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Influence of Waste Glass Powder as a Partial Replacement of Cement in Concrete

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Abstract: As the global construction industry increasingly relies on concrete for infrastructure, the significant carbon footprint of traditional cement production—responsible for approximately 7% of greenhouse gas emissions—presents a critical environmental challenge.

To mitigate global warming and address the growing crisis of industrial solid waste management, there is a vital shift toward integrating recycled industrial by-products as alternative binders.

Utilizing these waste materials not only diverts them from landfills but also offers a more energy-efficient and economical substitute for virgin resources.

This research explores the viability of such sustainable binders to enhance the ecological profile of concrete without compromising its structural versatility. By repurposing industrial waste within the vast scope of global construction, the industry can achieve a circular economy while reducing its overall environmental impact.

Keywords: Indian Standard, Ordinary Portland Cement, Super-plasticizer, Water–cementitious materials ratio.

I. INTRODUCTION

Concrete is a foundational construction material valued for its durability and versatility, yet its heavy reliance on Ordinary Portland Cement (OPC) contributes significantly to global CO_2 emissions.

As the industry moves toward "zero-emanation" goals, replacing non-renewable resources with sustainable alternatives has become an environmental and economic necessity. Industrial waste management poses a global challenge, and repurposing non-biodegradable materials like waste glass offers a viable solution to reduce landfill pressure and carbon footprints. When processed into a fine powder, waste glass functions as a high-silica pozzolan, reacting with cement alkalis to enhance the formation of Calcium Silicate Hydrate (C-S-H).

This chemical transition strengthens the cement paste structure, reduces permeability through a micro-filler effect, and mitigates the risk of Alkali-Silica Reaction (ASR). Beyond improving the mechanical bond between paste and aggregate, the integration of glass powder optimizes energy consumption and lowers overall construction costs. This research evaluates the performance of glass powder as a partial cement substitute, aiming to validate its role in creating a more sustainable, high-performance concrete for modern infrastructure.

A. *Objectives*

1) To compare the strength using Glass Powder in Concrete with control mix.
2) To established alternate for cement with partial use of Glass Powder.
3) To determine the strength of concrete with replacement of cement by Glass powder.
4) Utilizing Glass Powder as an alternative of cement will induce a relief on waste disposal.
5) Reduction in environmental pollution involving production of cement and a contribution to the economy as well.
6) To established alternate for cement with partial use of Glass Powder.

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II. LITERATURE REVIEW

A brief review of work already done in the fie

Author Name	Work	Result
Shilpa Raju, Dr. P. R. Kumar (July -2014),	Effect of Using Glass Powder in Concrete	replacement of 20% cement by glass powder was found to have higher strength. Also alkalinity test was done to find out resistance to corrosion
Dhanaraj Mohan Patil, Dr. Keshav K. Sangle	Experimental Investigation Of Waste Glass Powder As Partial Replacement Of Cement In Concrete	Initial strength gain is very less due to addition of GLP on 7th day but it increases on the 28th day. It is found that 20% addition of GLP gives higher strength. And also GLP size less than 90 micron is very effective in Enhancement of strength
Shruthi, Chandrakala,G Narayana 2015	Partial Replacement Of Cement In Concrete Using Waste Glass Powder And M-Sand As Fine Aggregate	It is found that up to 15% addition of GLP gives higher strength. And also GLP size less than 90 micron is very effective in enhancement of strength.
Ashutosh Sharma, Ashutosh Sangamnerkar (February 2015)”	Glass Powder – A Partial Replacement for Cement	the maximum increase in strength of concrete occurred when 10% replacement was done with glass powder
J.M. Khatib,E.M. Negim,H.S. Sohl,N. Chileshe(2012)”	Glass Powder Utilization in Concrete Production	indicate that the maximum strength of concrete occurs at around 10% glass powder. Beyond 10% glass powder the strength of concrete reduces and is lower than that of the control.
Gunalaan Vasudevan1, Seri Ganis Kanapathy pillay (2013)	“Performance of Using Waste Glass Powder in Concrete as Replacement of Cement	The results indicate that the concrete with using waste glass powder were able to increase the workability of concrete and also the compressive strength

III. METHODOLOGY

A. Proposed Methodology During the Tenure of Research work

This chapter describes the materials used, the preparation of the test specimens and the test procedures. All the tests and the results shall be shown from appropriate table andXX graph that can be prepared simultaneously. In order to achieve the stated objectives, this study is carried out in few stages. On the initial stage, all the materials and equipment’s needed must be gathered or checked for availability. Then, waste paper pulp and marble waste is material applied as partial replacement of cement and fine aggregates respectively in manufacturing fresh concrete used in the concrete mixes according to the predefined proportions. Once the characteristic of the materials selected has been tested through appropriate tests, the applicable standard of specification should be referred. Finally, the results obtained were analyzed to draw out conclusion. The flow chart of all the stages is indicated Figure1.

