An Experimental Study on Properties of Concrete with Different Colors of Glass Powder as a Partial Replacement of Cement

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by

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Abstract

We all know that concrete is among the most used material in the construction field. However cement being the main part of the constituents of concrete its production lead to pollution of the atmosphere. When cement is being produced there is a huge amount of green gases released into the atmosphere such as CO_2 and many others which will in turn cause the greenhouse effect.

Glass being a material with high silica content shows the feasibility of replacing cement to some extent without reducing the strength of concrete.

In this study Green glasses and Clear glasses were experimented to compare their results when used as a partial replacement of cement.These glasses were collected as waste materials from workshop glasses in PHAGWARA(PUNJAB).

Green grounded glasses having high consumption of calcium oxide/ lime (CAO),exhibit better pozzolanic activities than clear glasses therefore giving more strength to the concrete than clear glasses with same replacement percentage.

In this work 10%,20%.30% and 40% replacement of cement by green glass powder and clear glass powder was experimented along with Normal concrete without any replacement to check the optimum Percentage replacement of cement which can be feasible as well as the type of glass which will give better results than the other.

Replacement of cement by green glass powder up to 30% has given the highest peak value in terms of compressive,split tensile and flexure strength compared to clear glass and normal concrete.

ACKNOWLEDGEMENT

I am grateful to all people who helped me converting an idea into a practical application.I am thankful to my internal guide Assistant Professor **Mr.Anshul Garg** for his valuable guidance without which this work would not had been possible.

I also offer my appreciation to all teaching and non teaching staff members who spent their time in making this work feasible.

At last but not least,my acknowledgements are also due to my **parents** for their limitless support and motivation throughout my thesis work.

Signature of Student

Mwizerwa Fabrice.

Declaration

I Mwizerwa Fabrice bearing registration number (11212286),hereby declare that this thesis report entitled**“ An Experimental study on properties of concrete with different colors of glass powder as a partial replacement of cement”** submitted in the fulfillment of the requirements for the award of degree of Master of Civil Engineering ,in the school of Civil Engineering,Lovely Professional University,Phagwara is my own work.This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

Mwizerwa Fabrice

Date:

Place:

CERTIFICATE

Certified that this project report entitled **"An Experimental study on properties of concrete with different colors of glass powder as a partial replacement of cement"** submitted individually by Mwizerwa Fabrice (11212286) of School of Civil Engineering, Lovely Professional University, Phagwara, carried out the work under my supervision for the award of Degree. This report has not been submitted to any other university or institution for the award of any degree.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Emission of green gases into the atmosphere caused by the production of cement is being a major concern in this century of construction revolution. According to research made it has been found that producing one ton of cement results in the emission of 0.9 tons of carbon dioxide (CO_2) into the atmosphere. As engineers our responsibility is not only to design and analyze structure only but also to save the environment in which we are living.

Lot of waste glasses are being disposed off in landfill and causing a lot of environment issues. However glass in itself being a pozzolanic material and having a high content of silica can be recycled and be used as fragmentary substitution of cement. When glass is ground to cement particles size shows good pozzolanic properties,hence it can be reliable for use as fragmentary substitution of cement.

1.2 PHYSICAL PROPERTIES OF WASTE GLASS

The specific gravity and Finess passing through 90 micron sieve were tested and the values are listed below.

Sr.no	Physical Properties	Type of Glass	Value
1	Specific gravity	Green	2.63
		Clear	2.6
2	Finess passing 90Mm	Green	98
		Clear	98

Table 1.1: Physical properties of waste glass

1.3Chemical properties of waste glass

Various compounds found in waste glass and their corresponding percentage are listed in the following table 2.

Chemical Composition of Glass		
Compounds	Percentage(%) in each Glass	
	Green	Clear
$Si\ O_2$	71.44	71.48
Al_2O_3	1.70	1.60
Fe_2O_3	0.37	0.07
CaO	10.81	11.45
Mg O	1.65	1.23
$Na_2\ O$	13.24	13.36
$K_2\ O$	0.36	0.48
SO_3	0.16	0.27
TiO_2	0.04	0.03
Cr_2O_3	0.19	0.01

Table 1.2: Chemical properties of waste glass.

Chapter 2

Terminology

In this research work these are the following terms which have been used by the author and their corresponding meaning in the context of this study.

1.Fragmentary: Partially replacement of a certain material.

2.C.G : Clear Glass.

3.G.G: Green Glass.

4.F.A: Fine Aggregate.

5.C.A : Coarse Aggregate.

6.OPC: Ordinary Portland Cement.

Chapter 3

Literature Review

3.1 General

Glass is among one of the olden man- made materials which usually serves as doors, windows, bottles and etc..These man-made materials in nowadays are being disposed off in landfill after being used and the need of recycling them is of no doubt. Glass in itself is a highly silica content material which can make us think of its use as a binder material in concrete industry.

