Utilization of Waste Glass and Marble Dust Powder as Fine Aggregate and Cement Replacement in M25 Grade Concrete

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Abstract: Glass that a sustainable way to address environmental issues and lower construction costs is to use waste materials like shattered glass and powdered marble dust into concrete. Limited recycling markets and environmental accumulation make glass garbage, which makes up a sizable amount of the world's solid waste stream, problematic. Concrete's mechanical qualities, such as its compressive strength (9.75%), splitting tensile strength (18.38%), flexural strength (8.92%), and modulus of elasticity (5.28%) at 28 days, are improved when up to 20% of the fine aggregates are replaced with crushed waste glass, according to research. This substitution also helps with waste management.

A similar alternate application for the massive amounts of trash produced during production is provided by marble dust powder, a byproduct of marble sculpting. Research indicates that after 28 days of curing, M20 grade concrete's compressive and tensile strengths are improved when up to 10% of the fine aggregates are substituted with marble dust powder. This method reduces disposal problems and encourages resource efficiency by using marble waste.

In addition to addressing environmental issues, combining these waste elements into concrete produces stronger, more affordable building materials. These developments show promise for improving material performance, cutting waste, conserving natural resources, and implementing sustainable building practices.

Keywords: *Flexural Strength, Modulus of Elasticity, Splitting Tensile Strength, Marble Dust.*

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I. INTRODUCTION

Glass leftovers may now be recycled into concrete, which helps reduce waste accumulation and address environmental concerns. Research has shown that it is possible to successfully include waste glass into concrete mixtures, providing a sustainable alternative to traditional concrete ingredients. Recycling leftover glass in concrete not only minimizes the loss of naturalresources but also lowers environmental hazards since it produces glass concrete, an unusual kind of concrete. (1-2) According to research, tiny waste glass particles can replace up to 20% of thecement cast-off in the manufacturing process without compromising the mechanical characteristics of finished product. Even though glass aggregate concrete isn't as strong as regular concrete, it can still be utilized for indoor applications, curbs, sidewalks, and pavementswhere strength isn't as important. This shows that leftover glass can be an excellent alternative to conventional concrete aggregates, offering the benefits of conservation and environmentally responsible building techniques. Additionally, it has been distinguished that the accumulation of glass fragments to concrete may enhance some of its mechanical qualities while reducing its dead load. **(3)**

The raw materials used to make Portland Cement Concrete (PCC) include granite for coarse aggregates, river sand for fine aggregates, and limestone, shale, and clay for cement. However, because of their widespread use, these resources are becoming scarcer.

There is an urgent need for sustainable building methods as a result of the ongoing depletion of these natural resources without adequate regeneration. Innovative approaches to reducing resource depletion are becoming more popular, such as using repurposed materials. By reducing building expenses and garbage disposal fees, these techniques not only lessen their negative effects on the environment but also have

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positive economic effects. For instance, recovered aggregates from concrete waste and industrial byproducts like fly ash, slag, and silica fume are being investigated as possible substitutes. (4)

- *Glass*

Glass is a special kind of inert material that can be recycled again and again without losing its chemical composition. Regrettably, a large amount of glass becomes unsuitable for recycling;the effectiveness of this procedure is influenced by several circumstances. First, the effectiveness of the procedures used for gathering and classifying different hues of glass. Whendifferent colors, such as clear, green, or amber—are combined, they lose their suitability for practice in the manufacture of new glass containers. The number of contaminants that could bepresent in the stockpile has an impact second, and shipping costs have the last say. (5)

- *Glass Concrete*

Glass concrete is a unique kind of concrete that is made by partially substituting crushed glassparticles of specific sizes for either gravel or sand, or for both. The Alkali-Silica interaction, achemical interaction between the silica in glass and the alkali in cement that generates gel, presents certain challenges when using crushed waste glass as an aggregate. This reaction causes expansions and swelling when moisture is present, ultimately leading to the deterioration of concrete. This reaction can happen in regular concrete if the usual aggregate has a high silica content.