ANALYSIS THE MATERIAL TEST DATA

↓

PREPARING CONCRETE MIXES

↓

TESTING CONCRETE

↓

RESULT ANALYSIS

↓

CONCLUSION

Figure 1. : Flow Chart of the Study

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Chemical Properties of Glass Powder

Table no.1:- Chemical Properties of Glass Powder

Oxides	Oxides Present In Glass Powder (%)
CaO	11.42
SiO2	72.61
Al2O3	1.38
Fe2O3	9.70
MgO	0.79
Na2O	13.7
K2O	0.43

IV. CASTING DETAIL

A total of eight series of concrete specimens including the control specimen were prepared in order to examine the effect of substituting Glass Powder (0, 5, 10,15,20,25 and 30% by weight) in place of cement to investigate the basic strength properties of concrete. For each mix six samples of cube were prepared.

Ordinary Portland cement (OPC), grade 43 is used throughout the investigation. The Glass powder obtained as an industrial by-product directly from the deposits of Glass factories, which is generated during the sawing, shaping and polishing processes of Glass Powder. The coarse aggregate used in this investigation have a maximum size of 20 mm with grading confirming to IS-383-1970. The natural river sand passing through 4.75mm sieves are used throughout the process. Ordinary clean potable tap water free from suspended particles and chemical substances was used for mixing and curing of concrete throughout the experiment

The design of concrete mix is done as per guidelines of IS 10262: 2009 with a grade of M25 of concrete. The simple hand mixing method was employed for mixing of concrete. First coarse and fine aggregates are fed alternately, followed by cement. Then required quantity of water was slowly added into the mix to make the concrete workable till it attains a uniform colour. The mixing was done for two minutes for all the ingredients to mix properly. Compaction of all the specimen was done by using shake table vibrator. The top surface of concrete is levelled, finished smooth by using a trowel and wooden float. The specimen detail and date of concreting was specified on top surface to identify it properly. After six hours, all the concrete specimens were removed from the mould and placed in the curing tank for 7, 14 and 28 days curing purpose.

The various tests on the concrete ingredients that were required for the proper design mix were carried out separately and given by –

A. Concrete Ingredients

Cement
Sand
Aggregate
Water

V. MATERIAL TESTS

Material / Test	Parameter / Standard	Methodology & Apparatus	Key Experimental Values
Cement	Standard Consistency (IS: 4031-P4)	Vicat Apparatus (10mm plunger); measured at 33-35mm penetration from top.	34%
	Soundness (Le-Chatelier)	Measured expansion after 3 hours of boiling in a split brass mould.	< 10mm (Pass)

	Initial Setting Time	Time elapsed until 1.13mm needle penetrates 33-35mm from top (0.85P water).	155 Minutes
	Final Setting Time	Time until annular attachment fails to leave an impression on the surface.	270 Minutes
Fine Aggregate (Sand)	Specific Gravity (Pycnometer)	Mass-based ratio of dry solids to distilled water using a 1kg pycnometer.	2.62 (S.G.), 0.66% (Abs.)
	Grading (Sieve Analysis)	Dry sieving of 1kg sample for 15 mins through standard ISO/IS sieves.	Zone II
Coarse Aggregate	Specific Gravity (Desiccator)	Determination of displaced volume using a grease-sealed desiccator.	2.86 (S.G.), 0.20% (Abs.)
	Grading (Sieve Analysis)	Mechanical gradation of 5kg sample; 20mm nominal size.	Well-graded
Waste Glass Powder	Physical Properties	Fine white powder, odorless, processed from recycled glass blocks	S.G.: 2.42 g/cm³
Concrete (Hardened)	Compressive Strength	Axial loading of 150 mm^3 cubes until failure using a UTM/CTM.	Strength = P/A

