A Study on Sustainable Approach of Using Higher Percentage of Stone Dust in Concrete by Partially Replacing Cement with Silica Fume and Glass Powder

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Abstract

Concrete is one of the most used construction material in the world. It is a family of binding materials like cement, aggregate and water. Cement being one of the most important materials of concrete family is also a hazard to environment and health as production of cement releases harmful gas like $C0_2$. Our basic aim of this study is to replace percent content of cement from concrete by replacing it with desirable waste materials like silica fume and glass powder. It is better to make wealth out off waste rather dump it and give rise to pollution. This not only would be eco-friendly but also economical. Also replacing fine aggregate with partial amount of stone dust as in present case natural sand is becoming sparse and immoderate.

In recent years it has been found that by replacing cement from concrete with, pozzolanic materials, silica fume and glass powder increases the strength of concrete.

In this research mixture of silica fume and glass powder were used by replacing percent content of cement from concrete to study its effect upon concrete strength. The mix proportion of 1:1:2 was selected for all the concrete samples with water-cement ratio of 0.45 and maximum size of aggregate was 20 mm. Both silica fume and glass powder were introduced with different percentages of 5%, 7.5%, 10% and 15% respectively. Another sample of 0% silica fume and glass powder i.e.; without them, was prepared in order to compare strength of newly formed concrete with the standard concrete. It was found that concrete with mixture of silica fume and glass powder by replacing cement in concrete increases the concrete strength. Such as compressive strength increased by 33%, split tensile strength increased by 8% and flexural strength increased by 4% at the age of 28 days. Through this research it was concluded that at 28 days the strength of concrete increases by replacing 10% of cement through mixture of 10% silica fume and glass powder respectively.

Also in the present time where fine aggregate like sand is becoming costlier and inadequate, it is need for an hour to find an alternative. Stone dust is such alternative which can be used as a replacement of sand in concrete. During this study it was found that stone dust not only is suitable but also potential replacement of sand as fine aggregate. It was found that at a replacement of 60% of natural sand from concrete with stone dust, maximum strength was attained based on compressive strength.

KEY WORDS: Compressive strength, glass powder, concrete, partial replacement, CO2, Silica Fume
OBJECTIVE: The main objective of the study is to compare the compressive, flexural and tensile strengths for the designed mix specimen (M25) with conventional and replaced concretes

RIVIEW OF LITERATURE

1. An Experimental Investigation on Partial Replacement of Cement by Silica Fume and Fine Aggregate by Glass Powder in Concrete

L. Summit Kumar Shukla Jun 2015

It has been observed that maximum compressive strength noted for 15% replacement of cement with silica fume with values (30.72 N/mm2 and 46.24 N/mm2) are higher than those of the conventional concrete (28.78 N/mm2 and 46.13 N/mm2) at 7 and 28 days, whereas split tensile strength of the Silica fume concrete (1.86 N/mm2) is increased by about 3.33% over those of the normal concrete (1.8 N/mm2) when 15% of cement is replaced by SF at 28 days and the characteristic strength of higher grade of cement concrete is achieved only by using the M25 grade designed mix proportion. Hence silica fume can be successfully used partially up to 15% as an alternate for cement with the increase in strength and durability of the concrete.
It is also observed that, up to 20% replacement of fine aggregate by glass powder the strength of concrete after 28 days is increased and however above 20% concrete strength decreases. GP can be successfully used partially up to 20% as an alternate for fine aggregate thereby reducing the environmental effects and scarcity of sand. GP concrete is strong and durable compared to sand concrete.

2. Waste Glass Powder as Partial Replacement of Cement for Sustainable Concrete Practice

G. M. Sadiqul Islam, M. H. Rahman, Nayem Kazi October 2016

The research paper has found out the chemical composition of glass powder and has concluded that the glass powder can be included among the pozzolanic materials as per the ASTM standard. It further observed that the optimum percentage that we can use of glass powder to attain maximum strength results after 90 days. It has been analyzed that the use of glass powder instead of cement can reduce the cost of concrete production by 14%. Further, this research says that the product of cement releases CO2 gas which is harmful to the environment, and hence the use of glass powder can help in reducing the CO2 in the atmosphere.

