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A Study on Mechanical Properties of Waste Glass Powder and Lime Stone Powder Mixed Concrete

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Abstract:

Glass is a non-bio degradable material. In this study we use waste glass material and lime stone powder as replacement materials. Use of glass powder as a partial replacement can improve the chemical, mechanical and physical properties of concrete. Use of glass as replacing material alternative to dumping it as a waste reduces the consumption of natural resources. By using waste glass powder and lime stone powder, production of cement can be reduced and also cost of cement production also reduced. Their mechanical properties such as compressive strength, split tensile strength and durability tests were also conducted and their results were investigated. The addition of limestone powder can effectively improve the shrinkage performance of cement mortar. The compressive strength test results indicated that concrete gave better strength and strength tests on concrete were carried out by adding 0–20% waste glass powder, in which binder (cement + lime stone powder) ratio is kept the same for all replacement levels. The lime stone powder increases the compressive strength and tensile strength.

Keywords — **waste glass powder, lime stone powder, compressive strength.**

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I. INTRODUCTION

Cement, the primary component of concrete that provides strength and acts as a binder for the other elements, is manufactured in vast quantities [1]. Utilizing waste glass as a substitute for cement has the potential to decrease the expenses associated with concrete production and the amount of cement used. Consequently, this would directly result in a reduction in CO_2 emissions, which are closely linked to cement manufacturing. Additionally, this practice decreases the expenses associated with concrete production by utilizing a waste material [2]. Globally, there is a significant production of waste glass powder (WGP), with over 200 million tons of solid trash generated, of which approximately 7% constitutes glass waste [3]. The concrete industry is a significant contributor to global warming due to its massive emission of CO_2 into the environment [4].

Minimizing the quantity of CO_2 in the manufacturing of concrete yields a beneficial effect on the environment. This fact has resulted in a heightened interest in the development of solutions aimed at partially replacing cement. Alternative materials, such as fly ash, lime stone powder from other industries or natural raw materials like different fillers, can be used as substitutes for cement [5]. Lime serves as the principal adhesive in several mixtures, including lime putty or hydraulic lime. Lime is a resilient and adaptable substance that has been widely employed in building, particularly in applications such as lime concrete and lime mortar. Lime is an inorganic substance that mostly consists of carbonates, oxides, and hydroxides of calcium [6].

In most cases, limestone powder primarily functions as a filler due to its absence of pozzolanic and self-cementing capabilities. Currently, the recommended dosage of limestone powder in concrete is typically limited to a maximum of 15% [7]. At first, scrap glass was used as a replacement for fine aggregate in concrete. It was seen that this led to a deterioration in the mechanical and durability characteristics of the modified concrete. This degradation was attributed to the heightened likelihood of alkali-silica reaction (ASR) [8]. The utilization of finely fragmented glass powder as a substitute for cement has produced favourable outcomes. The ideal quantity of this glass powder is determined through an analysis of cement paste research. The characteristics of the modified mixtures including the glass powder are then compared to those of nominal concrete [9].

The concrete specimens were prepared by partially substituting Ordinary Portland cement with hydraulic lime at different proportions, namely 0%, 25%, 50%, and 75%. Similarly, the mortar samples were prepared by substituting Ordinary Portland cement with hydraulic lime at proportions of 0%, 25%, 50%, 75%, and 100%.The compressive strength of lime concrete cube specimens increases when lime is replaced up to 15%, but with larger percentages, the strength reduces significantly. [10].

When lime is added to mortars, it enhances both the fresh and hardened characteristics of the mixture. It improves the ability of the concrete to retain water and be easily worked with, increases the efficiency of its use, and enables high-quality work to be done on fresh concrete. Enhances resistance to natural movement, such as thermal expansion and contraction, creep, and frost, while also improving overall toughness by reducing cracking and debonding [11].

The main result of adding water to limestone powder is mainly the production of calcium hydroxide, which inhibits the development of strength in the mixture. Nevertheless, our research indicates that leftover limestone powder is suitable for partially replacing cement. [12]. an additional aspect that influences the durability of concrete is its capacity to absorb. By including limestone dust as partial replacement for sand at a proportion of 15%, the concrete's absorbability is reduced [13].

II. MATERIALS

The various materials used in this project are

- Cement
- Coarse aggregate
- Fine aggregate
- Lime stone powder
- Waste glass powder
- Water

A. *Cement*

The cement utilized in this experiment is Ultratech Ordinary Portland Cement, which is classified as Grade 53 and has a specific gravity of 3.15 and its other properties in accordance with the requirements of IS 12269-1987.

