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An Experimental Study on Crushed Glass Material for the Partial Replacement of Natural Sand in Concrete

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***Abstract*— The experimental study reported in this paper deals with the performance of concrete containing crushed glass material as partial substitution for natural sand. In this project, natural sand is partially replaced by 5%, 8%, 10%, 20%, 30% and 40% of crushed glass material. The compression tests and split tensile tests are carried out on cubes and cylinders of conventional cement concrete and designed concrete for 7, 14 and 28 days. The results for designed concrete and conventional concrete are obtained and compared to determine the optimum value for the replacement of natural sand in cement concrete. This experimental study deals with prevention of environmental degradation, economic profits, development in strength and also enhances durability characteristics. As a sustainable solution to glass storage, it's a potential way to reuse the glass in concrete.**

***Index Terms*— Compressive strength, Crushed glass, Split tensile strength, Concrete.**

I. INTRODUCTION

Concrete is a very strong and versatile mouldable construction material. It consists of cement, sand and aggregate mixed with water. It is a site-made material unlike other materials of construction and as such can vary to a very great extent in its quality, properties and performance owing to the use of natural materials. The cement and water form a paste or gel which coats the sand and aggregate. When the cement has chemically reacted with water (hydrated), it hardens and binds the whole mix together. Concrete normally gains strength beyond 28 days. The quantum of increase depends upon the grade and type of cement, curing and environmental conditions. The design should be based on characteristic strength of concrete unless there is an evidence to justify higher strength for a particular structure due to the age.

One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen, sulphate, chloride etc. Concrete is more vulnerable to chemical and climatic attack when it is exposed to certain environmental conditions. Free water cement ratio is an important factor in governing the durability of concrete and should always be the lowest value. The purpose of concrete mix design is to ensure the most optimum proportions of the constituent materials to fulfill the requirement of the structure being built.

The cohesiveness and finishibility of concrete should be improved by increasing sand or aggregate ratio than by increasing the proportion of the fine particles in the sand. Strength and durability require lower water cement ratio. It is usually achieved by increasing the cement content, but by lowering the water at given cement content.

Concrete can be considered as two phase materials for convenience; paste phase and aggregate phase. Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and economy. Generally, the maximum size of aggregate should be as large as possible within the limits specified, but in any case not greater than one-fourth of the minimum thickness of the member. Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 5mm.

Water is one of the most important elements in concrete production. The water used for mixing and curing is potable, fresh, colourless, odourless, and tasteless water that is free from organic matter of any type. Water is needed to begin the hydration process by reacting with the cement to produce concrete. If too much of water is added, this will in fact decrease the strength of the concrete. The water-cement ratio is an important concept because other than the constituents for the concrete mix, the amount of water used would also determine its strength. In more details, if too little water were added, there would not be enough water available to finish the reaction, thus some of the cement would harden and bond with other dry cement shortening the hydration process.

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 environment friendly because it is non-biodegradable.. Glasses and its powder have been used as a construction material to decrease environmental problems. Glass material contents contribute greater strength and better thermal insulation due to its better thermal properties of the glass aggregate. When waste glasses are reused in making concrete products, the production cost of concrete will go down. Using crushed glass material for the replacement of natural sand can be justified both as a remedial for waste disposal and also for reducing environmental degradation.

The primary objective of this study is to find an alternative to natural sand. The secondary objectives include identification of effects of adding waste glass on the properties of fresh concrete mixes such as workability by slump measures; to check the effectiveness of fine aggregate replacement by crushed glass material in concrete; to study the influence of waste glass on properties of hardened concrete mixes such as: compressive strength, split tensile

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strength. The details of this experimental study are discussed in the following sections.

II. EXPERIMENTAL STUDY

A. Materials

i. Cement

Cement is a binder, a substance that sets and hardens and can bind other materials together. In this experimental study, Ordinary Portland cement 53 grade conforming to IS: 12269-1987 is used. The properties of cement used are given below in Table 1.