Introduction

As we know concrete is a combination of cement, aggregate (course and fine), water. Concrete is the most widely used material in construction globally. However with the release of CO2 by cement manufacturing there is something to think about our future sustainable environment. The release of CO2 has put a serious threat globally. As per estimation 7% of total CO2 is released due to cement production. Now civil engineers need to give their part to minimize the concentration of CO2. Production of cement is associated with release of CO2 and we need to make efforts to replace cement by certain materials like silica fume, glass powder, fly ash, rice husk etc. have shown promising results by replacing %cement from concrete. Silica fume being finer than cement diminishes the permeability of concrete. It affects the mobility of water and bleeding of concrete is eliminated. Waste glass when ground to very fine powder and used in replacement of cement shows pozzolanic properties in concrete. But in this research, we have considered glass powder as a replacement of cement by certain percentages like 5%, 7.5%, 10%.
So, as a Civil Engineers it is important to consider the replacement of cement in concrete in order to limit risks. The use of such waste materials not only give promising results in concrete properties but also are economical and environment friendly. With the expanding of green concrete industry, it is important to study concrete that contains waste Materials like silica fume, glass powder, fly ash, rice husk etc. have shown promising results by

replacing %cement from concrete. Silica fume being finer than cement diminishes the permeability of concrete. It affects the mobility of water and bleeding of concrete is eliminated. Waste glass when ground to very fine powder and used in replacement of cement shows pozzolanic properties in concrete.

Partial replacement of cement in concrete by these materials will reduce the overall surge in CO2. These materials do not affect the quality of concrete, however to some degree increase its strength and quality. Workability, water absorption, reducing heat of hydration are some other properties affected by these replacements of cement in concrete.

Water Cement Ratio

The procedure of ease and taking instance of transportation, taking care of, and situation of the concrete in the structure with the base adversity is called Workability. To keep up the functionality, water-cement extent assumes an indispensable job for setting and cementing of cement. For the enough degree of usefulness, the measure of water used ought to be least or by and large water- cement proportion is inversely corresponding to the nature of concrete. In this way, the water cement proportion ought to be picked cautiously by the methods for consistency strategy.

Materials

The strength of a material is almost always the first property that the engineer needs to know about. If the strength is not adequate, then the material cannot be used and other properties are not even considered. any kind of engineering works depends up on the wide range of materials to give a structural views of engineering arts and to enhance the properties like strength, permeability, durability, temperature resistant etc. it should be studied before which materials are suitable for enhancing which type of property in the concrete.

Cement

An integral part of the urban infrastructure. It has been used to make concrete as well as mortar and to secure the infrastructure by binding the building blocks Cement is a significant constituent of the concrete, relying on the evaluation of the concrete, which is utilized to tie the fine aggregate and coarse aggregate in concrete. It is an argillaceous and calcareous material which a fine dark powder in nature. The significant constituent of cement is lime (Ca O). CO2 is the result that is discharged during the assembling of cement. During the assembling of cement, the utilization of normal assets is excessively high (for example lime). CaCO3 + heat = Ca O + CO2.

Chemical composition of cement& glass materials

Composition (% by mass)/ property	Cement	Glass powder
Silica (SiO2)	20.2	72.5
Alumina (Al2O3)	4.7	0.4
Iron oxide (Fe2O3)	3.0	0.2
Calcium oxide (Ca O)	61.9	9.7
Magnesium oxide (MgO)	2.6	3.3
Sodium oxide (Na2O)	0.19	13.7
Potassium oxide (K2O)	0.82	0.1
Sulphur trioxide (SO3)	3.9	-
Loss of ignition	1.9	0.36
Fineness % passing (sieve size)	97.4(45 µm)	80 (45 µm)
Unit weight, Kg/m3	3150	2579
Specific gravity	3.15	2.58

Fine aggregate

Aggregate is idle mineral materials such as sand, gravel, and crushed It is an essential ingredient in concrete that consists of natural sand or crushed stone. it provides dimensional stability to the mixture fine aggregate is finer than the coarse aggregate and assumes a significant job infill the pores of the concrete. elastic modulus and abrasion resistance of the concrete can be influenced with fine aggregate the size of the sand molecule is under 4.75mm and the particular gravity of sand is close by 2.7.

