-/+) 0.01 for every (+/-) 0.05 change in water cement ratio).

STEP 8: MIX CALCULATIONS

FINE AGGREGATE:

Refer clause 5.5.1 in IS 10262-1982

V= (W+ (c/Sc) + ((1/p) (fa/Sfa))x1/1000

V=1m^3

Entrapped Air = 2 = 100-2

= 98%

V=0.98

0.98= (191.6 + (445.58/2.85) + ((1/0.301) (fa/2.7)) 1/1000

Fa=513.87 kg/m^3.

COARSE AGGREGATE:

Refer clause 5.5.1 in IS 10262-1982

V= (W+ (c/Sc) + ((1/1-p) (ca/Sca)) x 1/1000

0.98= (191.6 + (445.58/2.85) + ((1/1-0.301) (ca/2.7)) 1/1000

Ca= 1192.56 kg/m^3.

STEP 9: MIX PROPORTION

TABLE:-4.1 MIX PROPORTION

Water	Cement	Fine Aggregate	Coarse Aggregate
191.6	445.58	513.87	1192.56
0.43	1	1.15	2.68

STEP 10: M_{25}RATIO

TABLE:-5.2 MIX RATIO

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Cement	Fine aggregate	Coarse Aggregate	W/c ratio
1	1.15	2.68	0.43

5.0 TESTING

5.1 GENERAL

The testing program consists of, the cubes & cylinder were tested for their compressive strength this includes the conventional specimens.

5.2 CASTED SPECIMENS

For this experiment the specimens used for the test were cubes and cylinder

5.3 CASTING OF SPECIMENS

Hand mixing was used for conventional handling of with SBW, SBA, QD, Sand and cement were mixed dry and kept separately. Then coarse aggregate, SBW and dry mix of cement, SBA, sand & QD were kept in three layers and approximate amount of water was sprinkle on each layer and mixed thoroughly.

FIGURE: -5.1CASTING OF SPECIMENS

AGE OF TESTING

The tests were conducted at 28 days. A total of specimens were casted for testing.

54Cube specimens for compressive strength.

15 Cylindrical specimens for compressive strength.

5.4 TESTS ON HARDENED CONCRETE

5.4.1COMPRESSION TEST

The compressive strength of concrete is defined as the load which causes the failure of specimen, per unit area of cross-section in uniaxial compression under given rate of loading. The strength of concrete is expressed as N/mm^2.The compressive strength at 7 days and 28 days after casting is taken as a criterion for specifying the quality of concrete. This is termed as grade of concrete. IS 456 – 2000 stipulates the use of 150 mm cubes.

TABLE:-6.2 COMPRESSIVESTRENGTH OF CUBES FOR M25 GRADE CONCRETE

Age of Curing	**Cement Concrete**	**% of Sheet Glass PowderAdded**			
Proportions	**0**	**10%**	**20%**	**30%**	**40%**
7 Days	21.25	23.80	24.22	22.78	19.18
	21.52	23.79	24.09	22.69	19.22
	21.72	23.98	24.00	22.80	19.20
Average	**21.52**	**23.89**	**24.12**	**22.80**	**19.21**
14 Days	25.18	23.68	30.00	26.92	22.48
	25.28	24.00	29.98	27.00	22.50
	25.30	23.90	31.00	26.98	22.46
Average	**25.26**	**23.89**	**30.07**	**26.98**	**22.47**
28 Days	28.98	33.76	35.98	31.18	25.68
	29.00	33.92	36.06	31.20	25.75
	29.08	33.88	36.03	31.16	25.70
Average	**29.01**	**33.89**	**36.02**	**31.16**	**25.72**