As a siliceous material glass can exhibit good pozzolanic activity when ground to the finest particle size possible and therefore it can be reliable as a substitute of cement in concrete.

3.2 Review of previous Studies

Bajad M.N et al (2011) conducted the study on concrete containing glass powder as a substitute of cement when it is exposed to its chemical durability and proved that the highest compressive strength is attained at twenty percent replacement of cement by glass powder in either cases whether concrete was exposed to chemical durability or when it was not exposed to chemical durability and he stated that the increment goes up to twenty five percent replacement but after which it will start reducing.

Chikhalikar S M (2012) examined the behavior of properties of concrete containing fibre as reinforcement incorporating glass powder as a pozzolanic material and found that thirty percent replacement of cement by glass powder gives maximum compressive strength as compared to normal concrete however the peak value was observed at twenty percent replacement.He also carried out a survey on flexural of concrete incorporating glass powder as a substitute of cement and stated that twenty percent replacement of cement by glass powder gives the optimal value of flexure strength.

Dali J.S et al (2012) conducted a study on the properties of concrete incorporating admixtures from minerals when it is exposed to a sequence of wet and dry and at elevated temperatures and proved that twenty percent replacement offers the highest strength whether concrete was exposed to a sequence of wet and dry or when it was not exposed to a sequence of wet and dry. They also conducted the study on properties of concrete having admixtures from minerals once it is

exposed to a sequence of wet and dry and elevated temperatures and finalized that up to twenty five percent substitution of cement by waste glass powder gives a high compressive strength but the optimum value of compressive strength was seen at twenty percent replacement of cement by glass powder in either cases which are concrete exposed to a sequence of wet and dry and concrete without being exposed to a sequence of wet and dry.

Dr G Vijayakumar et al (2013) have substituted cement by glass powder in proportion of twenty percent,thirty percent and forty percent and have seen that it will increase the compressive strength by 19.6%,25.3% and 33.7% respectively.Substitution of cement by glass powder up to forty percent increases the split tensile strength by 4.4% respectively.Glass powder concrete enhances the compressive,tensile and flexure strength considerably when compared to normal concrete.The following figures represent the results obtained in their study.