VI. RESULT & DISCUSSION

A. M25 Grade Compressive Strength

Table No. 2: M25 Grade Comp. Strength of Concrete

Sr. No	Glass powder	Avg. Strength (N/mm²) 7 Days	Avg. Strength (N/mm²) 14 Days	Avg. Strength (N/mm²) 28 Days
1	Control Mix	20.78	27.11	31.56
2	5%	20.89	27.56	31.91
3	10%	21.22	27.89	32.89
4	15%	21.89	28.44	33.67
5	20%	22.44	28.78	34.13
6	25%	20.56	26.67	31.22
7	30%	18.56	24.89	29.08

B. Compressive Strength Test Result at 7 Days

The compressive strength test result for M25 Grade of concrete after 7 days of curing is as given in table:

Table 3: compressive strength test result at 7 Days

Sr. No	Glass powder	Load (KN)	Avg. Load (KN)	Strength (N/mm²)	Avg. Strength (N/mm²)
		7 Days			
1	Control Mix	445	468	19.77	20.78
		490		21.77	

2	5%	445	470	19.77	20.89
		495		22	
3	10%	435	478	19.33	21.22
		420		18.66	
4	15%	530	485	23.55	21.56
		440		19.55	
5	20%	455	498	20.22	22.11
		505		22.44	
6	25%	430	463	19.11	20.56
		595		26.44	
7	30%	390	418	17.33	18.56
		445		19.77	

