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Experimental Study on Concrete Using Cement With Glass Powder

T.Subramani[1], S.B.Sankar Ram[2]
[1]*Professor & Dean, Department of Civil Engineering, VMKV Engg. College, Vinayaka Missions University, Salem, India*
[2]*PG Student of Structural Engineering, Department of Civil Engineering, VMKV Engg. College, Vinayaka Missions University, Salem, India*

Abstract: - Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of green house gases, such as CO2, to the atmosphere. Among the greenhouse gases, CO2 contributes about 65% of global warming. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. Glass is used in many forms in day-to-day life. It has limited life span and after use it is either stock piled or sent to landfills. Since glass is non-biodegradable, landfills do not provide an environment friendly solution. Hence, there is strong need to utilize waste glasses. Many efforts have been made to use waste glass in concrete industry as a replacement of coarse aggregate, fine aggregate and cement. Its performance as a coarse aggregate replacement has been found to be non-satisfactory because of strength regression and expansion due to alkali-silica reaction. The research shows that there is strength loss due to fine aggregate substitution also. Efforts have been made in the concrete industry to use waste glass as partial replacement of coarse or fine aggregates and cement. In this study, finely powdered waste glasses are used as a partial replacement of cement in concrete and compared it with conventional concrete. This work examines the possibility of using Glass powder as a partial replacement of cement for new concrete. Glass powder was partially replaced as 10%, 20%, 30% and 40% and tested for its compressive, Tensile and flexural strength up to 28 days of age and were compared with those of conventional concrete; from the results obtained, it is found that glass powder can be used as cement replacement material up to particle size less than 75μm to prevent alkali silica reaction.

Keywords: *Experimental Study, Concrete, Using Cement, Glass Powder*

I INTRODUCTION

Concrete is a blend of cement, sand, coarse aggregate and water. The key factor that adds value to concrete is that it can be designed to withstand harshest environments significant role. Today global warming and environmental devastation have become manifest harms in recent years, concern about environmental issues, and a changeover from the mass-waste, mass-consumption, mass-production society of the past to a zero-emanation society is now viewed as significant. Normally glass does not harm the environment in any way because it does not give off pollutants, but it can harm humans as well as animals, if not dealt carefully and it is less friendly to environment because it is non-biodegradable. Thus, the development of new technologies has been required. The term glass contains several chemical diversities including soda-lime silicate glass, alkali-silicate glass and boro-silicate glass. To date, these types of glasses glass powder have been widely used in cement and aggregate mixture as pozzolana for civil works. The introduction of waste glass in cement will increase the alkali content in the cement. It also help in bricks and ceramic manufacture and it preserves raw materials, decreases energy consumption and volume of waste sent to landfill. As useful recycled materials, glasses and glass powder are mainly used in fields related to civil engineering, for example, in cement, as pozzolana(supplementary cementitious materials), and coarse aggregate. Their recycling ratio is close to 100%, and it is also used in concrete without adverse effects in concrete durability. Therefore, it is considered ideal for recycling Recently, Glasses and its powder has been used as a construction material to decrease environmental problems. The coarse and fine glass aggregates could cause ASR(alkali-silica reaction) in concrete , but the glass powder could suppress their ASR tendency, an effect similar to supplementary cementations materials (SCMs). Therefore, glass is used as a replacement of supplementary cementitious materials.

II MATERIALS USED

In this project waste materials were utilized to produce building bricks. The following materials were used in this investigation

2.1 Cement

Cement is one of the binding materials in this project. Cement is the important building material in today's construction world 53 grade Ordinary Portland Cement (OPC) conforming to IS: 8112-1989. Table 3.1 gives the properties of cement used.