B. *Coarse aggregate*

Angular aggregates of maximum size 20 mm with a specific gravity of 2.65 confirming to the requirements of IS 383-1970. The coarse aggregate is obtained from local quarry.

C. *Fine Aggregate*

The fine aggregate used in this study is m-sand. It is obtained from the local crusher near our locality.

D. *Lime Stone Powder*

Limestone, the predominant type of calcium carbonate, is widely utilized in the production of cement. Cements of various varieties are primarily produced by heating a blend of approximately 75% limestone and 25% clay to create a calcium silicate clinker, which is further pulverized and combined with a tiny quantity of gypsum [14].

FIG 1 LIME STONE POWDER

In this project lime stone powder is obtained from nearby local manufacturers.

TABLE 1- LIME STONE PROPERTIES

SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	others
1.08	0.48	95.12	0.39	8.86	2.01

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E. Waste Glass Powder

Glass is a silica-rich amorphous material that has the potential to exhibit Pozzolanic properties when its particle size is smaller than 90 micro meters.

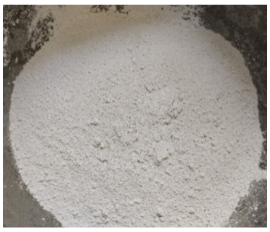

FIG 2 WASTE GLASS POWDER

Waste glass powder is obtained from ARPN Alagappa Nadar & Bros, manufacturer in Madurai, Tamil Nadu.

TABLE 2- WASTE GLASS PROPERTIES

LoT	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O
0.24	76.39	2.19	6.05	1.18	8.86	2.84

F. Water

For the purpose of this investigation study, the concrete was prepared by combining laboratory tap water.

III. METHODS

Basic properties of concrete is consists of limestone powder and waste glass powder. A total of 5 of experimental groups were created, with the one control mix. A control mix is of m35 grade and 0.4 water cement ratio. This control (or) nominal mix is studied against 4 replacement mix. In this four replacement mix, 10 percent limestone powder (LS) is taken as constant. In first mix, 10 percent of limestone powder and 5 percent waste glass powder (WGP) is used as replacement for cement.

In second replacement mix 10 percent lime stone powder and 10 percent waste glass powder (WG) were used as replacement for cement. In third mix 10 percent lime stone powder, 15 percent waste glass powder were used. In the fourth replacement mix, 10 percent replacement mix and 20 percent waste glass powder were used as partial replacement for cement in concrete.

The specimens in the aforementioned groups were cubic in shape, with dimensions of 150mm x 150mm x 150mm, and there were a certain number of specimens in each group. The concrete had a design strength value of C35, and the Table provides the particular ratios for the different mixes.

TABLE 3
CONCRETE MIX PROPORTION

Symbol	W/C	C	W	LS	WGP	FA	CA
NM	0.4	395	158	-	-	680	1249
LS10 WG 5	0.4	337.7	158	39.5	17.78	680	1249
L10 WG 10	0.4	319.9	158	39.5	35.55	680	1249
L10-WG 15	0.4	302.2	158	39.5	53.33	680	1249
L10 WG 20	0.4	284.4	158	39.5	71.1	680	1249

Concrete mixes proportion (Unit Weight, Kg/m^3)

G. Preparation of samples

The mechanical properties of concrete were assessed using M35 grade of concrete in this experiment. The cement is partially substituted with limestone powder and waste glass powder. The fundamental characteristics, such as the specific gravity of fine aggregates, the sieve analysis of coarse aggregates, and the consistency and setting time of cement, were determined. Before preparing the samples all the materials has to be checked carefully.

Prior to blending concrete, ensure the precise measurement of different substances in accordance with the prescribed mix proportion. Sequentially add coarse aggregate, fine aggregate, cement, limestone powder, and waste glass powder into the mixer. Subsequently, introduce the water reduction agent into the mixing water.

FIG 3 CASTING OF CUBES

Lastly, pour the water into the blender and process for a duration of 3 minutes. The concrete was subsequently introduced into the mould and uniformly vibrated. After 24 hours, the mould was extracted and assigned a number, and the sample was then placed inside a conventional curing tank.

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IV. EXPERIMENTAL SCHEME

H. Compressive Test

The concrete compressive strength testing was conducted at certain time intervals of 7 days, 14 days, 28 days, and 90 days after the concrete was mixed, following the guidelines outlined in ASTM C39.

The compressive strength of concrete is determined by dividing the load at which failure occurs by the cross-sectional area of the specimen. The compressive strength of a material is calculated by dividing the load applied to it by the cross-sectional area of the material.