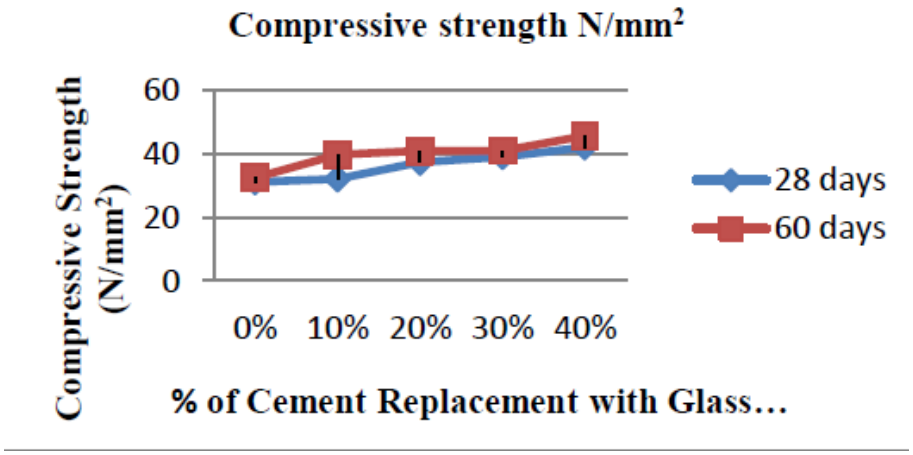

Figure 3.1 showing variation of compressive strength along with glass powder

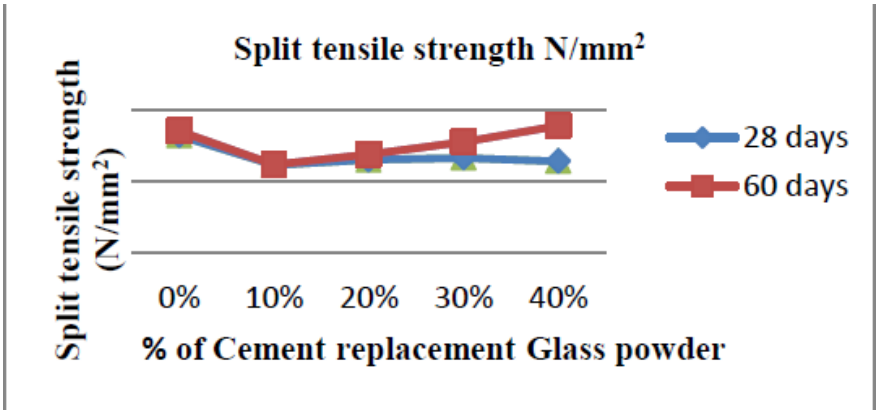

Figure3.2:Showing variation of split tensile strength along with glass powder

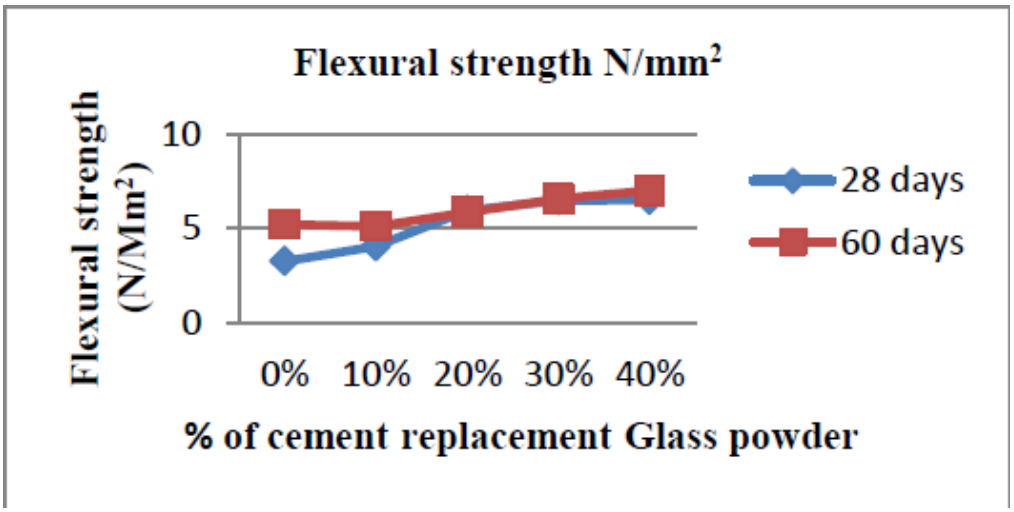

Figure3.3:Showing variation of Flexure Strength along with glass powder

They have also observed that when waste glass is ground to the finest particle size possible it will behave as an excellent filler and will have enough pozzolanic properties to act as a substitute of cement and the effect of Alkali silica Reaction will not interfere.

Jangid Jitendra B et al (2012) have conducted an experiment on concrete incorporating glass powder as a substitute of cement and finalized that up to forty percent substitution of cement by glass powder the compressive strength increases up to twenty percent and they have also seen that beyond forty percent replacement the compressive strength will drop down. They also investigated the flexural of concrete incorporating glass powder as a substitute of cement and found that up to thirty five replacement of cement by glass powder the flexure strength was high than that of normal concrete and the optimal flexure strength was observed at twenty percent replacement of cement by glass powder after which it starts decreasing.

Khatib.J.M. et al (2012) have investigated behavior of concrete containing glass powder as a substitute of cement and found that the maximum compressive strength appeared at ten percent substitution of cement by glass powder and concluded that beyond ten percent the compressive strength of concrete containing glass powder will drop down and will be less compared to normal concrete.

Khmiri A et al (2012) studied concrete possessing transparent and colored glass of various sizes (100 and 80 micron,80 and 40 micron and less than 40 micron) and concluded that the

compressive strength of ground glass attains more than eighty two percent for sizes less than forty micron.

Kumarappan (2013) fragmentary substitute cement by glass powder and concluded that up to ten percent substitution of cement by glass powder it is possible to substitute cement as it has shown more compressive strength than normal concrete.

Malik.M.Iqbal et al (2013) conducted a study on concrete incorporating waste glass powder as a substitute of cement and stated that absorption of water percentage decreased with the increase in waste glass powder content.The lowest water absorption was seen at forty percent replacement of cement by waste glass powder.

Nassar Roz Ud Din et al (2012) carried out a research on the durability and strength of recycled aggregate concrete incorporating crushed glass as fragmentary substitute of cement and concluded that water absorption of concrete was observed to be remarkably reduced with the introduction of crushed waste glass as a substitute of cement in either water cement ratio was low or high.

Nwaubani Sunny (2013) have studied the effects of mortar containing glass powder and found that there is a decrease in compressive strength.However this decrease becomes less significant with extended curing time.They have also seen that the particle size distribution of glass powder used in their experiment played a vital role in influencing the strength development of mortar.They have also investigated effects of waste glass powder fineness on properties of cement mortars and proved that water absorption increased with the increase in glass powder content.Substitution of five percent and that of twenty percent of glass powder content attains same values to that of normal concrete.