Table 2.1: Properties of cement

Description of test	**Test results obtained**	**Requirements of IS: 8112 1989**
Initial setting time	65 minutes	Min. 30minutes
Final setting time	270 minutes	Max. 600minutes
Fineness (specific surface by Blaine's air permeability test)	412.92 m^2/kg	Min. 225 m^2/kg

Figure. 2.1 Cement

Ordinary Portland cement, 53Grade conforming to IS: 269 – 1976.Ordinary Portland cement, 53Gradewas used for casting all the Specimens. Different types of cement have different water requirements to produce pastes of standard consistence. Different types of cement also will produce concrete have a different rates of strength development. The choice of brand and type of cement is the most important to produce a good quality of concrete. The type of cement affects the rate of hydration, so that the strengths at early ages can be considerably influenced by the particular cement used. It is also important to ensure compatibility of the chemical and mineral admixtures with cement.

2.2 Fine Aggregate

Locally available river sand conforming to Grading zone II of IS: 383 –1970. Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens.(Fig.2.2 and Table 2.2)

Table 2.2 Property Of Fine Aggregate

S.NO	**PROPERTIES**	**VALUE**
1	Specific Gravity	2.65
2	Fineness Modulus	2.25
3	Water absorption	1.5%

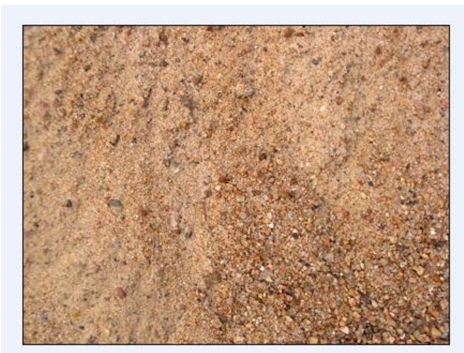

Fig 2.2 Fine Aggregate

Locally available river sand conforming to Grading zone I of IS: 383 –1970.Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens.

2.3 Coarse Aggregate

Fig 2.3 Coarse Aggregate

Table 2.3 Property Of Coarse Aggregate

S.NO	PROPERTIY	VALUES
1	Specific Gravity	2.68
2	Size Of Aggregates	20mm
3	Fineness Modulus	5.96
4	Water absorption	2.0%
5	Impact Test	15.2%
6	Crushing Test	22.5%

Crushed granite aggregate with specific gravity of 2.77 and passing through 4.75 mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability. Locally available crushed blue granite stones conforming to graded aggregate of nominal size 20 mm as per IS: 383 – 1970.Crushed granite aggregate with specific gravity of 2.77 and passing through 4.75 mm sieve and will be used for casting all specimens. Several investigations concluded that maximum size of coarse aggregate should be restricted in strength of the composite. In addition to cement paste – aggregate ratio, aggregate type has a great influence on concrete dimensional stability. (Fig.2.3 & Table 2.3)

2.4 Water

Casting and curing of specimens were done with the potable water that is available in the college premises.

2.5 Glass Powder

Glass powder is finely ground glass. These fine glass particles remind you of talcum powder. Use extreme care when handling this dry powder pigment to prevent breathing the dust particles. Make sure you wear a respiratory mask when working with this powder, preferably one that is NIOSH approved. Check to see that the powder has the same COE as your other fusing glass. This will ensure that your projects will not have built up stress. Powder glass is so versatile and useful. It can be purchased in every color of the rainbow. Glass is a rigid liquid i.e. super cooled liquid, static, not solid, not a gas but does not change molecularly between melting and solidification in to a desired shape. Glass is one of the most versatile substances on earth used in many applications and in a wide variety of forms. Glass occurs naturally when rock high in silicates melt at high temperature and cool before they can form a crystalline structure. Obsidian or volcanic glass is a well known example of naturally occurring glass. When manufactured by human's the glass is a mixture of silica, sand, lime and other materials. The elements of glass are heated to 9820 Celsius. eat can return the glass to a liquid and workable form, making it easy to reuse and recycle. (Fig.2.4)

Fig 2.4 Glass powder

III MATERIAL CHARACTERISTICS

3.1 CEMENT:

The type of cement used was Portland Pozzalona Cement.