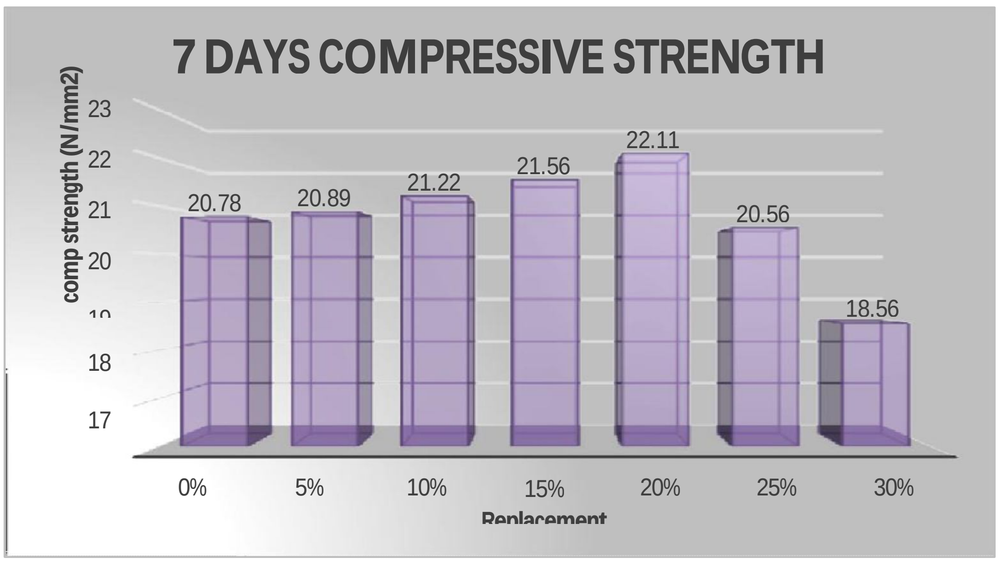

Figure 2:- The Compressive Strength Of Concrete At 7 Days

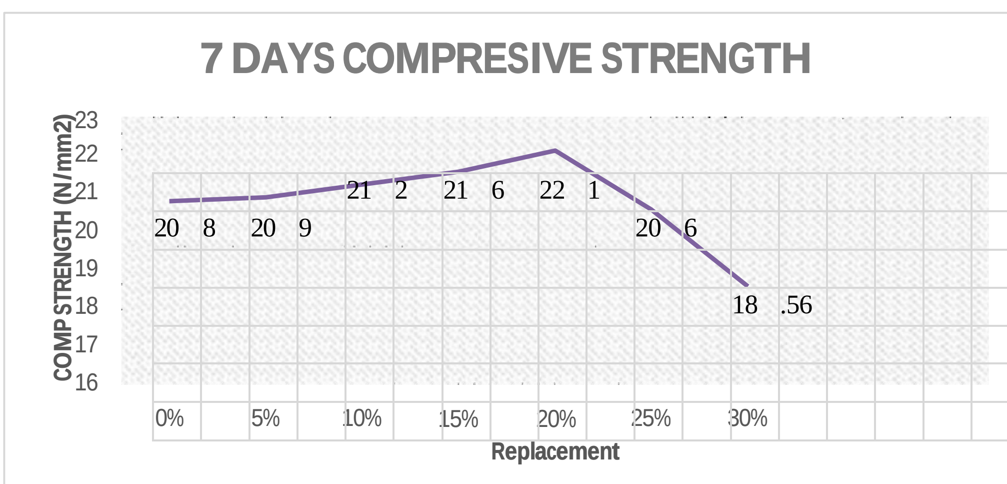

Figure 3:- The Compressive Strength Of Concrete At 7 Days

Observation:

In this graph we can see that the compressive strength of control mix at 7 days for M25 Grade is minimum than 5% to 10% replacement of cement by glass powder. But the compressive strength of control mix is maximum than 25% to 30% replacement of cement by glass powder.

Hence from this graph of 20% replacement of cement by glass powder gives 1.06 times more compressive strength than control mix. Hence, we can conclude that 20% replacement of cement by glass powder gives maximum strength.

C. 14 Days Compressive Strength

The compressive strength test result for M25 Grade of concrete after 14 days of curing is as given in table:

Table 4: compressive strength test result at 14 Days

Sr. No	Glass powder	Load (KN)	Avg. Load (KN)	Strength (N/mm^2)	Avg. Strength (N/mm^2)
		14 Days			
1	Control Mix	590	610	26.22	27.11
		630		28	
2	5%	595	620	26.44	27.56
		645		28.66	
3	10%	575	628	25.55	27.89
		680		30.22	
4	15%	580	633	25.77	28.11
		685		30.44	
5	20%	700	705	31.11	31.33
		710		31.55	
6	25%	555	600	24.66	26.67
		645		28.66	
7	30%	605	560	26.88	24.89
		515		22.88	