ASR can be mitigated in a variety of ways. Meyer (2000) (6-9) provided some ideas to lessen the alkali-silica reaction phenomenon. In this method, the ASR problem is reported and its long-term harmful impacts are demonstrated. The following are the suggested fixes:

- Recycled glass should be ground to at least 300µm, the US standard size.
- Substituting mineral admixtures, as meta kaolin, for a portion of the cement, as they can adsorb alkalis ions and so lessen the reaction.
- Because the reaction happens when moisture is present, concrete should be sealed to keep it dry.
- Unless alkalies from the environment can be held at bay, using a low-alkali cement, which is probably less effective.

- *Marble Dust Powder*

The construction sector is working to implement these improvements in order to save natural resources, cut down on landfill trash, and minimize carbon emissions—all while preserving or even enhancing the functionality of concrete structures. With less of an impact on the environment, the use of supplemental cementitious materials (SCMs) such as fly ash and rice husk ash helps meet the growing demand for concrete. The building industry is shifting toward more sustainable, circular methods as a result of these developments. (10-12).

- *Use in Concrete*

Marble powder is most frequently used in concrete as a partial substitute for cement. The concept is to use marble dust in place of some of the cement, which can help make the material more sustainable by lowering the requirement for cement manufacture. One of the main causes of climate change is carbon dioxide emissions, which are greatly increased by the energy-intensive cement industry. By adding marble powder to the mixture, less cement is needed, which lowers carbon emissions and creates a more ecologically friendly concrete mix. (13-15)

II. LITERATURE REVIEW

Concrete, a fundamental construction material, has evolved significantly over the decades. Ilangovana et al. (2008) highlight its massive global use, emphasizing the need for sustainability due to its environmental footprint. Comprising 60–75% aggregates, concrete's durability and cost-efficiency make it indispensable, but innovative modifications are necessary to reduce its ecological impact.

Aggregates play a critical role in concrete performance. Vieira et al. (2016) describe how fine and coarse aggregates fill structural voids and provide strength. However, the environmental harm from excessive natural sand extraction has led researchers like Pilegis et al. (2016) to advocate for manufactured sand (crusher dust) as a viable alternative, despite its higher water demand due to angularity.

Cement, the main binding agent in concrete, is also a significant contributor to CO_2 emissions. Al-Zubaidi and Tabbakh (2016) note that while compounds like C3S and C2S enhance strength, the energy-intensive production process generates nearly one tonne of CO_2 per tonne of cement. Replacing cement with supplementary cementitious materials is a key strategy to lower concrete's carbon footprint.

Waste glass has emerged as an environmentally friendly additive. Studies (Jani et al., 2014; Warnphen, 2019; Salman, 2020; Upreti, 2021) consistently show that finely ground glass can improve compressive strength and workability up to an optimal replacement level (usually around 10–20%). However, higher proportions may compromise mechanical integrity due to poor bonding and angularity. Research also notes that the alkali-silica reaction (ASR) can cause expansion and cracking in glass-containing concrete (Caijun et al., 2007; Özkan et al., 2007), though this can be mitigated by combining glass with pozzolans like fly ash or slag.

Waste glass use also improves sustainability by addressing solid waste disposal and reducing dependence on natural sand. Findings by Najm (2022) and Shahril (2022) further affirm that up to 20% glass substitution maintains structural integrity and enhances durability, with acceptable reductions in workability and splitting tensile strength.

Marble dust powder (MDP) is another alternative examined for its cement replacement potential. Studies (Yadav, 2024; Bahrami & Ihsan, 2023; Yaswanthsai & Chandramouli, 2022) reveal that MDP can enhance strength

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properties when used at optimal levels (around 10–15%). Though higher replacement percentages tend to reduce mechanical strengths, MDP shows promise for sustainable concrete development when combined with other industrial by-products like copper slag or recycled concrete aggregates.

➢ *Objective of the Study*

- **To evaluate the influence** of replacing fine aggregates with waste glass (up to 20%) and marble dust powder (up to 10%) on key mechanical properties of concrete—namely, compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity.

- **To promote sustainable construction** by reducing environmental waste through the reuse of post-consumer glass and marble industry byproducts.

- **To analyze the economic and structural viability** of using waste materials in concrete production, aiming for improved strength performance and cost-efficiency in building materials.