Coarse aggregate

For durable construction concrete in buildings and to fulfill the requirements of ideal concrete good coarse aggregates are necessary, which is retained on the 4.75mm sieve those aggregates are called coarse aggregate. For the most part,10 to 20 mm size of coarse aggregate is utilized in concrete. Angular shape when utilized in concrete than it invigorates great strength to concrete yet diminishes the functionality, if the round state of coarse aggregate is utilized then it builds the usefulness however diminishes the strength as a contrast with precise shape coarse strength. The particular gravity of the coarse total is 2.85.

Silica Fume

Silica fume is additionally called small-scale silica, the micro silica formed when (Si O) gas produced in the furnace mixes with oxygen, oxidizes to Si02 (CAS number 69012-64-2, and EINECS number 273-761-1) it is a non-crystalline polymer of silica dioxide, silica. It is an amazingly fine powder assembled because of silicon Ferro Silicon compound creation and contains round particles with an ordinary estimation of 150 NM. Its principal application is as pozzolanic material for first-class concrete.

SILICA FUME	ASTM – C- 1240	ACTUAL ANALYSIS
SIO2	85% MIN	86.7%
LOI	6% MAX	2.5%
MOISTURE	3%	0.7%
POZZ ACTIVITY INDEX	105% MIN	129%
SP SURFACE AREA	>15M2/GM	22M2/GM
BULCK DENSITY	550 TO 700	600

ASR:

alkali silica reaction, which causes an expansive silicate gel to form with reactive aggregates present in concrete. Reactive aggregates include glass, flint, chert, or certain rhyolites. The expansive force of the silicate gel is greater that the tensile strength of concrete, so the concrete will crack. Depending on the reactivity of the aggregate and the alkali content of the cement, cracking can occur as early as days, or it can be delayed for many months or even years later. As cracking occurs, more water enters the interior of the concrete to mobilize the alkalis present. In severe cases, over the years, ASR cracking can destroy the strength of the concrete and ultimately reduce it to rubble.

Pozzolana:

An amorphous (glassy) powdered siliceous material that responds to the alkali content in cements to react with lime in the high pH environment in concrete to form additional CSH (calcium silicate hydrate) binder within the pore structure of the concrete. Pozzolans are effective as minus 325 mesh powders. Pozzolans vary widely in reactivity, color, water demand, and in chemical composition. Much of the chemistry associated with certain pozzolans, such as sulfides, carbon, sulfates, and alkalis can be quite deleterious to the long-term durability of concrete.

Glass Powder

Powder glass has very small particles, with a typical median grain size between 30 µm down to as fine as 0.1 µm. it comes from a variety of sources including curbside pickup, fiberglass factories, and by relaxing a mix of materials, like silica, caco3, and soda ash debris at high temperatures. By the technique of pounding, processing, and sieving. Millions of tons of waste glass are delivered wherever all through the world. At the point when the glass becomes waste, it is masterminded as land filler, which is outlandish as glass powder doesn't disintegrate in nature. Using a waste glass powder and byproduct silica fume in concrete as an incomplete substitution of cement can be a noteworthy development toward the progress of a reasonable foundation framework. Lower mean compressive strengths, compared to the control mortar (0% glass replacement) were obtained at 7, 14, 28, and 56 days age. Except for 25% glass addition, all other cement replaced mortars' mean compressive strength exceeded that of control mortar at 90 days. 10% cement replacement level gave the greatest compressive strength in mortar Aggregates made from soda-lime glass can be used in concrete if properly mitigated for ASR.

EXPERIMENTAL PROGRAM

Concrete mix proportion and preparation

Trial mix designs were conducted to obtain the target strength of (?) MPa at 28 days with a workability of () mm as per Indian Standard Specifications IS: 10262- 1982. The glass powder replacement in cement was varied (0–? %). Mix proportion of concrete is shown in ( ) . The mixture was prepared with water to cement ratio of (?). Firstly, stone chips and sand were dry mixed for a minute. Appropriate quantity of glass powder was blended with cement in a separate container and then incorporated into the aggregate matrix (mixed earlier). Measured quantity of water was added to the matrix and thoroughly mixed for 5 more minutes. After mixing, workability of the concrete was determined using slump test. It was confirmed that the slump values of concrete at different glass replacement level remained within the target slump range of () mm without changing the water content. The concrete was placed, compacted and surface finished with a smooth steel trowel in cube mould. The material was kept within the mould for 24-h in moist condition before demoulding. After demoulding the concrete was placed under fresh curing water in tank for specified period before testing. No admixtures were used in concrete compressive strength tests.