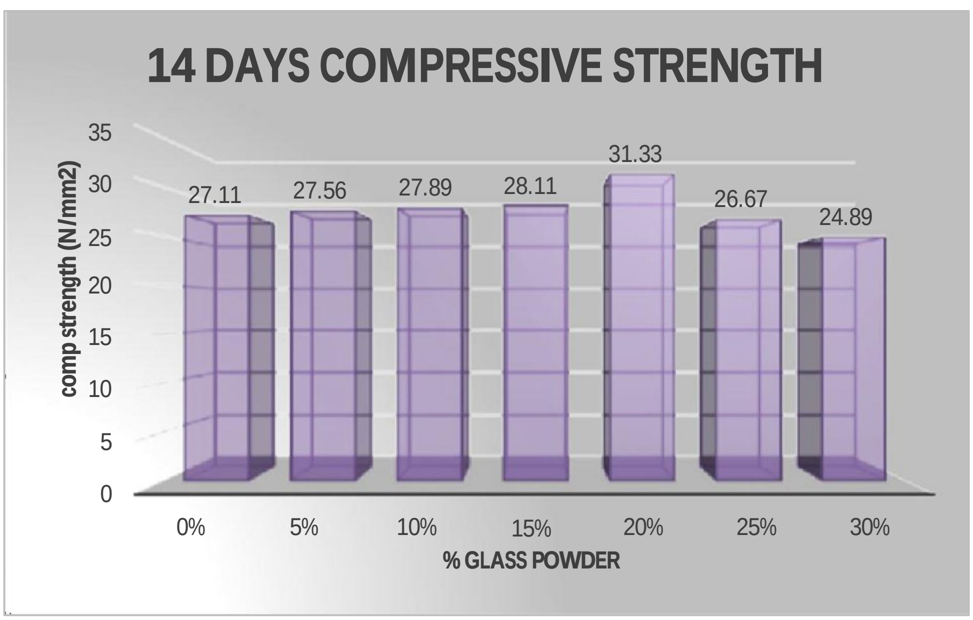

Figure 4:- The Compressive Strength Of Concrete At 14 Days

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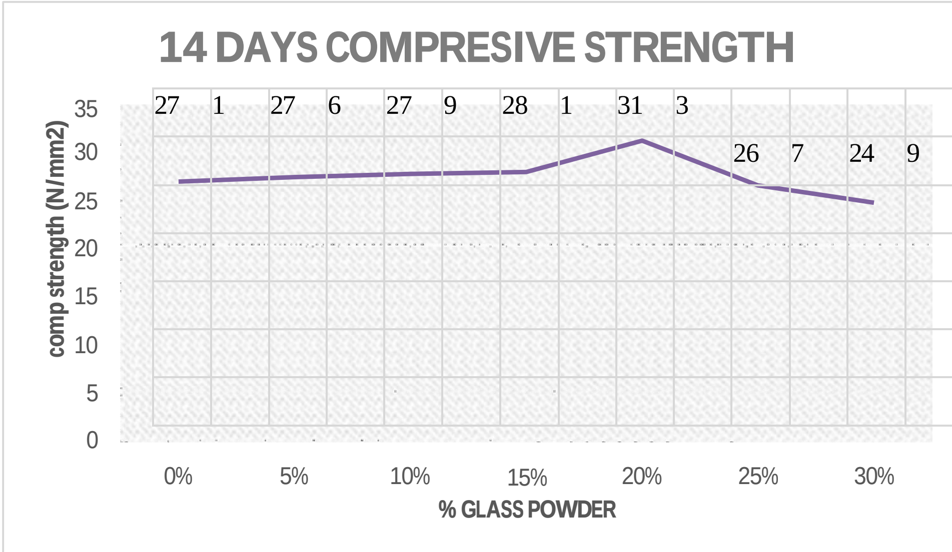

Figure 5:- The Compressive Strength Of Concrete At 14 Days

Observation:

In this graph we can see that the compressive strength of control mix at 14 days for M25 Grade is minimum than 5% to 10% replacement of cement by glass powder. But the compressive strength of control mix is maximum than 25% to 30% replacement of cement by glass powder.

Hence from this graph of 20% replacement of cement by glass powder gives 1.15 times more compressive strength than control mix. Hence, we can concluded that 20% replacement of cement by glass powder gives maximum strength.

D. 28 Days Compressive Strength

The compressive strength test result for M25 Grade of concrete after 28 days of curing isas given in table:

Table 5: Compressive Strength test result at 28 Days

Sr. No	Glass powder	Load (KN)	Avg. Load (KN)	Strength (N/mm²)	Avg. Strength (N/mm²)
		28 Days			
1	Control Mix	675	710	30	31.56
		745		33.11	
2	5%	680	718	30.22	31.91
		755		33.55	
3	10%	725	748	32.22	32.89
		755		33.55	
4	15%	790	773	35.11	34.33
		755		33.55	
5	20%	775	793	35.33	35.24
		790		35.11	
6	25%	715	703	31.77	31.22
		690		30.66	
7	30%	640	653	28.44	29.08
		665		29.55	