III. MATERIALS USED

➢ *Cement*

The materials used in the study were readily available locally. As per the Indian Standard IS 269:2015 for Ordinary Portland Cement (OPC), (16-17) the cement used in this study conformed to the specifications for 43 Grade OPC. **Table** presents the physical properties and chemical composition of the cement as per the guidelines provided in IS 4031 (Part 2 to Part 15) for testing methods and IS 269 for general requirements.

Table 1 Chemical Properties of Cement

Chemical structure	
Oxide	**Content %**
CaO	63.17
SiO_2	19.98
Al_2O_3	5.17
Fe_2O_3	3.27
MgO	0.78
SO_3	2.39
All Alkalis	0.9
L. O. I.	1.88
I. R.	1.46
L. S. F.	0.86

➢ *Aggregates*

Coarse aggregate: - Locally sourced crushed stone coarse aggregates, with a maximum size of 20 mm and a bulk density of 1531 kg/m³, were used in the study. (18)The aggregates were washed thoroughly to remove any adhering dust or impurities and dried to a surface dry condition. The sieve analysis of the coarse aggregates was conducted in accordance with IS 2386 (Part I):1963 – Methods of Test for Aggregates for Concrete: Part I – Particle Size and Shape. The results of the sieve analysis are presented in **Table** .

- *Fine Aggregates: -*

Locally available natural river sand, with a maximum size of 4.75 mm, was used as the fine aggregate in the experimental work. The sand was sieved by IS 2386 (Part I):1963 – Methods of Test for Aggregates for Concrete: Part I – Particle Size and Shape. As shown in Figure 3.1, the sand was passed through a standard set of IS sieves. The results of the sieve analysis are presented in

Table .

Table 2 Sieve Analysis of Course Aggregates

Size Sieve (mm)	Weight %	AS per Indian Standard
19.4 mm	99.9	99.9
12.5mm	93.4	90-100
9.5 mm	67.1	40-70
4.75mm	9.38	0-15
2.36 mm	0.62	0-5

Table 3 Sieve Analysis of Fine Aggregates

Sievesize (mm)	% Passing	Indian StandardSpecifications
4.75	98.56	95-100
2.36	91.31	80-100
1.18	62.15	50-85
0.60	33.12	25-60
0.30	8.6	5-30
0.15	0.84	0-9.9

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Fineness modulus =3.04

IV. RESULTS AND OBSERVATIONS

The slump test findings are shown in **Table** which shows that when the ratio of waste glassrises comparative to the control mix, the slump ideals significantly decrease. Slump values were measured at 65 mm, 56.5 mm, and 52 mm for samples comprising 30, 40, and 50 percent waste glass, individually, as in Fig 4.1. The uneven shape waste glass is responsible for this reduction in slump values, as it affects the fineness modulus and of the concrete mixture. Park et al. (2004) observed a similar pattern in their previous study, noting that larger aggregates ofwaste glass, with sharpy and extra pointed grain forms than sands, led to lower slump values in concrete as soon as the quantity of waste glass remained higher.

Table 4 Slump Tests for Different Mixes

Mix	**W/C**	**Slump (mm)**
Control	0.55	80
30% Replacement	0.55	65
40% Replacement	0.55	56.5
50%Replacement	0.55	52

- *Compressive Strength*

The compressive strength of the waste and controlled glass concrete mixtures at 7 days, 14 days, and 28 days are shown in *Fig* . Furthermore, the expansion of compressive strength with period aimed at the controlled mix and mixtures including 30, 40, and 50 percent glass aggregate in place of some sand is made known in **Error! Reference source not found.**. Concrete gains more compressive strength when leftover glass is added. Concrete gains more compressive strength when leftover glass is added. Significantly,the blend with 40 percent waste glass fine aggregate obtained a maximum 28 days compressive strength of 34.22 MPa, meaning that it was stronger than the controlled blend by as much as 5.28%