Table.1: Properties of cement

Physical property	Results	Reference
Standard consistency	**20%**	IS4031(part4):1988
Fineness	**4%**	IS4031(part1):1996
Vicat Initial setting time	**30 mins**	IS 269-1989 IS 8112-1989 IS 12269-1987
Vicat Final setting time	**170 mins**	

ii. Aggregates

Aggregates can be categorized into coarse and fine aggregates. In this empirical study, Coarse aggregate which passes through 20 mm IS sieve and retained on 4.75 mm according to IS: 383-1970, naturally occurring crushed stone used in the work. Fine aggregate resulting from natural disintegration of rock and which passes through 4.75 mm IS sieve and contains 75 micron and conforms to IS 383-1970, zone-2 is used. Table 2 illustrates the properties of aggregates.

Table.2: Properties of aggregates

Types	Physical Property	Results	Reference
Coarse	Specific Gravity	**2.6**	IS 2386-part III
Fine	Specific gravity	**2.62**	IS 2386:1963 part III clause 2.4.2
	Sieve analysis Zone. Fineness modulus	**Zone ll IS 383:1970**	Table 4 IS 383:1970 IS 2386:1963 part I

iii. Crushed glass material

Crushed glass material are generally angular in shape and some flat and elongated particles It passes through 2.36mm IS sieve and retained on 300µm is used in this experimental study. It is similar to natural sand and exhibits properties of fine aggregate. Table 3 emphasizes the properties of crushed glass material.

Table.3: Properties of Crushed glass material

Property	Results
Colour	white
Specific gravity	2.57

The slight variation in specific gravity of crushed glass material is due to the dryness of material, manufactured from the glass factory.

Fig.1: crushed glass material

It is a transparent material produced by melting a mixture of materials such as silica, soda ash, and $CaCO_3$ at high temperature followed by cooling where solidification occurs without crystallization. In its original form, glass comes as a balanced combination from three main raw natural materials: sand, silica, and limestone. The crushed glass material was obtained from glass factory situated at Kuniyamuthur, Coimbatore.

B. Mix proportions

Concrete mix design may be defined as the art of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength. The mix proportions shall be selected to ensure the workability of the fresh concrete and when concrete is hardened, it shall have the required strength, durability and surface finish. The mix design of M20 grade of concrete is done by IS method following the guidelines of IS10262-1982(6). The type of cement used in this experiment is OPC 53 grade conforming to IS12269-1987. The minimum and maximum cement content should be 320kg/m³ and 450kg/m³. The selection of maximum water cement ratio from T-5 IS456 is 0.45. As per our mix design calculation the ratio of M-20 grade of Cement concrete is **1:1.7:2.7** and this mix design are used throughout our empirical study. The varying mix proportions of fine aggregate and crushed glass material are depicted in table 4.

Table.4: Mix proportions

Mix proportions	% of replacement	Crushed glass material	Fine aggregate
		kg/m³	
Conventional concrete	-	-	698
Mix 1	5%	34.9	663.1
Mix 2	8%	55.84	642.16
Mix 3	10%	69.8	628.2
Mix 4	20%	139.6	558.4
Mix 5	30%	209.4	488.6
Mix 6	40%	279.2	418.8

The quantity of cement, water and course aggregate used in this mix proportions remains same and are given by,

Cement = 400 kg/m³
Water = 191 kg/m³
Course aggregate = 1083 kg/m³
The main objective of designed concrete mix is to determine the most economical and practical combination of readily available materials to produce concrete which will satisfy the performance requirement under particular conditions of use. The mix design is based on the quantity, quality and grading of the materials, any variation in quantity, quality and gradation will result changes in the mix design.

III. RESULTS AND DISCUSSION

The cement concrete cube size of 150mm*150mm*150mm and cylinder size of 150mm*300mm were casted. These specimens are subjected to compression test and split tensile test after 7, 14 and 28 days of curing. Henceforth, the results are tabulated accordingly. These denouements are compared with the conventional concrete results to find out the optimum value of replacement for natural sand with crushed glass material, given 5%, 8%, 10%, 20%, 30% and 40%.

A. Conventional concrete

Conventional concrete was also manifested as normal concrete, which has ingredients such as aggregates, water and cement. After seven days of curing, the development of the strength of conventional concrete starts. On reaching 28 days almost 75-80% of the total strength is attained.