Figure 6:- The Compressive Strength of Concrete At 28 Days

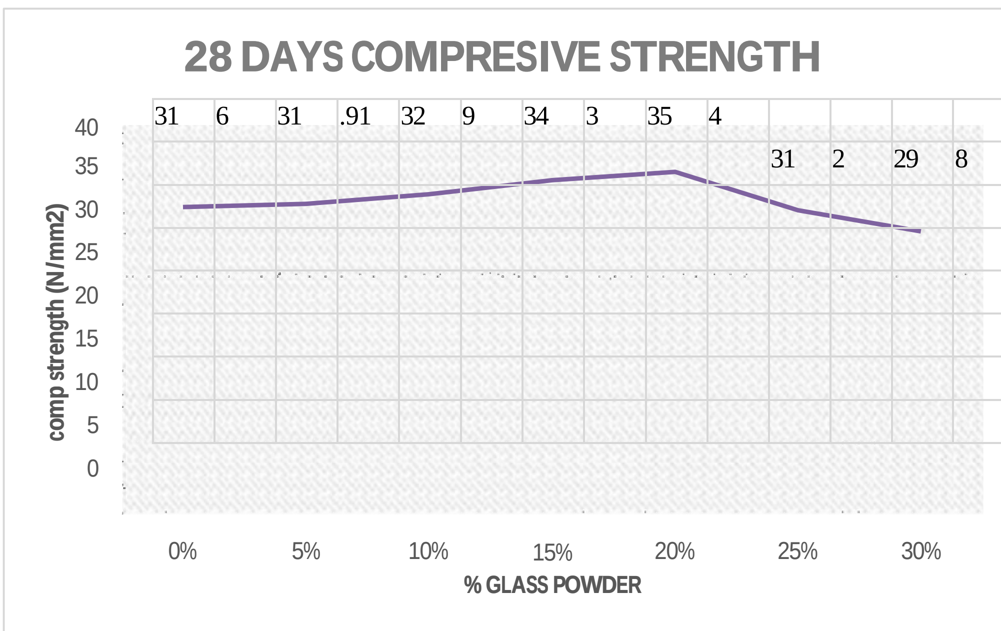

Figure 7:- the Compressive Strength of Cube At 28 Days

Observation:
In this graph we can see that the compressive strength of control mix at 28 days for M25 Grade is minimum than 5% to 10% replacement of cement by glass powder. But the compressive strength of control mix is maximum than 25% to 30% replacement of cement by glass powder.
Hence from this graph of 20% replacement of cement by glass powder gives 1.11 times more compressive strength than control mix. Hence, we can conclude that 20% replacement of cement by glass powder gives maximum strength.

E. Comparative compressive strength for 7,14 and 28 days
The compressive strength test result for M25 Grade of concrete after 7,14 and 28 days of curing is as given in table:

Table 6: compressive strength test result at 7,14 and 28 Days

Sr. No	GP	Comp. Strength (N/mm²)	Avg. Strength (N/mm²)	Comp Strength (N/mm²)	Avg. Strength (N/mm²)	Comp Strength (N/mm²)	Avg. Strength (N/mm²)
		7 Days		14 Days		28 Days	
1	Control Mix	19.77	20.78	26.22	27.11	30	31.56
		21.77		28		33.11	
2	5%	19.77	20.89	26.44	27.56	30.22	31.91
		22		28.66		33.55	
3	10%	19.33	21.22	25.55	27.89	32.22	32.89
		18.66		30.22		33.55	
4	15%	23.55	21.56	30.22	28.11	35.11	34.33
		19.55		25.77		33.55	
5	20%	20.22	22.11	31.11	31.33	35.33	35.24
		22.44		31.55		35.11	
6	25%	19.11	20.56	24.66	26.67	31.77	31.22
		26.44		28.66		30.66	
7	30%	17.33	18.56	26.88	24.89	28.44	29.08
		19.77		22.88		29.55	