Oliveira.L.A Pereira et al (2010) conducted a research on the assessment of the pozzolanic activity of glass powder with various colors of green,amber and flint and their particle size range was from (75 to 150 micron,45 to 75 micron and less than 45 micron) as a substitute of cement acting as a filler or binder in mortar and concrete.He stated that thirty percent of glass powder ranging between 45-75 micron can be used as cement substitute in either mortar or concrete without any negative effect due to the alkali silica reaction.

Patel Dhirendra et al (2012) have experimented a work on study on behavior of cement sand mortar paste incorporating fine and coarse glass powder as a substitute of cement and concluded

that up to fifteen percent substitution of cement by glass powder is the optimum feasible replacement.

Patil Dhanraj Mohan et al (2012) have tested the outcomes of waste glass powder particles having sizes from 150 micron to 90 micron and less than 90 micron.They have seen that initial strength gain is very low because of the extra glass powder added on seven day but it increases on twenty eight day.They have also found that twenty percent addition of glass powder offers more strength.They stated that glass powder with particle dimension less than ninety micron is very effective in enhancement of strength.

Sameer Shaikh et al (2015) have replaced cement by glass powder in proportion of five,ten,fifteen and twenty percent and have found that it will increase the flexural strength at the end of twenty eight counted day by 5.88%,30%,44.85% and 13.97% respectively.They stated that concrete incorporating glass powder increases the compressive,split tensile and flexure strength significantly at 15% replacement when compared to normal concrete.Glass powder with fine particles size has proved to be excellent filler and may have sufficient pozzolanic properties to act as a substitute of cement.

Shayan Ahmad (2002) finalized that substitution of cement by glass powder up to thirty percent would be feasible without any negative effect of long-term. He also stated that up to fifty percent of cement replacement by glass powder can used in concrete of 32 Mpa strength grade with acceptable strength development properties.

Vandhiyan R et al (2013) carried a research on substituting cement by waste glass powder and finalized that a significant increase in the flexure strength was observed at ten percent replacement of cement by glass powder.They also investigated the substitution using waste glass powder and finalized that there was a remarkable increase in strength gain especially for fifteen percent glass powder gave an increment of twenty nine percent in strength at the seven day more than the normal concrete.However after twenty eight days this difference drops down up to twenty three percent .He concluded that the strength was optimal up to ten percent replacement.

Vasudevan Gunalaan et al (2013) tested results of seven,fourteen and twenty-eight days of samples incorporating glass powder as fragmentary substitution of cement and the outcomes showed that up to twenty percent replacement glass powder gives the highest compressive strength at twenty eight days as opposed to other replacement of ten and fifteen percent which cannot give the optimum value even though they showed increment in first fourteen days results.

Vijayakumar G (2013) carried a detailed survey on the split tensile strength of concrete having glass powder and concluded that substituting cement by glass powder will improve the tensile strength of concrete when compared to normal concrete. They have also examined the flexural of concrete incorporating glass powder as a substitute of cement and concluded that up to forty percent substitution of cement by glass powder would be feasible to be used as it offers the maximum flexural strength.They have found that cement can be substituted up to forty percent by glass powder .At forty percent substitution of cement by glass powder the compressive strength of concrete containing glass powder has shown more value than normal concrete for twenty eight and sixty days results.

Wang Her Yung et al (2011) investigated their research on elevated temperature of cement mortar and its effect on their strength and finalized that replacing cement by glass powder up to ten percent will give a good compressive strength of the mortar especially if the addition of glass powder particle size is more than 4500 cm^2/g they concluded that this amount of glass powder substitution would be feasible for replacing cement.

Jitendra B Jangid et al (2014) have stated that the increase in strength was seen with rise in percentage of glass powder up to twenty percent .The highest percentage increase was thirty percent in term of compressive strength.Peak percentage increase was around twenty two percent at twenty percent substitution of cement by glass powder in term of flexure strength.They concluded that cement replaced beyond twenty percent by glass powder will show a decrease in term of compressive strength.

CHAPTER 4

Rationale and scope of the study

4.1 Rationale of the study

Previous studies have worked simply on clear glasses when acting as a substitute of cement in concrete. No other color other than clear glass had been used to check its effect on the hardened properties of concrete.

This project aims towards comparing Green glass and Clear glass effects on hardened properties of concrete when used at the same replacement level.The feasibility of using these waste glass as a partial substitute of cement will reduce the pollution of harmful gases into the atmosphere such as carbon dioxide (CO_2) released at the time of manufacturing cement.

This research will help us to understand the contribution in the fight against global warming which is the result of excess of greenhouse gases in the atmosphere by reducing the amount of cement usually manufactured and partially replace it by glass in powder form.

4.2Scope of the study

In this research M25 grade was used for experimental work. The cement is to be replaced (by weight) by both Green and Clear glass at 10%,20%,30% and 40% to get optimum results. The various mechanical properties like compressive strength, split tensile strength and flexural strength for each percentage replacement are to be examined.