FIG 4 COMPRESSIVE TEST OF CUBES

I. Split Tensile Test

The split tensile strength of the cylinder specimens was measured at 28 days for all five distinct mixes. The split tensile test is a technique employed to ascertain the tensile strength of concrete cylinders. The approach is derived from ASTMC496, which is a standardized test method for cylindrical concrete specimens. This method is comparable to IS 5816-1999. The Cylinder specimen is correctly positioned on the machine and load is applied steadily increases until the specimen collapses. $T = 2P/\pi Ld$,

Where,

T is the stress in N/mm^2

P is the load applied

L is the length of the specimen and

d is the diameter of the specimen.

FIG 5 SPLIT TENSILE TEST OF CUBES

J. Durability Tests

Subsequent materials and poor compaction at later ages affected the excellence and durability of concrete. Numerous experiments were conducted on concrete mixtures, including water absorption and acid tests

1. Acid Test: The concrete cube specimens were immersed in the water mixed with 5 percent of concentrated hydrochloric acid. The acid test is calculated by

(Initial weight – final weight) / initial weight x 100

FIG 6 ACID TEST OF CUBES

2. Water Absorption Test: In accordance with IS 1124, concrete samples were used for this test. Cube samples of 100 mm were prepared as the specimen size for this test.

The cubes were then dried in an oven at 105°C for 24 hours, and once they reached a consistent weight (W1), they were dipped into water. Cubes were taken out of the water, extra water was wiped off with a cloth, and weight was recorded as (W2)

Water absorption = $(W_2 - W_1) / W_1 \times 100$

V. RESULTS AND DISCUSSION

K. Compressive Test

As the duration of the curing process grows, the compressive strength of the material also increases. The compressive strength of the replacement mix

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exceeds the nominal mix compressive strength value.

TABLE 4 - COMPRESSIVE TEST RESULTS

MIX	21st day	28th day	56th day	90th day
NM	26.5	27	28.34	29.3
LS10 WGP 5	32	33.5	34.8	36
LS10 WGP 10	41.4	42	42.6	44
LS10 WGP 15	32.5	33	34.4	35.9
LS10 WGP 20	24	25.5	27	26

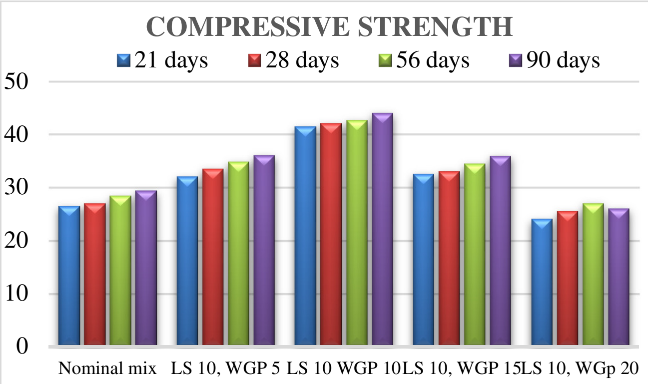

FIG. 7 COMPRESSIVE STRENGTH

From the graph, it is evident that the compressive strength value improves as the replacement percentage of waste glass powder increases, up to a maximum of 10 percent. The strength rates grew by 21%, 56% over a period of 21 days, with the strength increasing rates achieved by replacing waste glass powder up to 10%.

The compressive strength were increased by 24%, 55% for 28th day compressive strength. The strength diminishes following a 10% substitution of waste glass powder. The addition of 10% limestone powder and 20% waste glass powder yields moderate results in terms of compressive strength. The rise in compressive strength is attributed to the increase in pozzolanic and filler activity of the waste glass powder.

The reduction in compressive strength can be attributed to the inadequate bond between the aggregate and cement.The findings demonstrate that including a 10% dosage of limestone powder can enhance the compressive strength of concrete.

L. Split Tensile Test

This test is being conducted on cylinders with dimensions of 150mm by 300mm.

TABLE 5 - SPLIT TENSILE TEST

MIX	14th day	28th day	56th day
NM	2	2.5	3.6
LS10 WGP 5	1.98	2.6	3
LS10 WGP 10	2.3	2.9	3.9
LS10 WGP 15	2.2	2.4	3.1
LS10 WGP 20	2	2.17	2.9

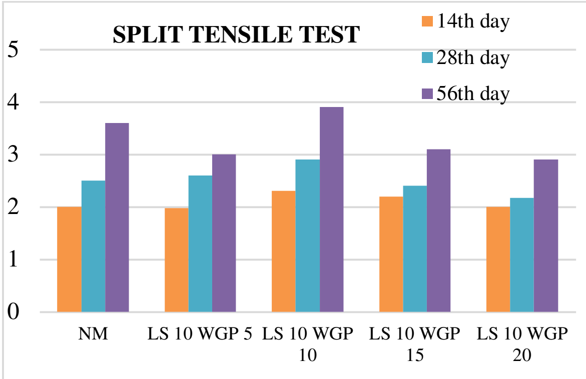

FIG. 8 SPLIT TENSILE STRENGTH.