3.1.1specific Gravity

The density bottle was used to determine the specific gravity of cement. The bottle was cleaned and dried. The weight of empty bottle with brass cap and washerW_1 was taken. Then bottle was filled by 200 to 400g of dry cement and weighed as W_2.The bottle was filled with kerosene and stirred thoroughly for removing the entrapped air which was weighed as W_3.It was emptied, cleaned well, filled with kerosene and weighed as W_4.

Specific gravity of Cement (G) = $$\frac{(W_2-W_1)}{(W_2-W_1) - (W_3-W_4)}$$

W_1 = Weight of empty density bottle with brass cap and washer in gm.
W_2 = Mass of the density bottle & cement in gm.
W_3 = Mass of the density bottle, cement & kerosene in gm.
W_4 = Mass of the density bottle filled with kerosene in gm.

3.1.2 Fineness (By Sieve Analysis)

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence faster development of strength. 100 grams of cement was taken on a standard IS SieveNo.9(90 microns). The air-set lumps in the sample were broken with fingers. The sample was continuously sieved giving circular and vertical motion for 15 minutes. The residue left on the sieve was weighed.

3.1.3 Consistency

The objective of conducting this test is to find out the amount of water to be added to the cement to get a paste of normal consistency. 500 grams of cement was taken and made into a paste with a weighed quantity of water (% by weight of cement) for the first trial. The paste was prepared in a standard manner and filled into the vicat mould plunger, 10mm diameter, 50mm long and was attached and brought down to touch the surface of the paste in the test block and quickly released allowing it to sink into the paste by its own weight. The depth of penetration of the plunger was noted. Similarly trials were conducted with higher water cement ratios till such time the plunger penetrates for a depth of 33-35mm from the top. That particular percentage of water which allows the plunger to penetrate only to a depth of 33-35mm from the top is known as the percentage of water required to produce a cement paste of standard consistency.

3.1.4 Initial Setting Time

The needle of the Vicat apparatus was lowed gently and brought in contact with the surface of the test block and quickly released. It was allowed to penetrate into the test block. In the beginning, the needle completely pierced through the test block. But after sometime when the paste starts losing its plasticity, the needle penetrated only to a depth of 33-35mm from the top. The period elapsing between the time when water is added to the cement and the time at which the needle penetrates the test block to a depth equal to 33-35mm from the top was taken as the initial setting time.

3.2 Coarse Aggregate

20mm down size aggregate was used.

3.2.1 Specific Gravity

A pycnometer was used to find out the specific gravity of coarse aggregate. The empty dry pycnometer was weighed and taken as W_1. Then the pycnometer is filled with 2/3 of coarse aggregate and it was weighed as W_2. Then the pycnometer was filled with part of coarse aggregate and water and it weighed as W_3. The pycnometer was filled up to the top of the bottle with water and weighed it as W_4.

Specific gravity of Cement (G) = $$\frac{(W_2-W_1)}{(W_2-W_1) - (W_3-W_4)}$$

- W_1 = Mass of empty pycnometer in gm.
- W_2 = Mass of pycnometer& coarse aggregate in gm.

- W_3 = Mass of the pycnometer, coarse aggregate & water in gm.
- W_4 = Mass of the pycnometer filled with water in gm.

3.2.2 Bulk Density

Bulk density is the weight of a material in a given volume. It is expressed in Kg/m^3.A cylindrical measure of nominal diameter 250mm and height 300mm was used. The cylinder has the capacity of 1.5 liters with the thickness of 4mm. The cylindrical measure was filled about 1/3 each time with thoroughly mixed aggregate and tampered with 25 strokes. The measure was carefully struck off level using tamping rod as straight edge. The net weight of aggregate in the measure was determined. Bulk density was calculated as follows.

Bulk density = (Net weight of coarse aggregate in Kg)/ (Volume)

3.2.3 Surface Moisture

100g of coarse aggregate was taken and their weight was determined, say W_1. The sample was then kept in the oven for 24 hours. It was then taken out and the dry weight is determined, says W_2. The difference between W_1 and W_2 gives the surface moisture of the sample.