Normal concrete specimen which is concrete without replacement of cement was also cast out.

The results obtained after partially replacing cement by both Green and Clear glass will be compared with normal concrete mix and then best result is taken into consideration for practical applications.

CHAPTER 5

Objective of the study

In this research work the ultimate goal is to find the optimum percentage replacement of cement by both Green and Clear glass and to compare between these two types of glass which one offers more strength to concrete than the other one.

To reach the objectives following steps must be taken into consideration:

1. To study the effect on compressive strength of concrete by partially replacing cement with both Green and clear glass powder at different percentages.
2. To study the effect on Split tensile strength of concrete by partially replacing cement with both Green and clear glass powder at different percentages.
3. To study the effect on Flexure strength of concrete by partially replacing cement with both Green and clear glass powder at different percentages.

As concrete is made for resisting compressive stresses in almost all structures my main focus in this work will be to compare compressive strength of normal concrete(without replacement) by concrete incorporating glass powder and after this the type of glass offering more strength than the other will noticed.

CHAPTER 6

Materials and Research Methodology

6.1 General

The main aim is to check the properties of materials to be used in the research work. The ordinary Portland cement(OPC 43), coarse aggregates, fine aggregate,water and waste glass are the materials to be used in experimental investigation.

6.2 Materials

6.2.1. Ordinary Portland cement

IS Code followed: IS4031-Part 1 to 15

Type of cement used =Ordinary Portland cement(OPC)

Initial setting time=37minutes

Final setting time=3hours and seven minutes=187 minutes

Finess Modulus =1%

Specific gravity=3.18

Normal consistency=30%

6.2.2. Coarse aggregate

Sieve analysis of course aggregate: The weight of sample of coarse aggregate tested was=3.454Kg and the procedure was as per IS 383: 1983

Is.sieve.size in(mm)	Weight.ofaggregate.retained in(g.m)	Percentage.of. weight retained	Cumulative percentage of total weight retained	Percentage Passing	Permissible value as.per.Is.383
20	60	1.73	1.73	98.27	85-100
16	1438	41.63	43.36	56.64	
12.5	1404	40.64	84	16	
10	468	13.54	97.54	2.46	0-20
4.75	84	2.46	100	0	0-5
Pan	0				

Table 6.1: Sieve analysis of course aggregate

Conclusion: Aggregate is single sized of 20mm size

Water absorption of coarse aggregate

Weight of coarse aggregate after surface dry(w_1) = 2.994 Kg

Weight of coarse aggregate after oven dry(w_2) = 2.980Kg

Water absorption formula= $(w_1-w_2)/w_1$=[(2.994-2.980)/2.94]x100 = 0.47%

The water absorption of coarse aggregate used is 0.47%

Specific gravity of Coarse Aggregate

Specific gravity can be explained as the ratio of the mass of a substance to the mass of a water for the same given volume.

Weight of aggregate used = 3.55Kg

(Basket+coarse aggregate) in air = 4.4 Kg

Basket only suspended in air = 0.9Kg

Aggregate only in air = 4.4kg-0.9kg = 3.5kg

Aggregate with basket fully submerged in water = 2.9kg(w_3)

Empty basket fully submerged in water=0.8kg(w_2)

Weight of coarse aggregate after oven dry = 3.454kg

Specific gravity=$w_4/[w_4-(w_3-w_2)]$ =3.454kg /[3.454kg-(2.9kg-0.8kg)]=2.55

The Coarse aggregate's specific gravity used is 2.55

6.2.3. Fine aggregate

Sieve- analysis of fine aggregate

Sieve.sieze	Weight.offine.aggregate retained(gm)	Percentage retained	Cumulative percentage retained	Percentage Passing	Permissible percentage as per.Is.383
10mm	0	0	0	100	100
4.75mm	0	0	0	100	90-100
2.36mm	0	0	0	100	75-100
1.18mm	764	76.4	76.4	23.6	55-90
600Mm	160	16	92.4	7.6	35-59
300Mm	24	2.4	94.8	5.2	8-30
150Mm	50	5	99.8	0.2	0-10
Pan	2	0.2	100	0	

Table 6.2: Sieve- analysis of fine aggregate

Conclusion:The fine aggregate being used is of Zone 2.

Absorptionof Water and Specific gravity of fine aggregate

Weight of fine aggregate used = 500 grms(w_3)

Flask+Water+Fine aggregate = 1830grms(w_1)

Flask+Water = 1510grms(w_2)

Weight of fine aggregate after oven dry = 494grms(w_4)

Water absorption = (w_3-w_4)/w_4= (500-494)/494 = 1.2%

Specific gravity = w_4/[w_3-(w_1-w_2)]=494/[500-(1830-1510)] = 2.7

6.2.4. Water

Water used all along this research work either in casting or in curing process was free from any detrimental contaminant and was as per IS 456-2000 requirements.