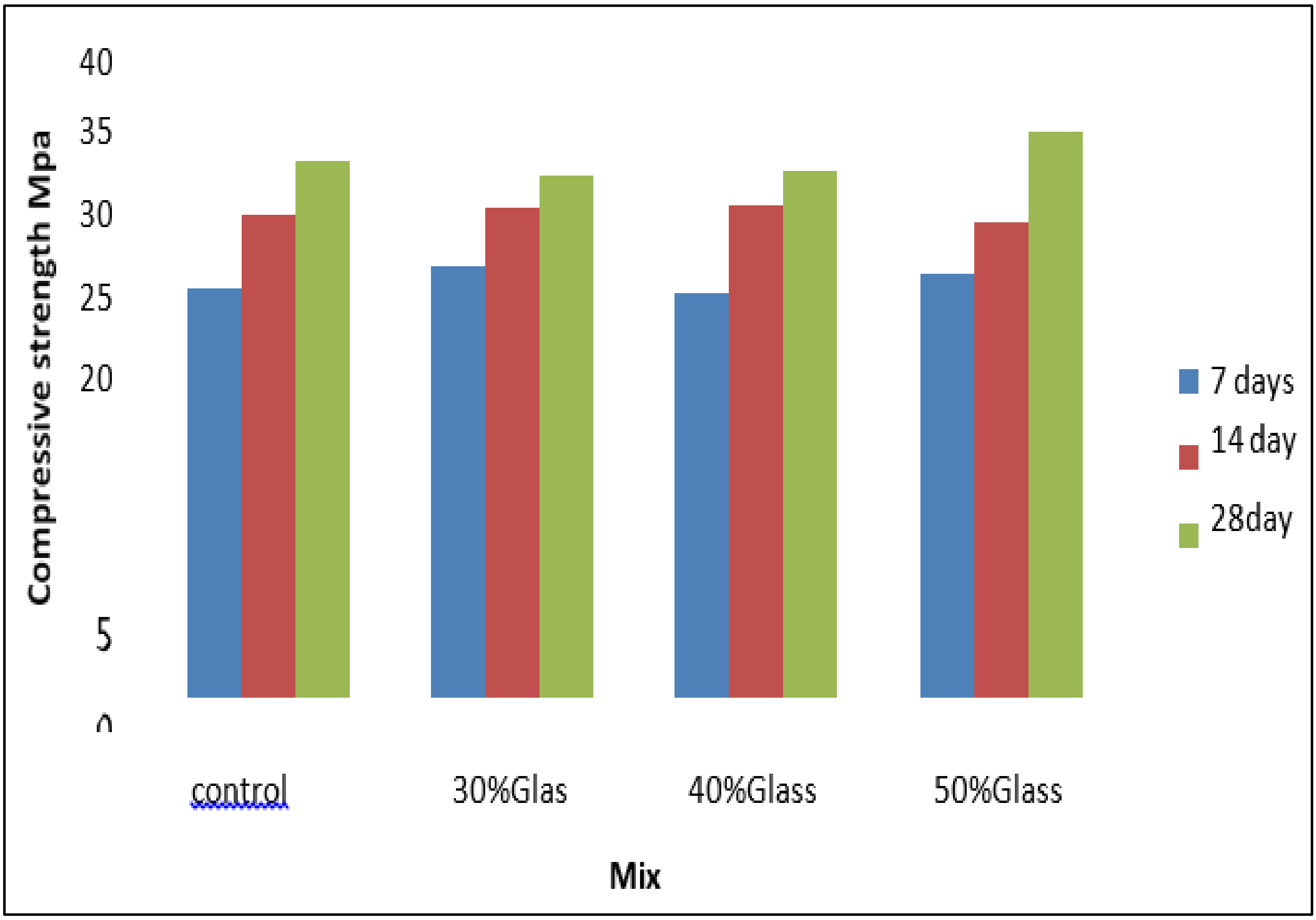

Fig 1 Comparing its Principles for Mixtures with Varying Glass Aggregate Substitutes and Mes under Control throughout Three Aging Curing Periods