Table.5 Test results for conventional concrete

Tests	Curing days	Strength (N/mm²)
Compression test	7	23.83
	14	26.44
	28	32.88
Split tensile test	7	1.17
	14	2.02
	28	3.51

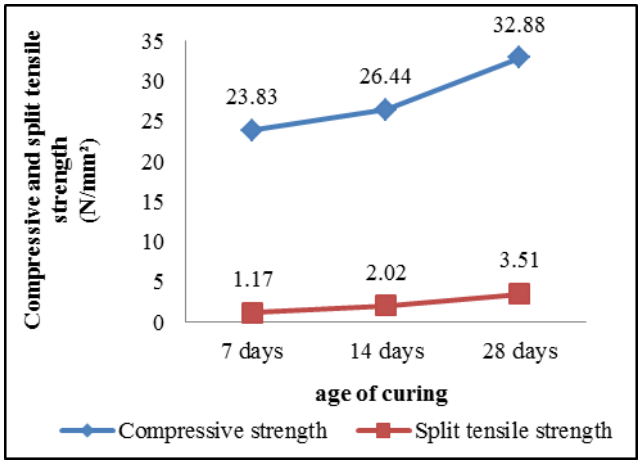


Fig.2 Results of compression and split tensile test

From the observation and graph shown above the results obtained for compressive strength is tracked to be 32.88 N/mm² and where as split tensile strength is 3.51 N/mm².These inferences are used for further empirical studies.

B. Designed concrete for various mixes

The designed concrete mix is used to produce a special concrete having desired workability, durability, compressive strength and split tensile strength which was attained at 28 days for a specified grade of concrete. The available materials for producing concrete can be used economically with comparatively low cost.

Table.6 test results for 7 days

Mix	Age of concrete	Compressive strength (N/mm²)	Split tensile strength (N/mm²)
5%	7	19.50	0.69
8%	7	24.41	1.37
10%	7	22.57	1.22
20%	7	15.6	1.02
30%	7	14.95	0.8
40%	7	14.50	0.85

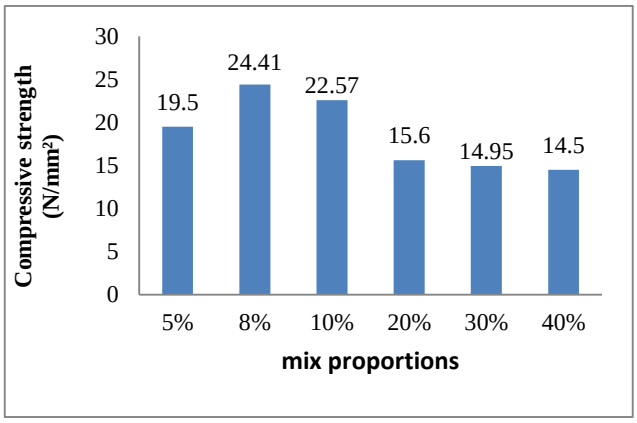


Fig.3 Compression test results of various mixes for 7 days

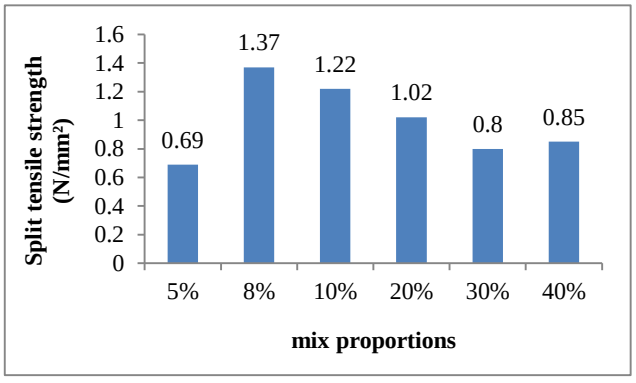


Fig.4 Split tensile test results of various mixes for 7 days

The test results obtained for seven days compressive and split tensile strength was used to analyze the gain of early strength and is calculated to be about a certain percentage than that of 28 days strength. The results are shown in the above table.6, for compression test and split tensile test. 8% replacement shows a noticeable increment when collating with results obtain for other design mixes.