3.2.4 Water Absorption

100g of nominal coarse aggregate was taken and their weight was determined, say W_1. The sample was then immersed in water for 24 hours. It was then taken out, drained and its weight was determined, says W_2. The difference between W_1 and W_2 gives the water absorption of the sample.

3.2.5 Fineness Modulus

The sample was brought to an air-dry condition by drying at room temperature. The required quantity of the sample was taken (3Kg). Sieving was done for 10 minutes. The material retained on each sieve after shaking, represents the fraction of the aggregate coarser then the sieve considered and finer than the sieve above. The weight of aggregate retained in each sieve was measured and converted to a total sample. Fineness modulus was determined as the ratio of summation of cumulative percentage weight retained (F) to 100.

3.3 Properties Of Water

Water used for mixing and curing shall be clean and free from injurious amounts of Oils, Acids, Alkalis, Salts, Sugar, Organic materials Potable water is generally considered satisfactory for mixing concrete Mixing and curing with sea water shall not be permitted. The pH value shall not be less than 6.

3.4 Properties Of Glass Powder

Properties Of Glass Powder given in Table 3.1 and Chemical composition of glass powder shown in Fig.3.1

Table 3.1 Properties Of Glass Powder

Composition (% by mass)/ property	Glass powder
Silica (SiO2)	72.5
Alumina (Al2O3)	0.4
Iron oxide (Fe2O3)	0.2
Calcium oxide (CaO)	9.7
Magnesium oxide (MgO)	3.3
Sodium oxide (Na2O)	13.7
Potassium oxide (K2O)	0.1
Sulphur trioxide (SO3)	-
Loss of ignition	0.36
Fineness % passing (sieve size)	80 (45 µm)
Unit weight,Kg/m3	2579
Specific gravity	2.58

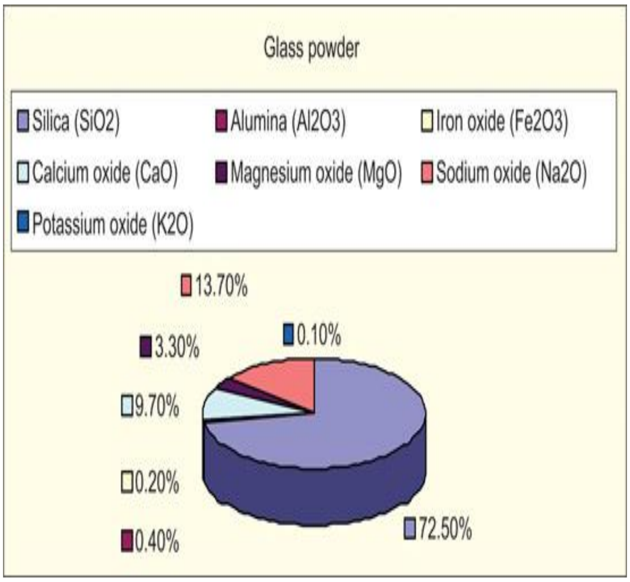

Figure 2.5 Chemical composition of glass powder

3.5 Fresh Concrete Properties
3.5.1. Workability

With the addition of furnace slag, the slump loss with time is directly proportional to increase in the slag content due to the introduction of large surface area in the concrete mix by its addition. Although the slump decreases, the mix remains highly cohesive.

3.5.2 Segregation And Bleeding

Furnace slag reduces bleeding significantly because the free water is consumed in wetting of the large surface area of the furnace slag and hence the free water left in the mix for bleeding also decreases. Furnace slag also blocks the pores in the fresh concrete so water within the concrete is not allowed to come to the surface.

3.5.3 Slump Test

Fresh concrete when unsupported will flow to the sides and sinking in height will take place. This vertical settlement is known as slump.(Fig.3.2 and Table 3.2)

- The workability (ease of mixing, transporting, placing and compaction) of concrete depends on wetness of concrete (consistency) i.e., water content as well as proportions of fine aggregate to coarse aggregate and aggregate to cement ratio.
- The slump test which is a field test is only an approximate measure of consistency defining ranges of consistency for most practical works. This test is performed by filling fresh concrete in the mould and measure the settlement i.e., slump.