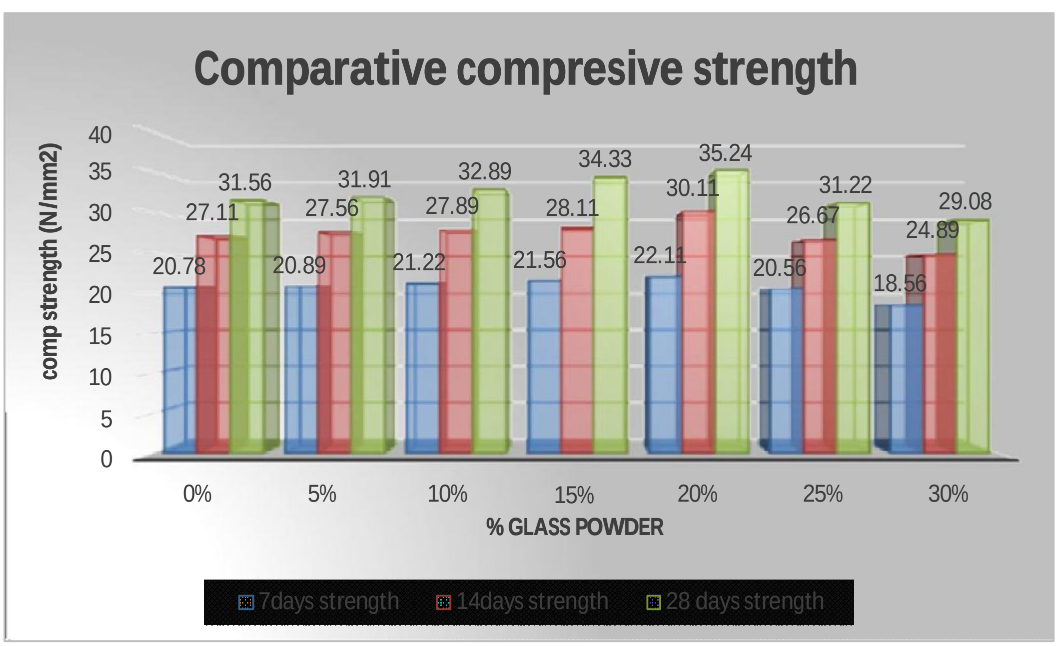

Figure 8:- The Comparative Comp. Strength Of M25 Grade Concrete

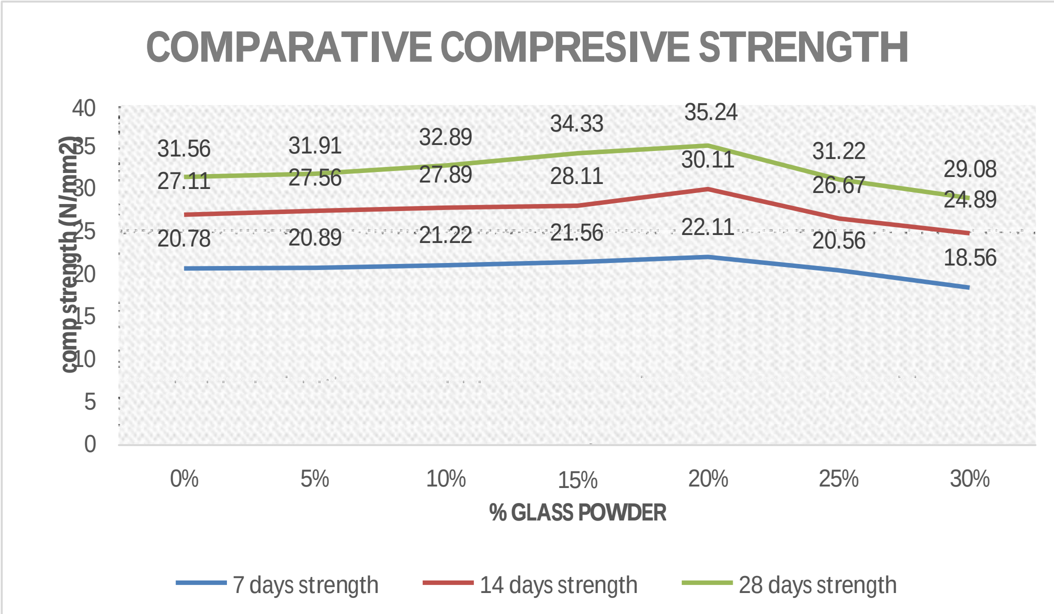

Figure 9:- The Comparative Comp. Strength Of M25 Grade Concrete

Observation:

In this graph we can see that the compressive strength of control mix at 7 days for M25 Grade is minimum than 5% to 10% replacement of cement by glass powder. But the compressive strength of control mix is maximum than 25% to 30% replacement of cement by glass powder.

Hence from this graph of 20% replacement of cement by glass powder gives times more compressive strength at 7 days than control mix, 1.15 times more compressive strength at 14 days than control mix, 1.11 times more compressive strength at 28 days than control mix.

Hence we can conclude that 20% replacement of cement by glass powder gives maximum strength.

VII. CONCLUSION & FUTURE SCOPE

The experimental investigation into the partial replacement of cement with industrial waste glass powder (WGP) reveals that a 20% substitution level serves as the optimal threshold for enhancing mechanical performance. This improvement is primarily attributed to the dual action of the pozzolanic reaction and the micro-filler effect, where the fine glass particles effectively occupy interstitial voids to create a denser concrete microstructure. While the high silica and alumina content of the glass powder significantly strengthens the paste-to-aggregate bond and reduces overall permeability, a dilution effect is observed when replacement exceeds 25%, resulting in a subsequent decline in compressive strength. Beyond structural benefits, utilizing finely ground WGP helps mitigate the risks of the Alkali-Silica Reaction (ASR) and offers a transformative environmental solution by reducing industrial waste accumulation and lowering the carbon emissions associated with traditional cement manufacturing.

