Study and experimental investigation of partial replacement of waste glass powder as cement in concrete

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Abstract— *Cement Manufacturing industry is one of the Carbon-di-oxide [co_2] emitting sources to the atmosphere . To reduce this emission the .alternative material to be used in the concrete in which the glass is adopted .Glass is an economical and environmental friendly construction material . Glass is non-biodegradable material not suitable for landfill . In this paper partial replacement of cementitious material in concrete in 10%,15%,20%. The replacement of glass powder decreases the unit weight and porosity by decreases in water absorption . The early consumption of alkalis by glass particles helps in reduction of alkali silica reaction . The workability of concrete is determined by using slump test and the crushing strength of aggregate is determined by using impact test .Therefore, the glass powder is used to some extent can replace the cement and contribute the strength development and characteristics of durability .*

Keywords — *Glass , Alkali silica reaction , co_2 , workability .*

I. INTRODUCTION

Concrete is the second largest material widely used . Cement industry emits 7% of green house gases to the atmosphere [5]. One ton of Carbon-di-oxide [co2] is released to the atmosphere for the production of one ton cement in industry. To reduce the emission the alternative materials to be used in concrete . There are many alternatives like rice husk ash , fly ash , egg shell , glass powder . When we are going for an alternative in construction it should be economical and easily available . The construction companies are interested in using recycled materials to give sustainable construction . In recent years there has been an increasing incentive to minimize the environmental effect of construction.industry through programs such as Leadership in Energy and Environment Design [LEED] green building rating system which rewards points for sustainable construction practices [7]. In India 5200 tonnes per day of glass is produced . Glass is an amorphous material produced by melting a mixture of silica, soda ash, $caco_3$ at high temperature followed by cooling where the solidification occurs without crystallization . Glass is non –biodegradable material so, it is not suitable for landfills . It is a inert material which could be recycled and used many times without changing their chemical properties . In glass powder the main concern is alkali silica reaction , the chemical reaction takes place between silica rich glass particle and the alkali in pore solution of concrete [3].The finely grounded glass doesnot contribute to the alkali silica reaction . The waste glass contains high silica [sio_2]-72% . The amorphous silica in glass would dissolve in alkaline environment due to OH^- ions in pore solution of cement paste . Then it reacts with calcium hydroxide [CH] to form secondary calcium silicate hydrate [C-S-H] this process is known as pozzolanic reaction [4] . As glass containing high silica content . It lead to studies on partical use of waste glass as raw material in concrete batching . The finely ground glass powder doesnot add alkali silica reaction [1] .A study on durability of concrete with waste glass powder pointed better performance against chloride permeability in long term but there is concern about alkali silica reaction [2].The finely ground glass powder reacts with alkali and cementitious product for increase the development in strength

II. MATERIALS AND METHODS OF EXPERIMENT

2.1 Cement and water:- Ordinary Portland cement of 43 grade is used to prepare the mix design . Water – cement ratio is 0.40 for this mix design.

- **Test On Cement :**

Initial Setting Time of Cement = 30 min
Specific gravity of cement
W2-w1/(w2-w1)-(w3-w4)0.79 = 3.21
(specific gravity of kerosene = 0.79)

2.2 Fine and coarse aggregate:- clean river sand of maximum size 4.75 mm are used as a fine aggregate and angular aggregate of size between 4.75 mm to 20 mm are used as a coarse aggregate.

Figure -1
Coarse aggregate

Figure -2
Fine aggregate

2.3 Waste glass powder:- Locally available glass is collected and converted into powder form . This material replace the cement in mix proportion . Before adding glass powder in the concrete, it has to be powdered to required size. In this experiment glass powder having particle size less than 90 µm was used.

Figure-3
Cement

Figure-4
Glass powder

2.4 Physical properties of cement, sand and glass powder.

Glass is a hard material that is normally breakable and transparent .It is a type of solid material that will not change its shape unless it being heated to a certain high temperature .It is durable due to strong bond between the molecules and the durability depend on its thickness .Due to its static behavior it doesnot react with other material and not decomposed by most acids. [21].The Physical properties are listed in below table.1.