Table 3.2 Slump Result

Ratio	Slump value
Conventional Concrete	
Control mix	25.5mm
Slag Concrete M25	
Ratio I	25.65mm
Ratio II	26. 20mm
Ratio III	26.50 mm

Figure. 3.2 Slump Test

3.6 Hardened Concrete Properties
3.6.1 Compression Test On Concrete Cubes

The determination of the compressive strength of concrete is very important because the compressive strength is the criterion of its quality. Other strength is generally prescribed in terms of compressive strength. The strength is expressed in N/mm^2. This method is applicable to the making of preliminary compression tests to ascertain the suitability of the available materials or to determine suitable mix proportions. The concrete to be tested should not have the nominal maximum size of aggregate more than 20mm test specimens are either 15cm cubes or 15cm diameter used. At least three specimens should be made available for testing. Where every cylinder is used for compressive strength results the cube strength can be calculated as under.Minimum cylinder compressive strength = 0.8 x compressive strength cube (10 cm x 10 cm) The concrete specimens are generally tested at ages 7 days and 28 days.

3.6.2 Split Tensile Test On Cylinder

Concrete is strong in compression but weak in tension. Tension stresses are likely to develop in concrete due to drying shrinkage, rusting of reinforcement, temperature gradient etc.

In concrete road slab this tensile stresses are developed due to wheel loaded and volume changes in concrete are available to determine this. Split test is one of the indirect methods available to find out the tensile strength.

3.6.3 Flexural Test On Beams

It is the ability of a beam or slab to resist failure in bending. It is measured by loading un-reinforced 6x6 inch concrete beams with a span three times the depth (usually 18 in.). The flexural strength is expressed as "Modulus of Rupture" (MR) in psi. Flexural MR is about 12 to 20 percent of compressive strength.

IV MIX DESIGN

4.1 Definition

Mix design is the process of selecting suitable ingredient if concrete and determines their relative proportions with the object of certain minimum strength and durability as economically as possible.

4.2 Objective Of Mix Design

The objective of concrete mix design as follows.

- The first objective is to achieve the stipulated minimum strength.
- The second objective is to make the concrete in the most economical Manner. Cost wise all concrete's depends primarily on two factors, namely cost of material and cost of labour. Labor cost, by way of formwork, batching, mixing, transporting and curing is namely same for good concrete.

4.3 Factors To Be Considered In Mix Design

1. Grade of concrete
2. Type of cement
3. Type & size of aggregate
4. Type of mixing & curing
5. Water /cement ratio
6. Degree of workability
7. Density of concrete
8. Air content

V TESTING PROCEDURE

5.1 General Procedure

Within the experimental research program concerning the development of mechanical properties of a partially replacement of cement by flyash, partially replacement of sand by bottom ash and glass is used reference concrete of grade M25 (REF) was considered with the following composition, accordingly. The w/c-ratio is 0.43. Coarse aggregates were chosen, having a particle size mainly varying between 2 mm and 20 mm. An intensive experimental program is performed to study the effect of internal curing on different types of concrete properties: (i) fresh properties (slump and density); (ii) mechanical properties (compressive strength, flexural strength, splitting tensile strength).

5.2 Compressive Strength Test

When a specimen of material is loaded in such a way that it extends it is said to be in tension. On the other hand if the material compresses and shortens it is said to be in compression.

On an atomic level, the molecules or atoms are forced apart when in tension whereas in compression they are forced together. Since atoms in solids always try to find an equilibrium position, and distance between other atoms, forces arise throughout the entire material which oppose both tension or compression. The phenomena prevailing on an atomic level are therefore similar.The "strain" is the relative change in length under applied stress; positive strain characterises an object under tension load which tends to lengthen it, and a compressive stress that shortens an object gives negative strain. Tension tends to pull small sideways deflections back into alignment, while compression tends to amplify such deflection into buckling.Compressive strength is measured on materials, components, and structures. By definition, the ultimate compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely. The compressive strength is usually obtained experimentally by means of a compressive test. The apparatus used for this experiment is the same as that used in a tensile test. However, rather than applying a uniaxial tensile load, a uniaxial compressive load is applied. As can be imagined, the specimen (usually cylindrical) is shortened as well as spread laterally. In the study of strength of materials, the compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structuresAt the time of testing, each specimen must keep in compressive testing machine. The maximum load at the breakage of concrete block will be noted. From the noted values, the compressive strength may calculated by using below formula.(Fig.5.1)