Mix design refers to the proportioning of concrete is the method of decision of relative degree of cement, F.A, C.A and water to get a perfect concrete quality.

For this study we were used M25 grade of concrete. Mix design carried out for M25 grade of concrete by IS 10262:2009,10262-1982. The proportioning of cement, F.A, C.A and water ordinarily ought to have enough functionality, max density and can be easily positioned in the structure.

The mixture will be prepared with the cement content of 350kg/m3 and water to cement ratio of 0.45. The mix proportion of materials is 1:1:2 and 1:1.2:2.4. Then natural fine aggregate was used. The replacement levels of cement, glass powder was used in terms of 5%, 7.5%, and 10% in concrete.

MIX PROPORTION [M25]

WATER	CEMENT	F. A	C.A
0.45 kg/m3	1kg/m3	1kg/m3	2kg/m3
158 kg/m3	350 kg/m3	350 kg/m3	700 kg/m3

22.5 lit/bag	50 kg (1bag)	50 kg/bag	100kg/bag

Fineness Modulus of Fine Aggregate:

	Coarse Aggregate		
I.S. Sieve size	Weight retained	Cumulative weight retained	Cumulative % retained
80mm	0	0	0
40mm	560g	560g	18.66%
20mm	1110g	1670g	55.66%
10mm	840g	2510g	83.66%
4.75	140g	2650	88.33%
Pan	270g		
			X= 246.31%

- Fineness modulus of fine aggregate = (246.31/100) = 2.4

Fineness Modulus of Coarse Aggregate:

I.S. Sieve size	Weight retained	Cumulative weight retained	Cumulative% retained
4.75mm	45.0g	45g	2.25%
2.36mm	311g	356g	17.8%
1.18mm	436.5g	792.5g	39.62%
600 micron	374g	1166.5g	58.32%
300 micron	312g	1479g	73.95%
150 micron	428g	1907g	95.35%
PAN	61g		X= 287.29%

- Fineness modulus of C.A = (287.29/100) = 2.87

OBSERVATION TABLE OF CONSISTENCY OF CEMENT:

% of Water	28%	30%	32%	34%
Initial reading	40	40	40	40
Final reading	16	10.5	10	10
Height of penetrated mm	24	29.5	30	30