Tabel.7 Test results for 14 days

Mix	Age of concrete	Compressive strength (N/mm²)	Split tensile strength (N/mm²)
5%	14	22.69	1.29
8%	14	29.16	2.77
10%	14	28.91	2.59
20%	14	21.23	1.72
30%	14	17.56	1.6
40%	14	17.13	1.49

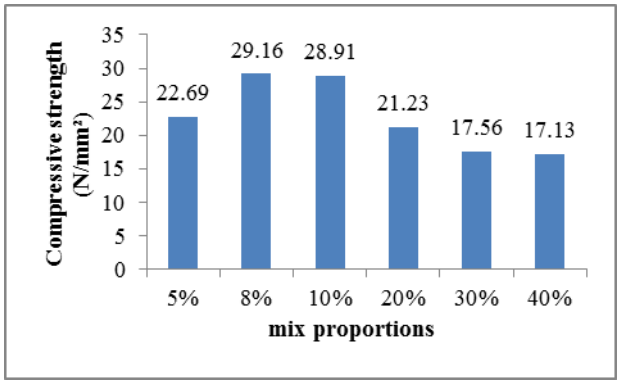


Fig.5 Compression test results of various mixes for 14 days

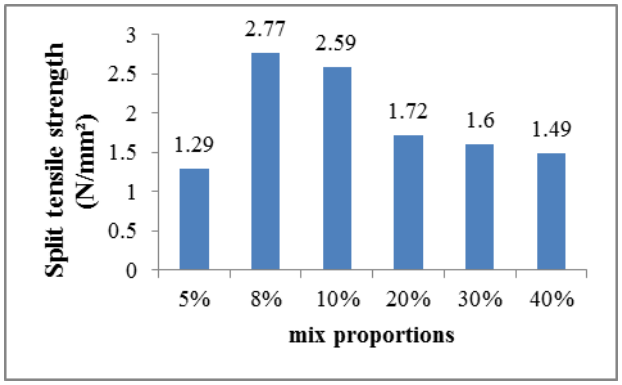


Fig.6 Split tensile test results of various mixes for 14 days

From the above graph, the results obtained for compression test and split tensile test for 8% replacement illustrates a small increment when compared to the test results acquired for 10% replacement.

As per the results obtained, it shows a notable increase in strength for the tests conducted after 28 days curing. The test results are provided in the table given below and respective graphs are plotted accordingly.

Table.8 Test results for 28 days

Mix	Age of concrete	Compressive strength (N/mm²)	Split tensile strength (N/mm²)
5%	28	25.14	2.10
8%	28	32.7	3.5
10%	28	37.68	4.09
20%	28	24.38	2.62
30%	28	21.68	2.72
40%	28	21.37	2.47