S.No.	*Properties*	*Specific gravity*	*PH*	*Color*
1	*Cement*	*3.15*	*9*	*Gray*
2	*Sand*	*2.65*	*7*	*Yellow*
3	*Aggregate*	*2.9*	*5.4*	*White*
4	*Glass powder*	*2.6*	*10.25*	*Grayish white*

Table.1.Physical properties of cement, sand and glass powder

2.5 Chemical composition of cement and glass powder.

The raw material used in manufacture of glass is silicon dioxide ,lime stone and soda ash. The primary reason for the popularity of glass is that its property can be varied according to requirements.
Glass can be made as strong as steel or more delicate than paper. Glass powder chemical properties include water resistance, acid resistance, phosphate resistance.The chemical property of glass gives resistance to attach by water , acids, alkalis . Glass containing larger amount of substance such as silicon dioxide (SiO2) ,Aluminium oxide (Al2O3) ,Titanium oxide (TiO2).[5,11]. The chemical properties are listed in below table.2

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S.No.	*Chemical Properties*	*Cement*	*Glass*
1	*Sio_2*	*20.20*	*67.33*
2	*Al_2O_3*	*4.70*	*2.62*
3	*Fe_2O_3*	*3.00*	*1.42*
4	*Tio_2*	*------*	*0.157*
5	*CaO*	*61.90*	*12.45*
6	*MgO*	*2.60*	*2.73*
7	*Na_2O*	*0.19*	*12.05*
8	*K_2O*	*0.82*	*0.638*
9	*ZrO_2*	*------*	*0.019*
10	*ZnO*	*------*	*0.008*
11	*SrO*	*------*	*0.016*
12	*P_2O_5*	*------*	*0.051*
13	*NiO*	*------*	*0.014*
14	*CuO*	*------*	*0.009*
15	*Cr_2O_5*	*------*	*0.022*
16	*So_3*	*3.90*	*------*

Table.2. Chemical composition of cement and glass powder.

2.6 EXPERIMENTAL PROCEDURE .

SLUMP TEST

Clean the internal surface of the mould and apply the oil . Place the mould on a smooth horizontal non porous base plate . Fill the mould with the prepared concrete mix in 4 approximately equal layers . Tamp each layer with 25 strokes with tamping rod in a uniform manner over the cross section of the mould . For the subsequent layers , the tamp should penetrate into the beneath layer . Remove the excess concrete and level it with help of trowel . Clean the mortar between the mould and base plate . Remove the mould from the concrete immediately and slowly in vertical direction . Measure the slump as the difference between the height of the mopuld and that of height point of the specimen being tested.

2.7COMPRESSIVE STRENGTH TEST

The concrete is poured in the mould and tampered properly to avoid the voids . After 24 hours the moulds are removed and test specimens are put in water for curing . The top surface of these specimen should be made even by trowel . These specimens are tested by compression testing machine after 7 days curing or 28 days curing . Load should be applied gradually till the specimens fails .The compressive strength of concrete is found by load at the failure divided by area of specimen

2.8 FLEXURAL STRENGTH TEST

Turn the specimen on it side with respect to its position when moulded , and centre it on the supporting bearing blocks . The load applying block shall be brought in contact with the upper surface with the centre line between the supports . Bring load applying block in full contact with the beam surface by applying a 100lbs . check to ensure that the beam is in uniform contact with the bearing blocks and the load applying block .

III.RESULT AND DISCUSSION

In initial stage , the materials and equipments needed are checked for availability . The concrete mixes according to mix design IS 10262-2009 (M25) and the replacement of cement by glass powder with 10% , 15%,20% respectively . casting of cube , beam .The dimensions are ,

CUBE (mm)	*BEAM (mm)*
150×150× 150	*500× 100× 100*

Table.3. SIZE OF MOULD USED

Then curing of cube , beam are made . After that compression strength and flexural strength test are conducted.

3.1.Slump test

The result of workability of concrete by slump test with cement replaced by glass powder in various percentage ranging from 10% , 15% , 20% . Slump values are 100mm , 92 mm , 73 mm respectively .By increasing the glass powder decrease in slump value. [6]

3.2.COMPRESSION TEST :

Cubes which prepared with different replacement of glass powder is tested after 28 days of curing for compressive strength value . For each mix 3 different cubes are prepare and average final value of compressive strength is calculated which is shown

S. NO	*CURING DAYS*	*COMPRESSIVE STRENGTH IN N/mm²*			
		NORMAL CONCRETE	*GLASS POWDER CONCRETE*		
			10%	*15 %*	*20 %*
1	*7*	*20.44*	*23.7*	*24.8*	*27.3*
2	*14*	*24.77*	*25.9*	*28.3*	*32.9*
3	*28*	*31.61*	*40.7*	*44.4*	*44.9*