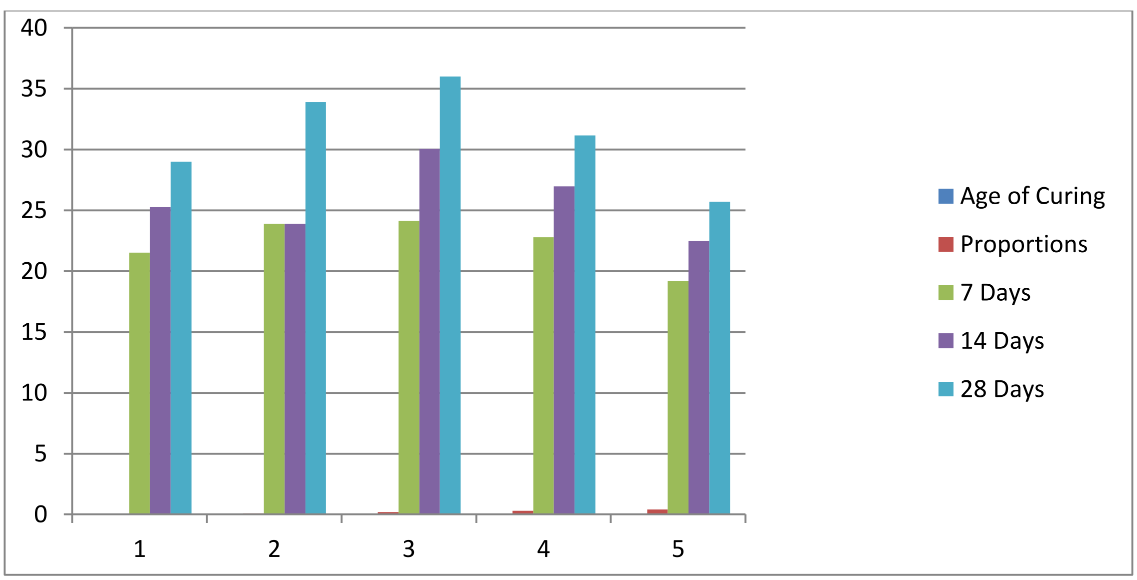

Fig 5.2 COMPRESSIVE STRENGTH OF M25 GRADE OF CONCRETE

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$F = P/A$ N/mm^2

Where,

P = load at which specimen fails in Newton.

A = Area over which the load is applied in mm^2

F= Compressive stress in N / mm^2

5.4.2TENSILE STRENGTH FOR CYLINDER

The cylindrical specimens were tested for tensile strength at an age of 7 and 28 days. Two specimens were tested for each percentage at 7 and 28 days and average of three was taken.The load was applied without shock and increased continuously until the resistances of the specimen to the increasing load broke down and no greater load can be sustained. The maximum load applied was then recorded. Any unusual type of failure was noted. According to IS-5816-1999- Tensile Strength of Concrete - Method of Test, the tensile strength was determined.

The size of the specimen is 10cm diameter and 20cm height.

Tensile strength = $2P/\pi LD$

Where,

P =Load on the cylinder in N.

L =Length of the cylinder in mm.

D =Diameter of the cylinder in mm.

TABLE:-6.3 TENSILE STRENGTH OFCYLINDER FOR M25 GRADE CONCRETE

Age of Curing	**Cement Concrete**	**% of Sheet Glass Powder Added**			
Proportions	**0**	**10%**	**20%**	**30%**	**40%**
7 Days	**2.14**	**2.09**	**2.01**	**1.82**	**1.6**
14 Days	**2.37**	**2.295**	**2.155**	**1.985**	**1.75**
28 Days	**2.6**	**2.5**	**2.3**	**2.15**	**1.9**

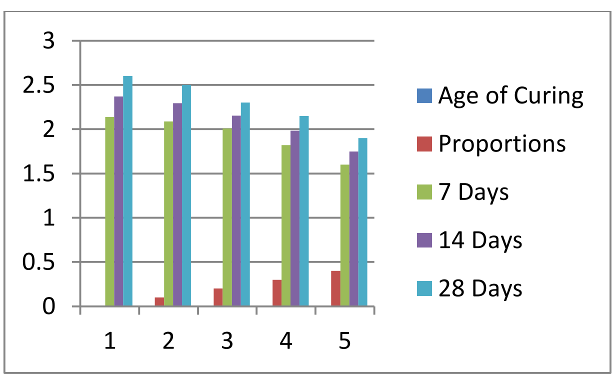

Fig 5.3 TENSILE STRENGTH OF CONCRETE

5.5 RESULTS AND DISCUSSION

Workability of the concrete increased as the percentages of SGP replacement increased, but it later decreases as the curing day's increases because of alkali silica reaction. The density of the concrete 2531 kg/m^3 at 0% replacement of SGP decreased but at 100% the density increased to 2689 kg/m^3 for cube at 28 days curing.

CONCLUSION

From the tests conducted on SGP replaced in fine aggregate for concrete as presented in various sections, the following conclusions are made:The SGP is suitable for use in concrete making. The fineness modulus, specific gravity, moisture content, un compacted bulk density and compacted bulk density at 10% Sheet glass powder (SGP) were found to be 2.25,3.27,2.57%,1510kg/m3 and 1620kg/m3For a given mix, the water requirement decreases as the SGP content increases. The compressive strength of cubes and cylinders of the concrete for all mix increases as the % of SGP increases but decreases as the age of curing increases due to alkali silica reaction.

The Tensile strength of cubes and cylinders of the concrete for all mix increases than that of conventional concrete age of curing and decreases as the SGP content increases. The Flexural strength of the beam of concrete for all mix increases with age of curing and decreases as the SGP content increases. 100% replacement of SGP in concrete showed better results than that of conventional concrete at 28days and 45 days curing but later it started to decrease its strength because of its alkali silica reactions.

The density of SGP concrete is more that of conventional concrete. SGP is available in significant quantities as a waste and can be utilized for making concrete. This will go a long way to reduce the quantity of waste in our environment. The optimum replacement level in fine aggregate with SGP is 10%.

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