Fig.8 Demonstrates the split tensile test conducted on a cylindrical concrete specimen. According to the figure, the use of 10 percent limestone powder and 10 percent waste glass powder yields more effective outcomes compared to the typical combination. The inclusion of 15 percent and 20 percent waste glass powder results in lower tensile strength compared to all other mixtures. The incorporation of 10 percent limestone powder and 5 percent waste glass powder results in a lower tensile strength compared to the traditional mixture. The inclusion of 15 percent waste glass powder and 10 percent limestone powder yields satisfactory outcomes.

M. Durability Tests

1. Acid Test:

The acid test results are shown below

TABLE 6-ACID TEST RESULT

Specimen	Percentage loss of weight in control mix specimen at 28 days	Percentage loss of weight in replacement mix specimen at 28 days
1	14.7	7.2
2	13.1	9.84
3	17	3.5

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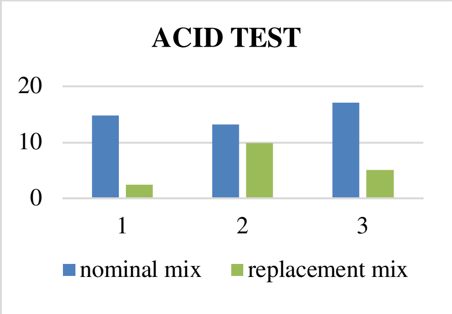

FIG. 9 ACID TEST.

Based on this figure 9, the replacement mix exhibits reduced reactivity to acid attack in comparison to ordinary concrete. The experimental results indicate that the performance of concrete containing a mixture of limestone powder and waste glass powder is superior to that of concrete made with a standard mix.

2. Water Absorption Test:

The results obtained from the water absorption test on concrete cubes were recorded. The increasing of lime powder content as cement replacement materials led to a decrease in the water absorption.

TABLE 6-ACID TEST RESULT

MIX	WATER ABSORPTION (%)
NM	2.5
LS10 WGP 5	1.8
LS10 WGP 10	1.75
LS10 WGP 15	1.4
LS10 WGP 20	1.35

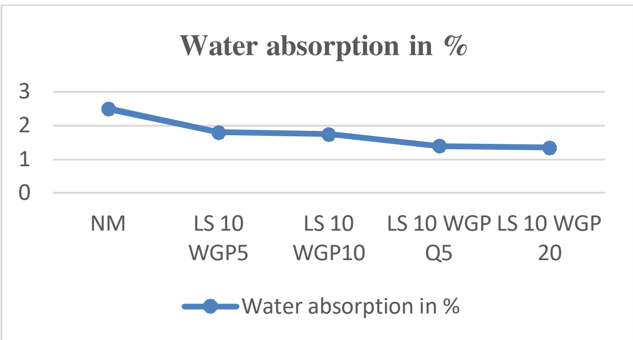

FIG. 10 WATER ABSORPTION.

The findings demonstrate that augmenting the quantity of Glass Powder and Lime stone Powder in the mixture decreases water absorption in comparison to the control mixture. The control mix exhibits a higher proportion of water absorption compared to the replacement mix. The decrease in water absorption can be attributed to the enhanced adhesion and density of the aggregate paste matrix resulting from the inclusion of glass and lime stone powder.

VI. CONCLUSIONS

The following conclusions are made

- The addition of waste glass powder and limestone powder enhanced the fresh properties of concrete, hence increasing its workability.
- The ideal replacement for cement with limestone powder was determined to be 10%.The replacement of cement with waste glass powder leads to a significant improvement in compressive strength, up to 10%.
- The extent of cement replacement with limestone powder and the reduction of emissions are closely tied to the level of replacement.
- The compressive strength of concrete increases up to the 10% replacement of waste glass powder and limestone powder. Further increase in waste glass powder causes decrease in compressive strength
- The split tensile test of concrete shows effective results at 10% replacement of Waste Glass Powder and Lime Stone powder.
- In acid tests, the replacement mix shows less reactive to the acid attacks than the conventional mix.
- Based on this study, it is evident that waste glass powder and limestone powder can be used as substitutes for cement in the production of concrete, yielding positive results.

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