6.2.5.Waste Glass.

Wastes glasses collected were first ground to cement particles sizes by the help of Los Angeles abrasion Testing machine and then sieved through 90 micron sieve size for both green and clear glasses as shown in [figures6.1&6.2].

Figure6.1: Green glass before sieving

Figure6.2:Green glass after sieving

6.3 Design Mix for M25

- Grade of concrete=M 25
- Cement type=OPC 43 grade
- Max size of coarse aggregate=20mm

- Max water/cement ratio=0.45
- Exposure condition=severe
- Maximum cement content=450kg/m^3

Data required for design mix obtained from testing are:

- Specific gravity of cement=3.18
- Specific gravity of CA=2.55
- Specific gravity of FA=2.74
- Absorption of water for CA=0.47%
- Water absorption for FA=1.2%
- Fine aggregate zone=2

Design mix steps:

1.Target mean strength

$F'_{ck}=Fck+t.s$

$F'_{ck}=25+(1.65x4)=31.6N/mm^2$

2.Selection of water cement ratio

From table 5 of Is 456-2000,w/c=0.5 but as per practical aspect we use generally 0.45

3.Selection of water content

From table 2 of Is 10262-2009 for CA 20mm

Water 186 kg(slump 50-75)

For 100 mm slump,follow clause 4.2 of Is 10262-2009

Water=186+(0.06x186)=197 liters

4.Cement content calculation

W/C ratio=0.45

Cement=197/0.45=437kg

5.Proportioning of Coarse and Fine Aggregate

W/c ratio = 0.5

Volume of 20mm CA in concrete=0.62

W/c ratio used =0.45

Reduction in w/c ratio=0.05

So 0.01must be added to volume of CA=0.62+0.01=0.63

Volume of FA in concrete=1-0.63=0.37

6.Mix calculations

Concrete volume=mass of cement/(specific gravityx1000)=437/(3.18x1000)=0.137m^3

Water volume=mass of water/(specific gravityx1000)=197/(1x1000)=0.197 m^3

Volume of all in aggregate(e)=1-(0.137+0.197)=0.666

Mass of CA=0.666x0.63x2.55x1000=1069kg

Mass of FA=0.666x0.37x2.74x1000=675kg

7.Mix proportion

Cement=437/437=1

FA=675/437=1.5

CA=1069/437=2.4

Ratio of Mix=1:1.5:2.4

Chapter 7

Results and discussion

7.1 Compressive Strength

The compressive strength at 7,28 and days of concrete incorporating green glass up to 30% replacement showed more strength than both clear glass with same replacement amount and normal concrete as shown in [figure7.1].Maximum load in newton at which the cube crushed divided by the cross-sectional area in mm^2 of the cube give us compressive strength of that particular cube in N/mm^2 or Mpa.The following are the average results at 7,28 and 56 days given in [table7.1].

Replacement	7 Days		28 Days		56 days	
	Green glass(G.G)	Clear glass(C.G)	Green glass(G.G)	Clear glass(C.G)	Green Glass(G.G)	Clear Glass(C.G)
0%	23.61	23.61	29.43	29.43	29.7	29.7
10%	29.15	21.64	30.66	30.40	30.97	30.71
20%	29.68	28.08	32.32	31.63	32.62	32.08
30%	30.8	28.88	36.16	34.16	36.88	35.2
40%	29.3	27.91	31.86	31.11	31.46	31.11