To expand upon these findings, future studies should transition toward a multi-parameter analysis that explores the interaction of glass powder with various cement types and varying water-cement ratios. Research could be widened to evaluate hybrid replacement strategies where both cement and fine aggregates are substituted with glass-derived materials, or to investigate the mechanical synergy created by introducing glass fibers into the matrix for improved tensile capacity. Furthermore, there is a significant need for advanced microstructural characterization to precisely quantify the chemical transitions within the interfacial transition zone. Finally, assessing the bond strength between glass-integrated concrete and steel reinforcement will be essential in determining the feasibility of this sustainable material for large-scale reinforced concrete applications and specialized structural engineering projects.

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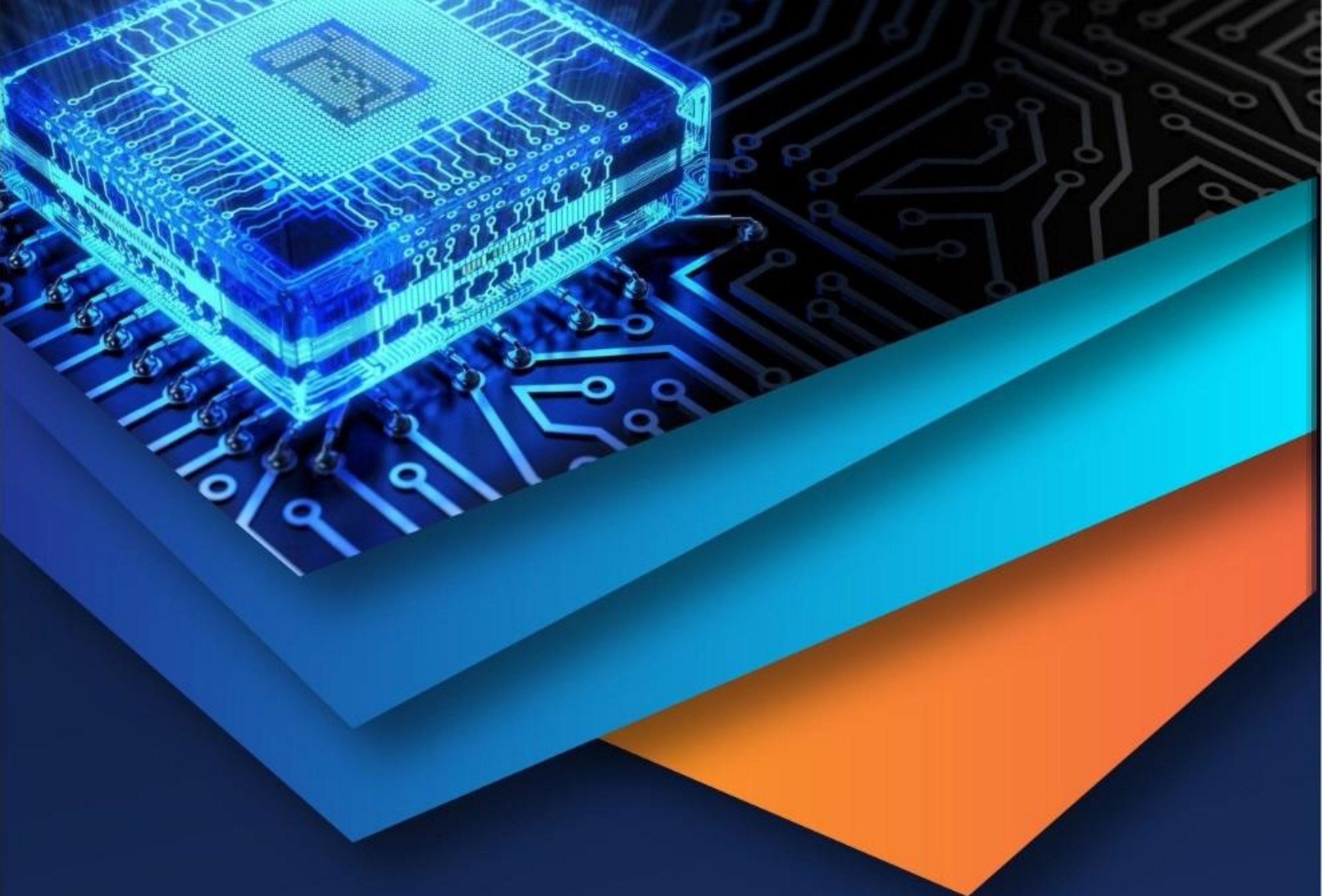

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