- Consistency

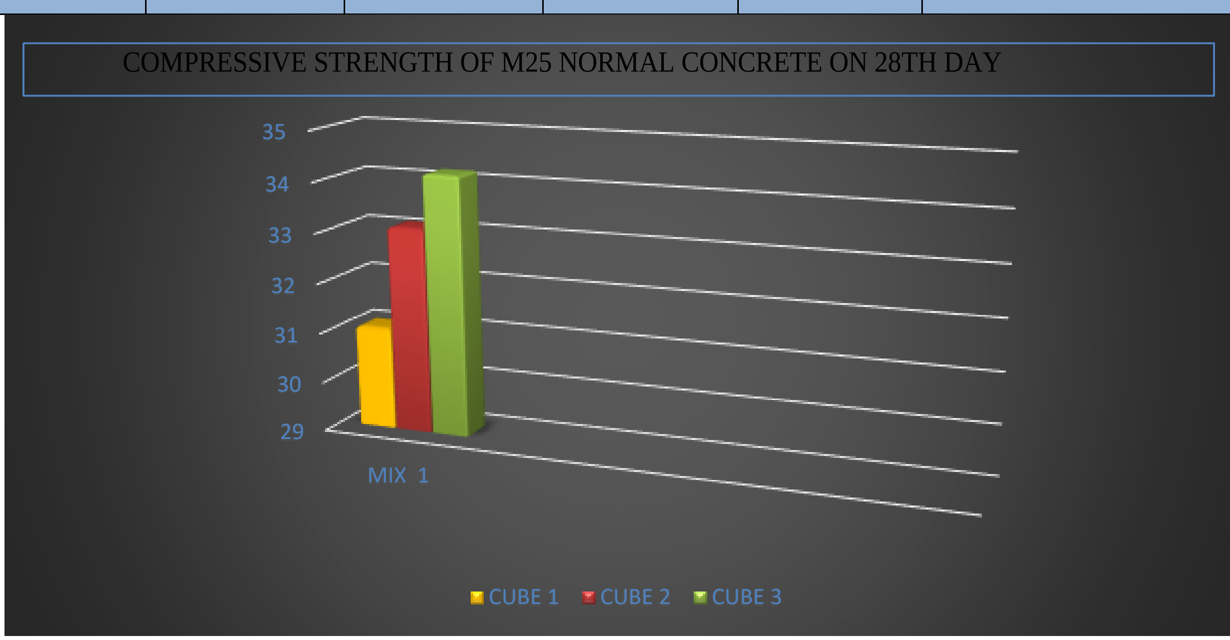
34% of the wt. of cement 400

Compressive Strength

The test was performed adjusting IS 516-1965 to get the Compressive quality strength of the concrete at the period of 28days. The example (solid shapes cubes) were tested utilizing CTM of 2000KN.

COMPRESSIVE STRENGTH OF M25 NORMAL CONCRETE ON 28TH DAY

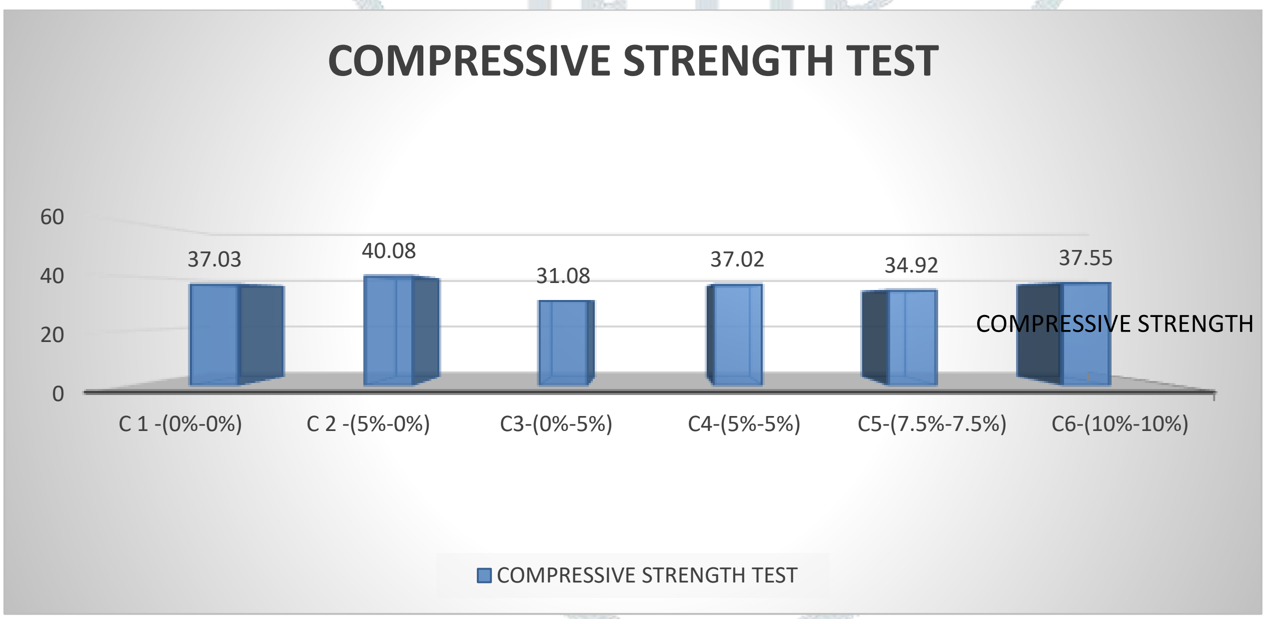
SR. NO	MIX	C 1	C 2	C 3	AVERAGE COMPRESSIVE STRENGTH (N/MM2)
1	Mix 1	31.05	33.12	34.20	32.79



COMPRESSIVE STRENGTH OF M25 NORMAL CONCRETE ON 28TH DAY

Results of Compressive Strength after replacement:

Mix	% of Glass Powder	% of Silica Fume	Compressive Strength N/mm^2
1	0	0	37.3
2	5	0	40.8
3	0	5	31.08
4	5	5	37.02
5	7.5	7.5	34.92
6	10	10	37.55



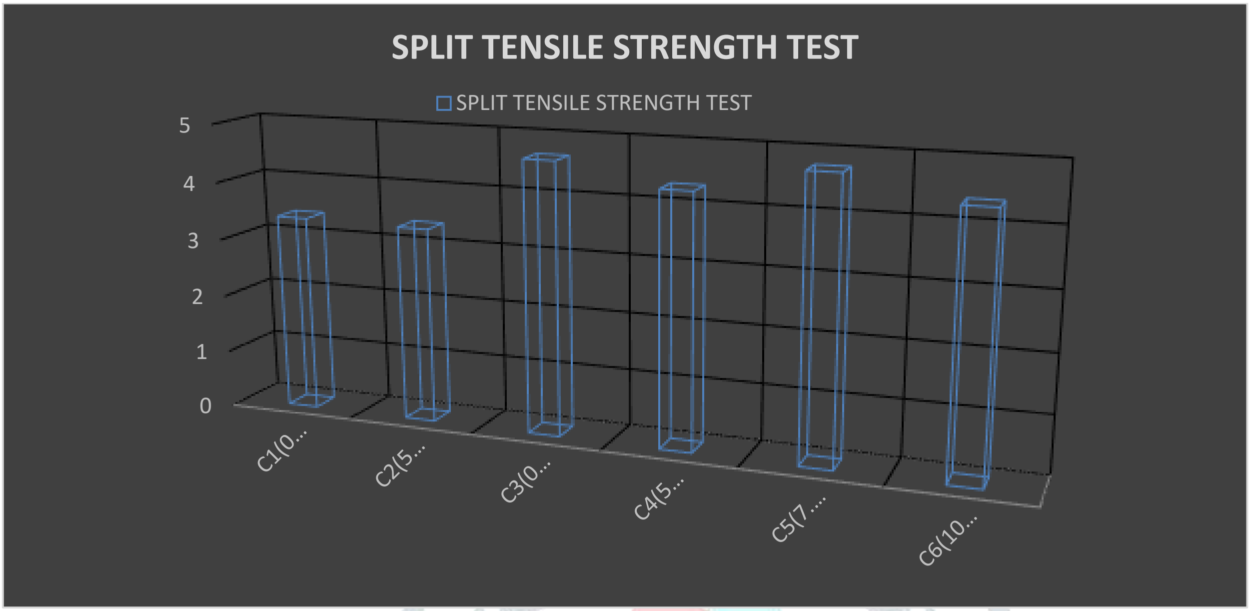
THE RESULT:
Glass powder replacement produces higher compressive strength than silica fume. And the higher compressive strength obtained by replacement of 5% glass powder.

Split Tensile strength

The test was led by adjusting IS 516-1959 to get the split tensile strength of the concrete at the period of 28days. It was tested in CTM of 2000KN.

Mix	% of Glass Powder	% of Silica Fume	Tensile Strength N/mm^2
1	0	0	3.39
2	5	0	3.37