Table7.1: Compressive strength at 7,28 and 56 days in Mpa

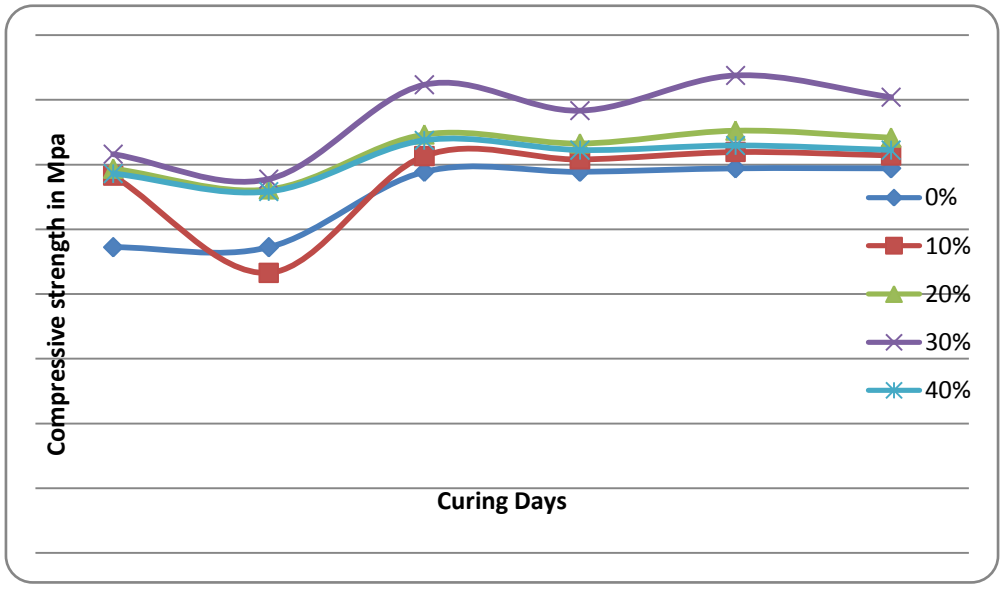

Figure7.1: Compressive strength of cubes at 7,28 and 56 days

7.2Split Tensile Strength

The Split tensile strength of concrete was measured as described in IS 5816:1999.Split tensile strength (fct) = 2p/πld where p is maximum load applied,π is constant,l is height of cylinder and d is diameter. Results for 7 days and 28 days are shown in [figure7.2].Average results of Split tensile strength are summarized in [table 7.2].

Replacement	7 Days		28 Days		56 days	
	Green glass(G.G)	Clear glass(C.G)	Green glass(G.G)	Clear glass(C.G)	Green Glass(G.G)	Clear Glass(C.G)
0%	1.86	1.86	2.15	2.15	2.23	2.23
10%	2.12	2.01	2.42	2.29	2.51	2.35
20%	2.29	2.18	2.85	2.70	3.05	2.76
30%	3	2.75	3.52	3.26	3.69	3.37
40%	2.19	2.10	2.71	2.58	2.54	2.45

Table 7.2: Split tensile Strength of cylinders at 7,28 and 56 days in Mpa

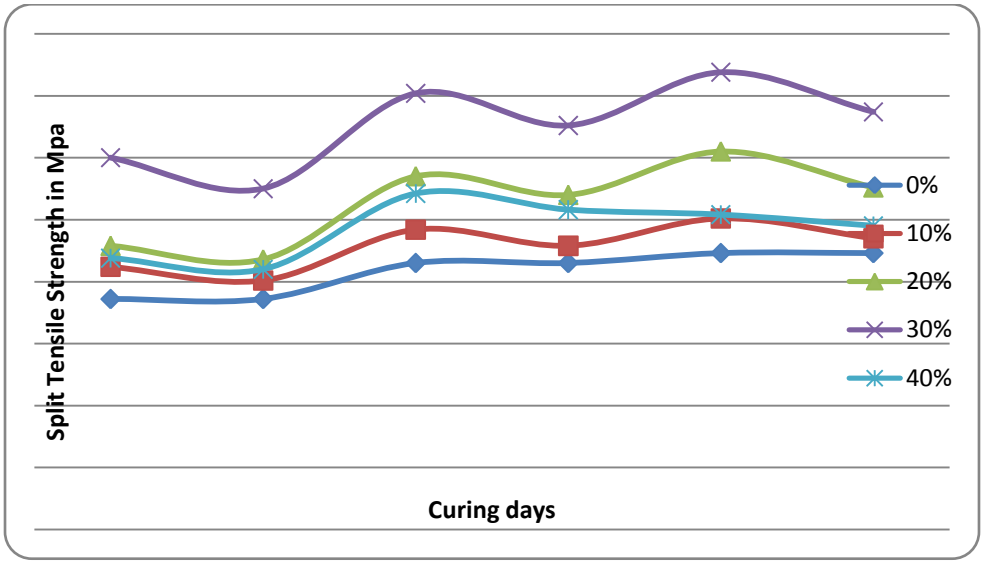

Figure7.2: Split tensile of cylinders at 7,28 and 56 days

7.3Flexure Strength

The flexure Strength of beams was measured as per IS 516:1959.Flexure strength (fb) = Pl/bd^2 where p is maximum load,l is length of beam,b is width and d is depth.Results are shown in

[figure7.3].Average Flexure strength of beams is given in following [table7.3] for 7,28 and 56 days results.