Table.4.AVERAGE COMPRESSIVE STRENGTH

Figure-5
Compression test set up

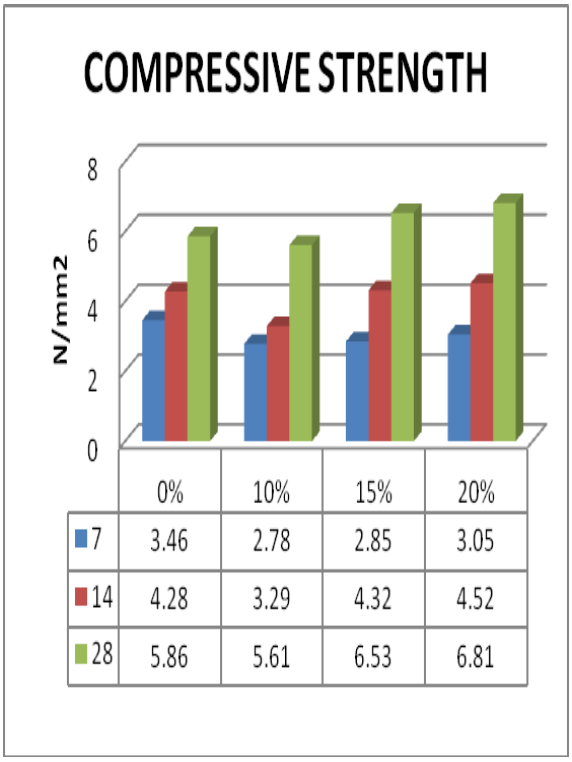

Figure -6 compressive strength of concrete at various stages

As per the above reading compressive strength of the glass powder concrete is higher than normal concrete . By increasing the glass powder upto 20% gives higher compressive strength.

3.3.FLEXURAL STRENGTH TEST:

The concrete containing 10% to 20% of glass powder shows the higher flexural strength when compare to the conventional concrete .

S.NO	*CURING DAYS*	*FLEXURAL STRENGTH IN N/mm²*			
		NORMAL CONCRETE	*GLASS POWDER CONCRETE*		
			10 %	*15 %*	*20%*
1	*7*	*3.46*	*2.78*	*2.85*	*3.05*
2	*14*	*4.28*	*3.29*	*4.32*	*4.52*
3	*28*	*5.86*	*5.61*	*6.53*	*6.81*

Table.5.AVERAGE FLEXURAL STRENGTH

Figure-6
Flexural test set up

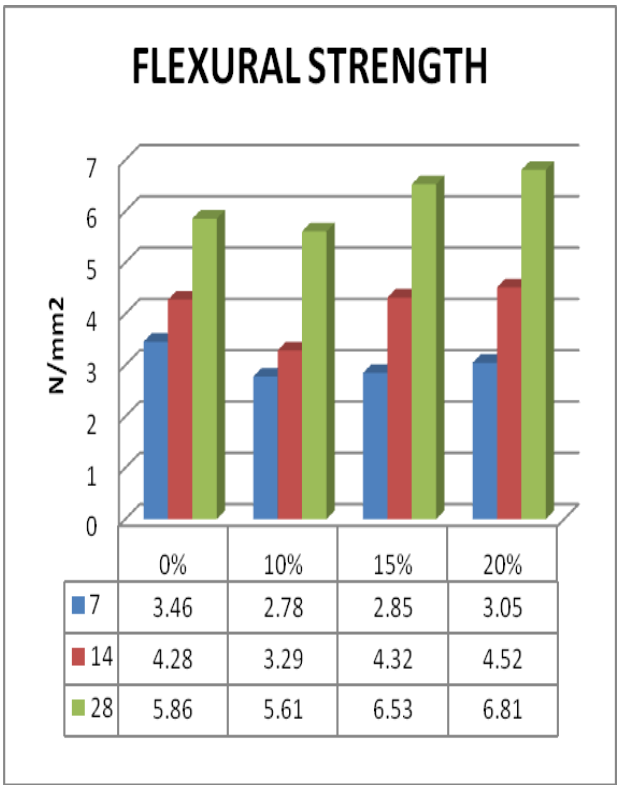

Figure -7 Flexural strength of concrete at various stages

As per the above reading flexural strength of the glass powder concrete is higher than normal concrete . By increasing the glass powder upto 20% gives higher flexural strength.By using glass powder as a partial replacement of cement in the concrete , increases the glass powder in the concrete and the workability decreases . By experimental view we found that both compressive strength and flexural strength shows higher result when compared to the conventional concrete .Due to the lower specific

gravity of glass powder , it decreases the unit weight of the concrete by increasing it . By correlating the compressive strength of conventional concrete (31.61 N/mm2) and glass powder concrete (44.59 N/mm2) , glass powder shows the higher compressive strength . By correlating the flexural strength of conventional concrete (5.86 N/mm2) and glass powder concrete (6.81 N/mm2) , glass powder shows the higher flexural strength . The finely grounded glass doesnot contribute to the alkali silica reaction and gives the higher value than large sized glass powder . considering strength criteria the replacement of cement by glass powder is feasible .

IV.CONCLUSIONS

Production of every 6 ton of glass powder concrete result in the reduction of each ton CO_2 emission from cement production . So by using the glass powder in the concrete reduces the green house gas emission . Usage of glass powder in concrete can prove to be economical as it as very much cheaper than cement and it also reduce the disposal problem of waste glass prove to be environmental friendly.

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