Compressive Strength = Load / Area

Size of the test specimen=150mm x 150mm x 150mm

Fig 5.1 Compression Test

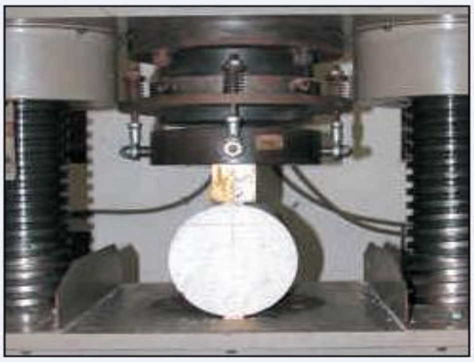

Fig 5.2 Split Tensile Test

5.3 Split Tensile Test

• The size of cylinders 300 mm length and 150 mm diameter are placed in the machine such that load is applied on the opposite side of the cubes are casted. Align carefully and load is applied, till the specimen breaks. The formula used for calculation. (Fig.5.2)

Split tensile strength = 2P/ µdl

5.4 Flexural Strength Test

During the testing, the beam specimens of size 7000mmx150mmx150mm were used. Specimens were dried in open air after 7 days of curing and subjected to flexural strength test under flexural testing assembly. Apply the load at a rate that constantly increases the maximum stress until rupture occurs. The fracture indicates in the tension surface within the middle third of span length.

VI TEST RESULTS

6.1 Ratios For Concrete (Extra Ingredients)
Various Percentange Of Glass Powder

RATIO –I
Glass powder – 10 % by replacement of Cement
RATIO - II
Glass powder – 20 % by replacement of Cement
RATIO - III
Glass powder – 30 % by replacement of Cement
RATIO - IV
Glass powder – 40 % by replacement of Cement

6.2 Compressive Strength Of Concrete

The Table 6.1,6,2 & 6.3 shows the strength gain at various percentages of glass powder replacement at 7, 14 & 28th day. It can be seen clearly that there a reduction in the strength at the 10% replacement. Waste glass when ground to a very fine powder, SiO_2 react chemically with alkalis in cement and form cementitious product that help contribute to the strength development. Also it may be due to the glass powder effectively filling the voids and giving rise to a dense concrete. When comparing the strength gain with the cement mortar strength gain it can be seen that there is increment of strength even at 10% glass powder replacement. This must be due to the dilution effect takes over and the strength starts to drop . The presents of excess glass powder without necessary calcium to react, forms weak pockets in the concrete that reduces the concrete strength, this happens due to alkali silicate reaction

Table 6.1 Compressive Test on Cube for 7 days

Control Mix	Compressive Strength In N/Mm^2 7 Days				
	Cc (0%)	Various % Of Glass Powder			
		10 %	20 %	30 %	40%
M25	8.23	9.20	9.03	8.96	8.52

Table 6.2 Compressive Test On Cube For 14 Days

Control Mix	Compressive Strength In N/Mm^2 14 Days				
	Cc (0%)	Various % Of Glass Powder			
		10 %	20%	30%	40%
M 25	19.76	20.2	19.6	19.14	18.8

Table 6.3 Compressive Test On Cube For 28 days

Control Mix	Compressive Strength In N/Mm^2 28 Days				
	Cc (0%)	Various % Of Glass Powder			
		10%	20%	30%	40%
M25	23.6	23.95	22.6	21.4	20.9

6.3 Split Tensile Strength Of Concrete

The Table 6.4, Table 6.5 and Table 6.6 Shows The Split Tensile Test On Cylinder For 7 Days, 14 Days & 28 Days of glass powder replacement at 28th day. It can be seen clearly that there a reduction in the strength at the 40 % replacement. The split tensile strength is improvement is marginal compared to the compressive strength increase.