Replacement	7 Days		28 Days		56 days	
	Green glass(G.G)	Clear glass(C.G)	Green glass(G.G)	Clear glass(C.G)	Green Glass(G.G)	Clear Glass(C.G)
0%	6.45	6.45	7.35	7.35	8.15	8.15
10%	7.2	6.35	8.5	7.65	9.3	8.8
20%	7.35	6.7	9.75	9.15	10.1	9.5
30%	9.15	7.3	11.35	10.2	11.5	10.5
40%	6.65	6.45	9.1	8.55	9.5	9.15

Table7.3:Flexure strength of beams at 7 and 28 days in Mpa

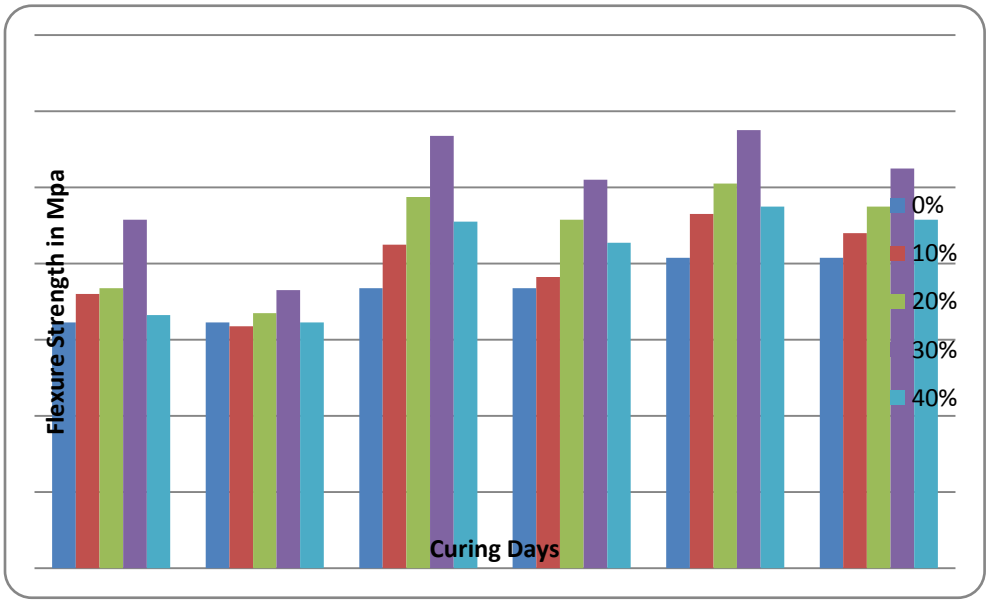

Figure7.3:Flexure Strength of Beams at 7,28 and 56 days

On 30% replacement in both Green and clear glasses were the optimum replacement percentage feasible in concrete and both were giving higher values than normal concrete in terms of compressive,split tensile and flexure strength.It was also observed that Green glasses due to their higher consumption of lime/calcium oxide(CAO) give higher strength than clear glasses with same replacement level.

Figure 7.4 showing set up of compressive test investigation

Figure 7.5 showing set up of split tensile test investigation

Figure 7.6 showing set up of flexure strength test investigation

Chapter 8

Conclusion and Future scope

After carrying out this work we can conclude the following observations :

- Green glass offers higher strength than clear glass with same replacement level.
- It was also observed that both green and clear glasses offer better results than the normal concrete without any replacement and this is due to the high silica content(SiO_2) found in both glasses.
- The use of waste glass powder as replacement of cement can be feasible up to 30% only and therefore glass can be also considered as a binding material like cement to some specified limit.

Further research work should investigate on whether once clear and green glasses are mixed together if it can give any further good benefit in terms of concrete strength.

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Appendix

1.Pozzolanic activity of waste glass

Alkali silica reaction(ASR) when waste glass was being used in concrete has been the main major drawback for its feasibility in concrete industry because of the negative outcomes it impacts to concrete in terms of strength.

However when wastes glasses are ground to the finest possible particle size of 90 micron or even less it exhibits good pozzolanic activity and suppresses the alkali silica reaction(ASR) to take place.

The pozzolanic activity of waste glass when used as a substitute of cement will depend on finest size of glass.The lesser the waste glass particle size it has, the more will be the pozzolanic activity of that waste glass regardless of the color of that glass.

2.Composition of Ordinary Portland Cement(OPC)

The Ordinary Portland cement is made by grinding and milling of the following materials :

- Lime or Calcium oxide(Cao): from limestone, chalk, shells, shale or calcareous rock.
- Silica Oxide(SiO_2): from sand, old bottles, clay or argillaceous rock.
- Aluminium Oxide($Al_2 O_3$):from bauxite, recycled aluminum, clay.
- Iron Oxide(Fe_2O_3): from from clay, iron ore, scrap iron and fly ash.
- Gypsum($Ca SO_4.2h_2O$) :found together with lime stone.

As we have seen in the introductionpart that silica content in waste glass occupies a high percentage than any other compound, It is clear in the above statement that one of the source of silica in cement manufacturing is the use of old bottles which are made by glass itself.

And this silica present in glass plays a vital role in the pozzolanic activity of waste glass together with its particle size to which it is ground.