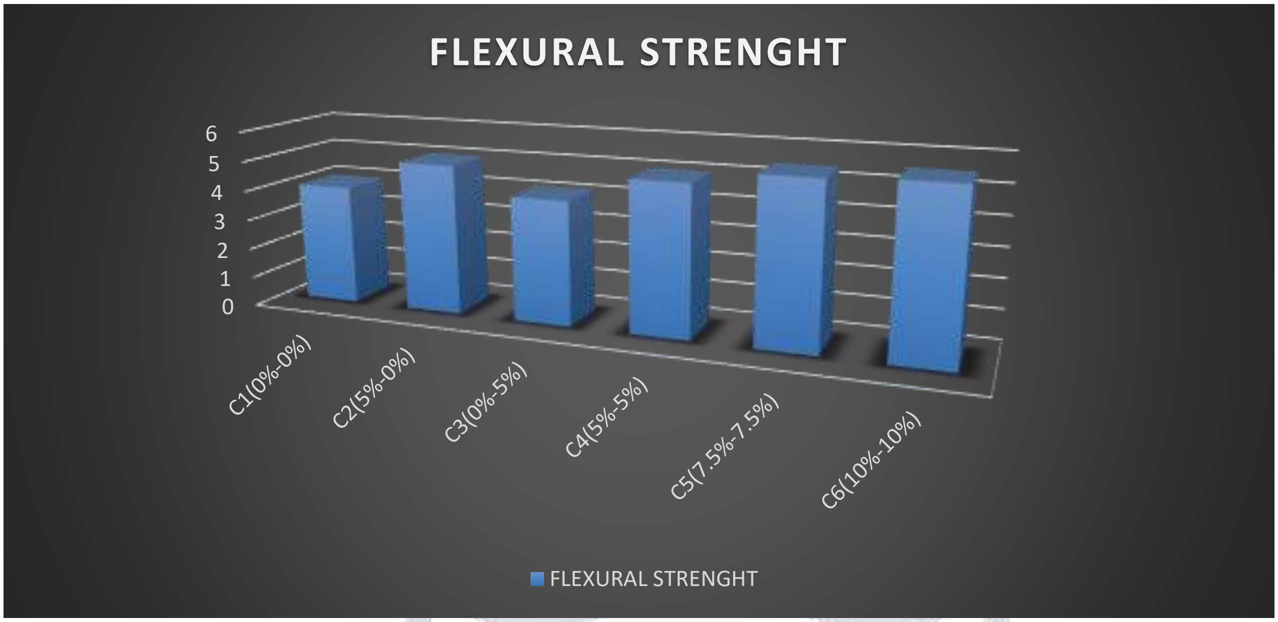
3	0	5	4.66
4	5	5	4.32
5	7.5	7.5	4.75
6	10	10	4.38



THE RESULTS:
Silica fume replacement produces higher tensile strength than glass powder.
And the higher tensile strength obtained by combination of 7.5% replacement of both.

Result of Flexural Strength after replacement: -

Mix	% of Glass Powder	% of Silica Fume	Flexural Strength N/mm^2
1	0	0	4.2
2	5	0	5.04
3	0	5	4.17
4	5	5	5.03
5	7.5	7.5	5.45
6	10	10	5.56



THE RESULT:

Higher flexural strength obtained by combination of 10% replacement of both glass powder and silica fume.

CONCLUSION

Following conclusions are made based on results obtained:

The principle change in the concrete with supplanting of cement with silica fume and glass powder is the quality. The general quality of the concrete including compressive, split tensile and flexural quality is improved.

It is consequently; likewise saw that result silica fume and squashed glass powder can be utilized in efficient and organized way as substitution material of cement.

It is seen that the quality of regular concrete shows a compressive quality of 40.8 N/mm2, split tensile of 4.75N/mm2. By supplanting the cement with glass powder and silica fume by 5%, 7.5% and 10% prompts expand the compressive quality, split tensile quality and flexural quality strength the ideal measure of silica fume and glass powder is 5% to 10%.

At the point when the cement is supplanted with silica cement and glass powder proficiently it increments the compressive quality, split tensile quality and flexural quality strength as contrast with the customary concrete.

Future Scope

As it is notable that concrete ventures are one of the central points of delivering CO2. Assembling 1 ton of cement produces 1 ton of carbon dioxide. The regular assets are getting lesser and lesser as the day passes, the contamination continues expanding and there will day come not long after that it will be hard to endure. What's more, one of the fundamental explanations of the contamination is cement which is likewise that is disregarded the most. As being polite Civil Engineer, we need to consider this substitution of material with the goal that the contamination gets less.

Following are the factors for future scope:

- Usages of this byproduct which will make the earth contamination free and furthermore the regular assets will be supported.
- By utilizing silica fume and glass powder higher evaluation of concrete can be accomplished.

- Self-compacting property of concrete can accomplish by utilizing waste glass powder
- The glass powder and silica fume are the pozzolanic materials. Therefore, compressive strength can be studied by using this material same as partially replacement of cement in concrete. And also, can be determined its optimum dosage range when concrete riches maximum strength.

RELEVANT IS CODES:

- IS: 10262-2009, Recommended Guidelines for Concrete Mix Design.
- IS: 456-2000, Code of Practice for Plain and Reinforced Concrete
- Sp. 23 IS Specification for Concrete Mix Design

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