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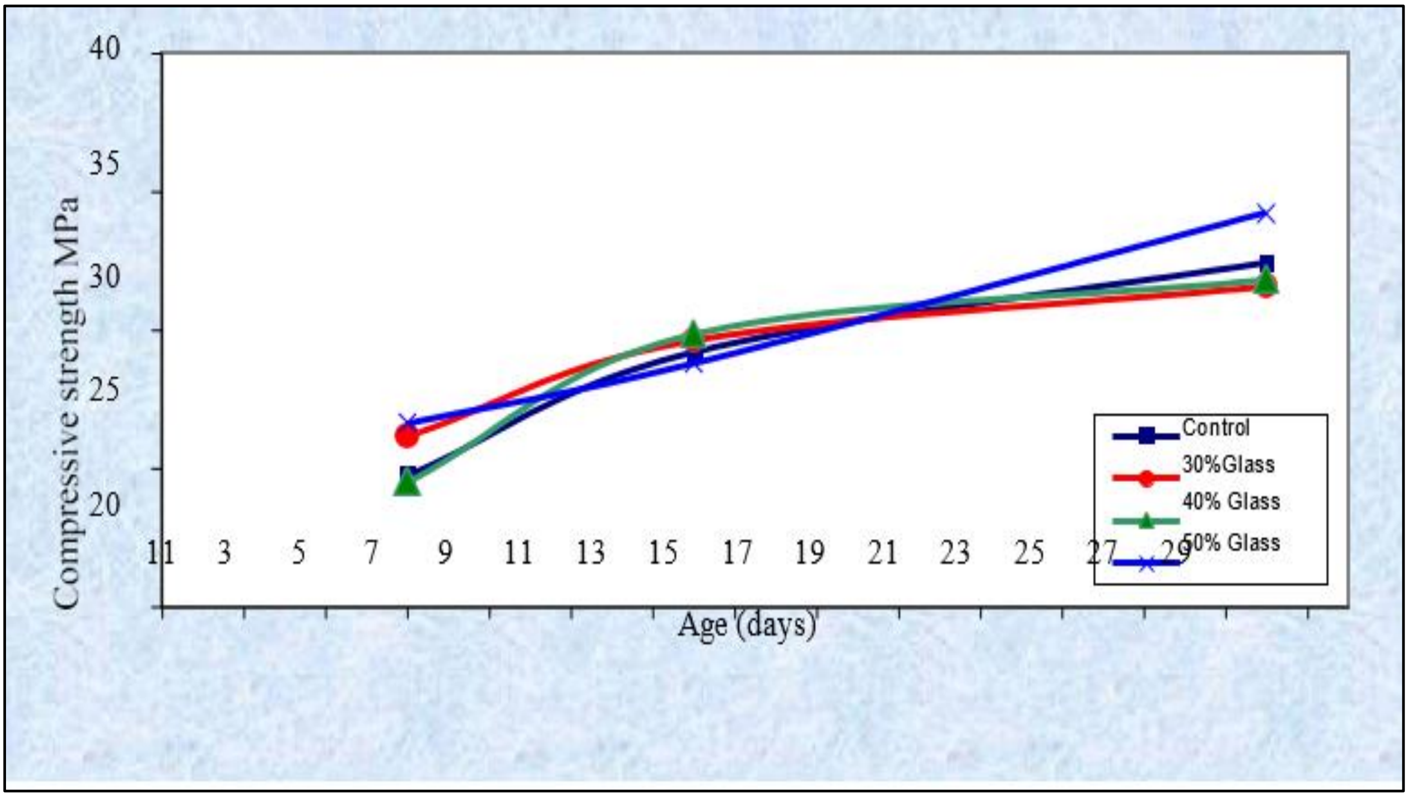

Fig 2 Compressive Strength Expansion for Mixtures with Varied Glass Aggregate Substitutes and Regulated Blends

➢ *Splitting Tensile Strength*

The glass-containing concrete is fragile, just like ordinary concrete. It is especially important since the clearest proof that alkali-silica reaction has occurred. Precisely, in moist conditions, the alkali-silica gel may expand and result in a tensile stress exclusive the concrete structure. This is assumed to be the primary cause of concrete deterioration, per Hadlington (2002).The splitting tensile strength after 7 days, 14 days, and 28 days of curing.