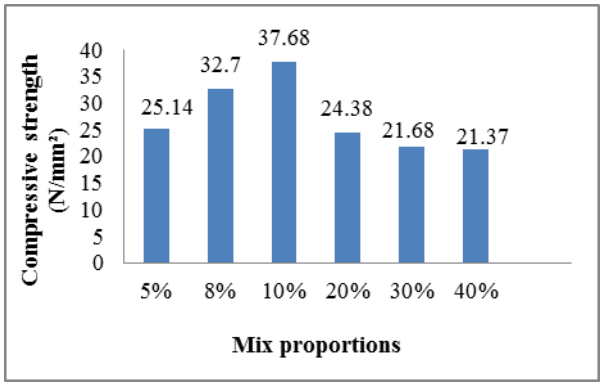


Fig.7 Compression test results of various mixes for 28 days

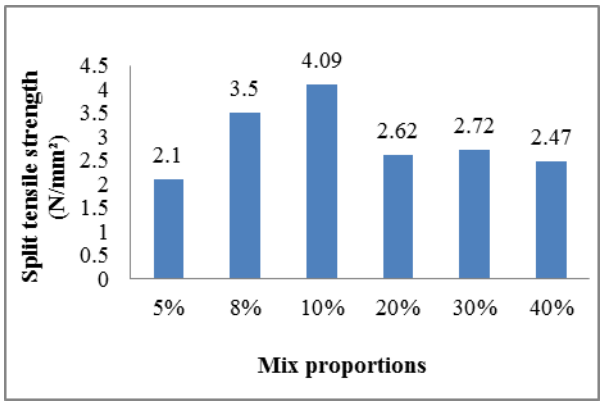
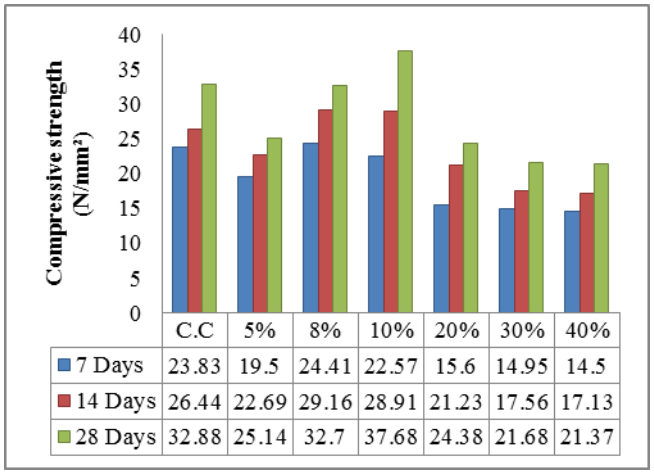


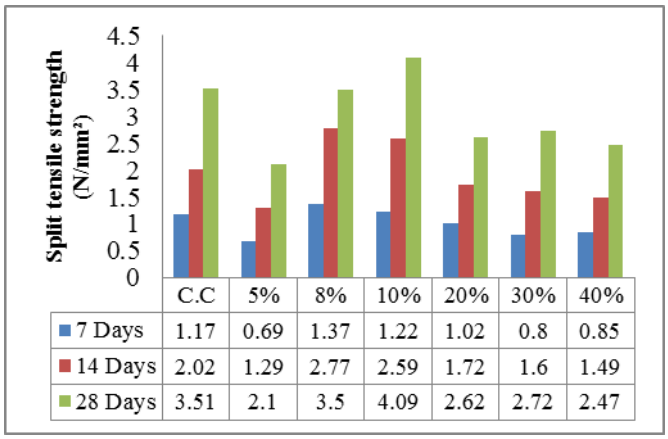
Fig.8 Split tensile test results of various mixes for 28 days

From the above tables, every single percentage of replacement, the concrete gains strength in 7, 14 and 28 days. It is evident that concrete gains strength rapidly in the initial days after casting. When its strength have reached in 28 days still continue to gain strength after the period but that the ratio of gain in compressive strength and split tensile strength is very less compared to that in 28 days.



	C.C	5%	8%	10%	20%	30%	40%
7 Days	23.83	19.5	24.41	22.57	15.6	14.95	14.5
14 Days	26.44	22.69	29.16	28.91	21.23	17.56	17.13
28 Days	32.88	25.14	32.7	37.68	24.38	21.68	21.37

Fig.9 Comparison of compression test results of various mixes



	C.C	5%	8%	10%	20%	30%	40%
7 Days	1.17	0.69	1.37	1.22	1.02	0.8	0.85
14 Days	2.02	1.29	2.77	2.59	1.72	1.6	1.49
28 Days	3.51	2.1	3.5	4.09	2.62	2.72	2.47

Fig.10 Comparison of Split tensile test results of various mixes

IV. CONCLUSION

The test results for conventional and designed concrete were compared in order to obtain the strength aspect of concrete. The denouements are tabulated by testing of cubes and cylinders for 7, 14 and 28 days. The results indicates that the maximum compressive and split tensile strength was attained for a partial replacement of natural sand by 10% replacement of crushed glass material. For 10% replacement, the compressive strength was increased about 15% and also the split tensile strength shows an increment of about 17% than that of conventional concrete. Further it depicts that the strength was decreased for less than 8% and between 10% and 40% replacement, the strength of concrete reduces and was lower than that of the control.

- By using low-cost and environmental friendly building materials from industrial waste, a sustainable concrete can be produced.
- It is an additional option for communities targeting glass for crushing, and to potentially reduce the costs of glass disposal and concrete production.
- Glass is a good waste material, which can be used as a partial replacement of fine aggregate in the concrete.
- Partial replacement of sand by crushed glass material is economical.

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