Table 6.4 Split Tensile Test On Cylinder for 7 days

Control Mix	Split tensile Strength in N/mm^2 7 DAYS				
	CC (0%)	Various % of glass powder			
		10%	20%	30%	40%
M25	1.98	2.26	2.15	2.08	1.84

Table 6.5 Split Tensile Test On Cylinder for 14 days

Control Mix	Split tensile Strength in N/mm^2 14 days				
	CC (0%)	Various % of glass powder			
		10%	20%	30%	40%
M25	2.35	2.67	2.54	2.32	2.14

Table 6.6 Split Tensile Test On Cylinder for 28 days

Control Mix	Split tensile Strength in N/mm^2 28 days				
	CC (0%)	Various % of glass powder			
		10%	20%	30%	40%
M25	3.04	3.28	3.02	2.98	2.84

6.4 Flexural Strength Of Concrete

The Table 6.7, Table 6.8 and Table 6.9 Shows flexural strength improvement at various percentages of glass powder replacement For 7 Days, 14 Days & 28 Days It can be seen clearly that there a reduction in the strength at the 40% replacement here also. The flexural strength improves considerably at 10 % replacement which is about 43 % compared to the control specimen.

Table 6.7 Flexural Test On Beam For 7 days

Control Mix	Flexural Strength In N/mm^2 7 DAYS				
	CC (0%)	Various % of glass powder			
		10%	20%	30%	40%
M25	5.2	5.64	5.42	5.36	5.18

Table 6.8 Flexural Test On Beam for 14 days

Control Mix	Flexural Strength In N/mm^2 14 DAYS				
	CC (0%)	Various % of glass powder			
		10 %	20%	30%	40%
M25	6.2	6.42	6.15	6.08	5.94

Table 6.9 Flexural Test On Beam for 28 days

Control Mix	Flexural Strength In N/mm^2 28 DAYS				
	CC (0%)	Various % of glass powder			
		10%	20%	30%	40%
M25	6.8	7.15	7.06	6.95	6.76

VII CONCLUSION

Based on experimental observations, the following conclusions are drawn.
1. The compressive strength of concrete cube up to a replacement proportion of 10% of cement.
2. In case of cement mortar the strength improves up to 15% replacement of cement.
3. There was marginal improvement in the Split tensile strength
4. A considerable improvement in the flexural strength was seen at 10% replacement of cement.
5. It can be concluded form the above result that 10% replacement of cement by glass powder is the best proportion.
6. Alkali-silica reactivity effect is controlled when glass powder with high Na2O is used.
7. Further investigation can be done by using plasticizers to improve the workability and strength. Also durability investigation can be done to see the long term effect of glass powder replacement.

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AUTHOR

Prof. Dr.T.Subramani Working as a Professor and Dean of Civil Engineering in VMKV Engg. College, Vinayaka Missions University, Salem, Tamilnadu, India. Having more than 25 years of Teaching experience in Various Engineering Colleges. He is a Chartered Civil Engineer and Approved Valuer for many banks. Chairman and Member in Board of Studies of Civil Engineering branch. Question paper setter and Valuer for UG and PG Courses of Civil Engineering in number of Universities. Life Fellow in Institution of Engineers (India) and Institution of Valuers. Life member in number of Technical Societies and Educational bodies. Guided more than 400 students in UG projects and 150 students in PG projects. He is a reviewer for number of International Journals and published 102 International Journal Publications and presented more than 25 papers in International Conferences.

S.B.Sankar Ram completed his Diploma in Civil Engineering in 1980 and AMIE in the branch of Civil Engineering in 1997. Now, he is working as a Assistant Executive Engineer in Rural development and Panchayat Raj Department of Government of Tamilnadu. Currently he is doing ME Degree in the branch of Structural Engineering in the Division of Civil Engineering,VMKV Engineering College,Salem.