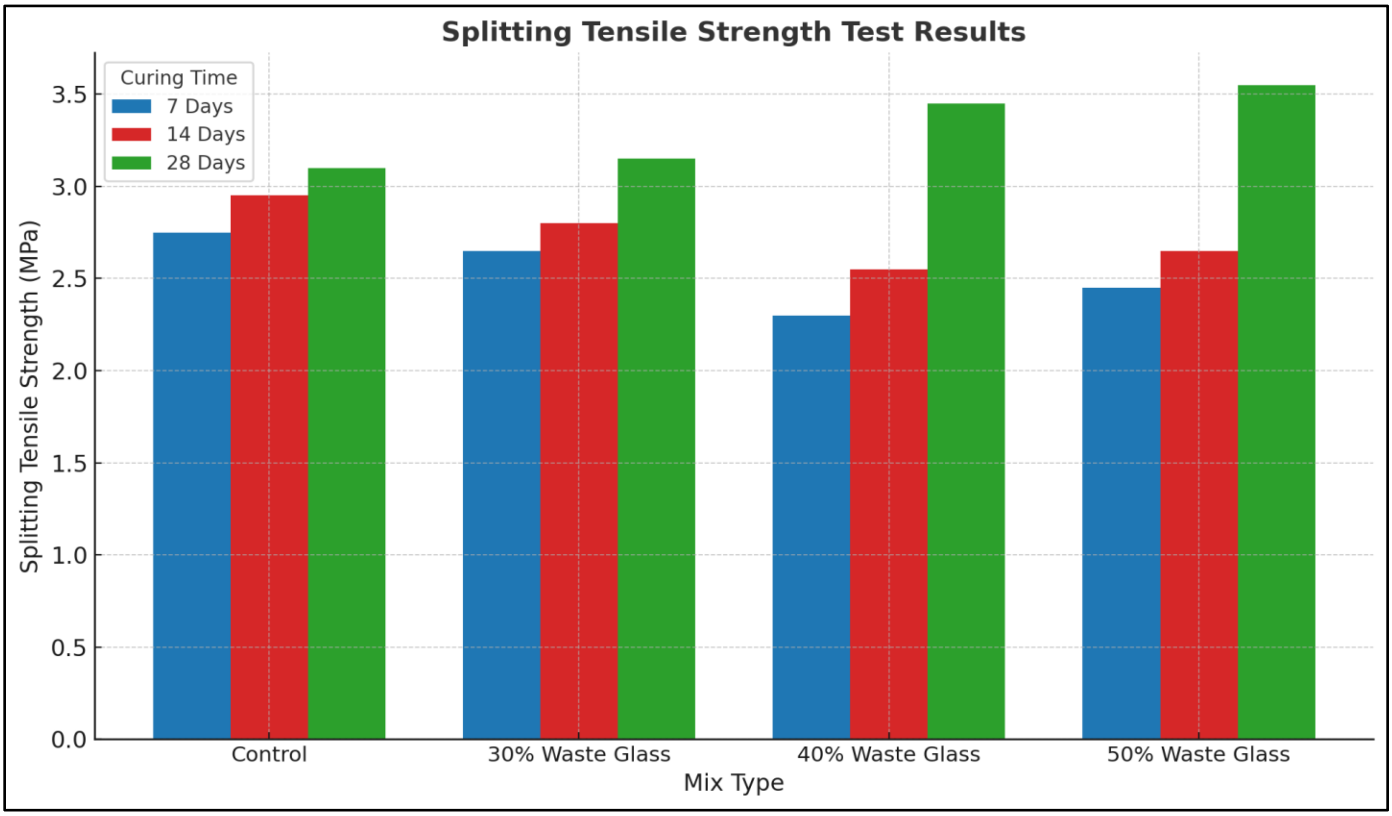

Fig 3 Splitting Tensile Strength Test Results

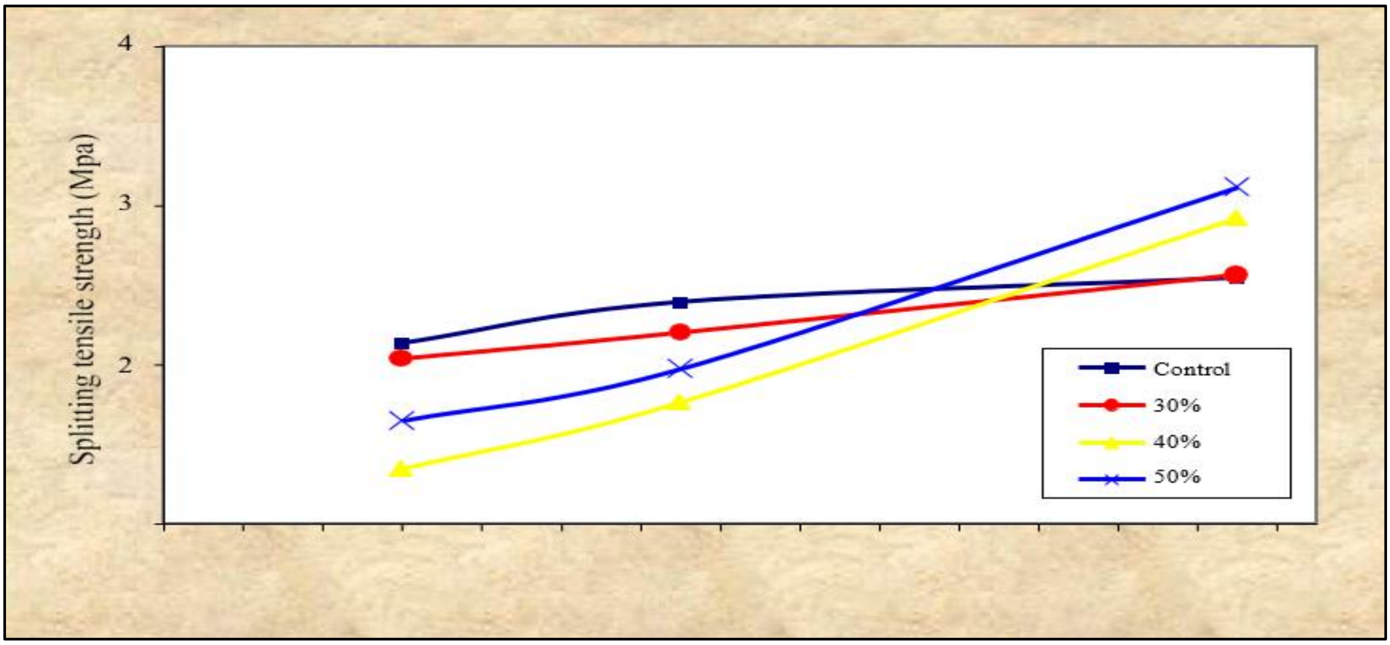

Fig 4 Comparison Graph Between Different Proportions of Mixes

➢ *Flexural Strength*

The results of this test at 7 days, 14 days, and 28 days are revealed in Tab 4.6.The concrete combinations aged 7 days, 14 days, and 28 days frequently exhibited the same trend. It demonstrations that all combinations show a constant surge in flexural strength with phase.

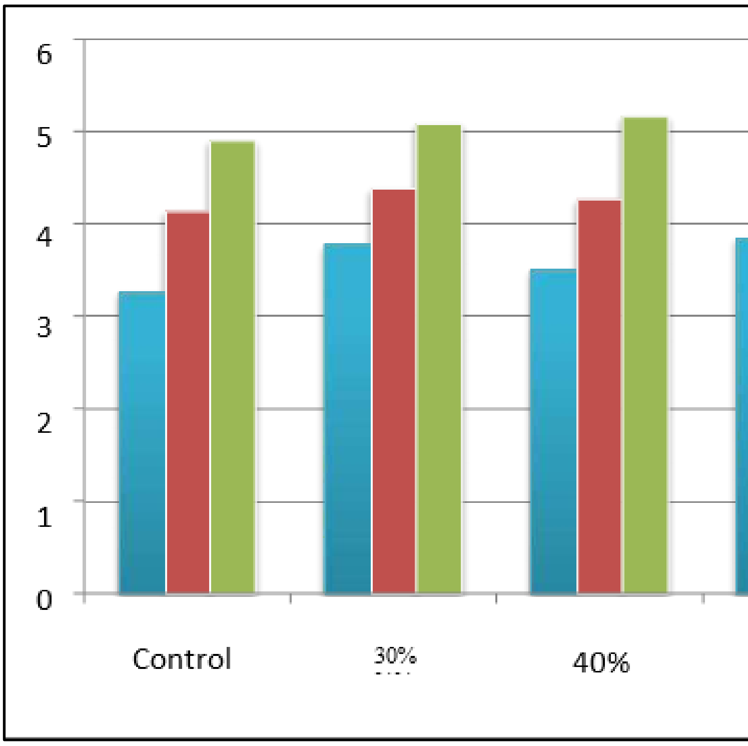

Fig equivalences the flexural strengths of mixtures that contain 30, 40, and 50 percent glass aggregate in place of the sand.

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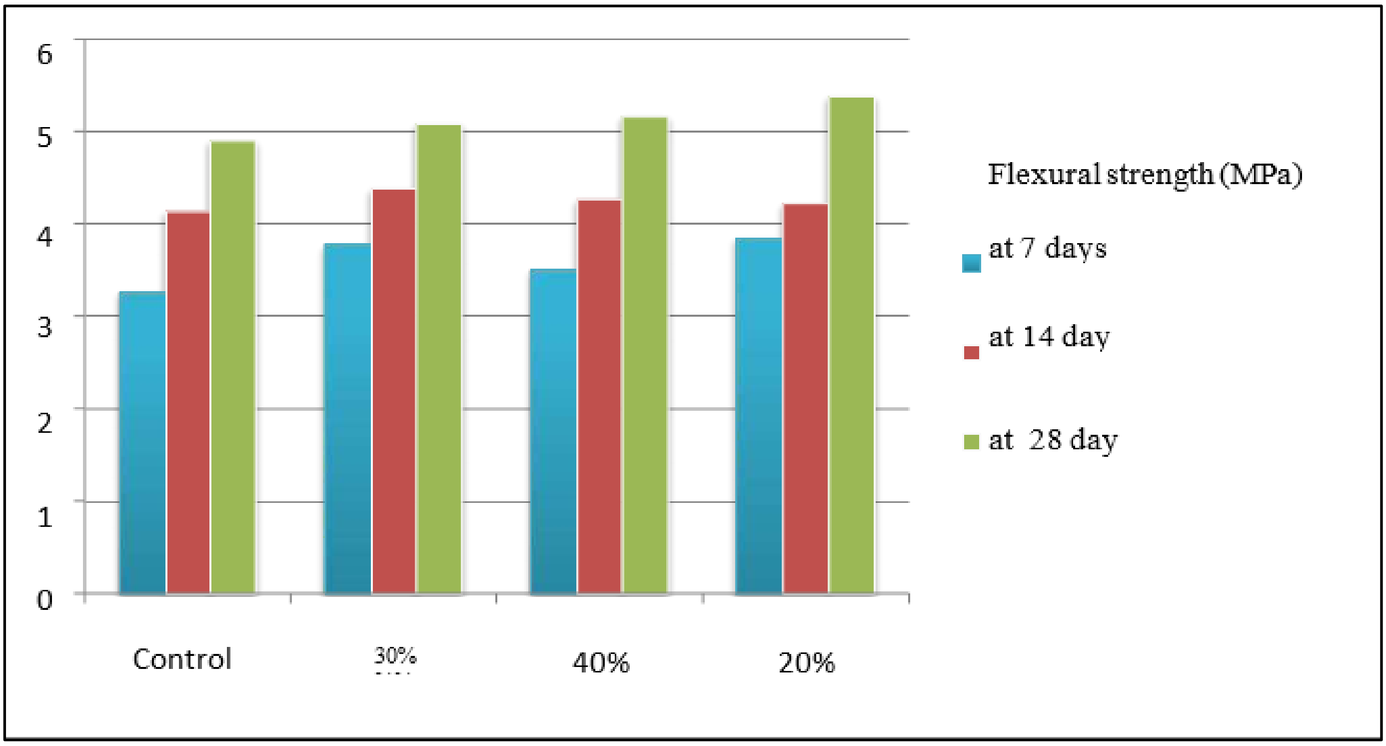

Fig 5 Results of Flexural Strength Tests

➢ *Modulus of Elasticity*

The moduli of elasticity of mixtures after 7 days, 14 days, and 28 days of curing are in **Fig** . These results demonstrate that mixes that include leftover glass perform better than blends under control. The replacement of glass aggregates is increasing this improvement. Thetest outcomes presented that the 28 days modulus of elasticity standards tended to increase beyond the basic combination by 2.54, 5.45, and 9.75 percent when the content of waste glass amplified by 30, 40, and 50 percent respectively, as illustrated in **Fig** .

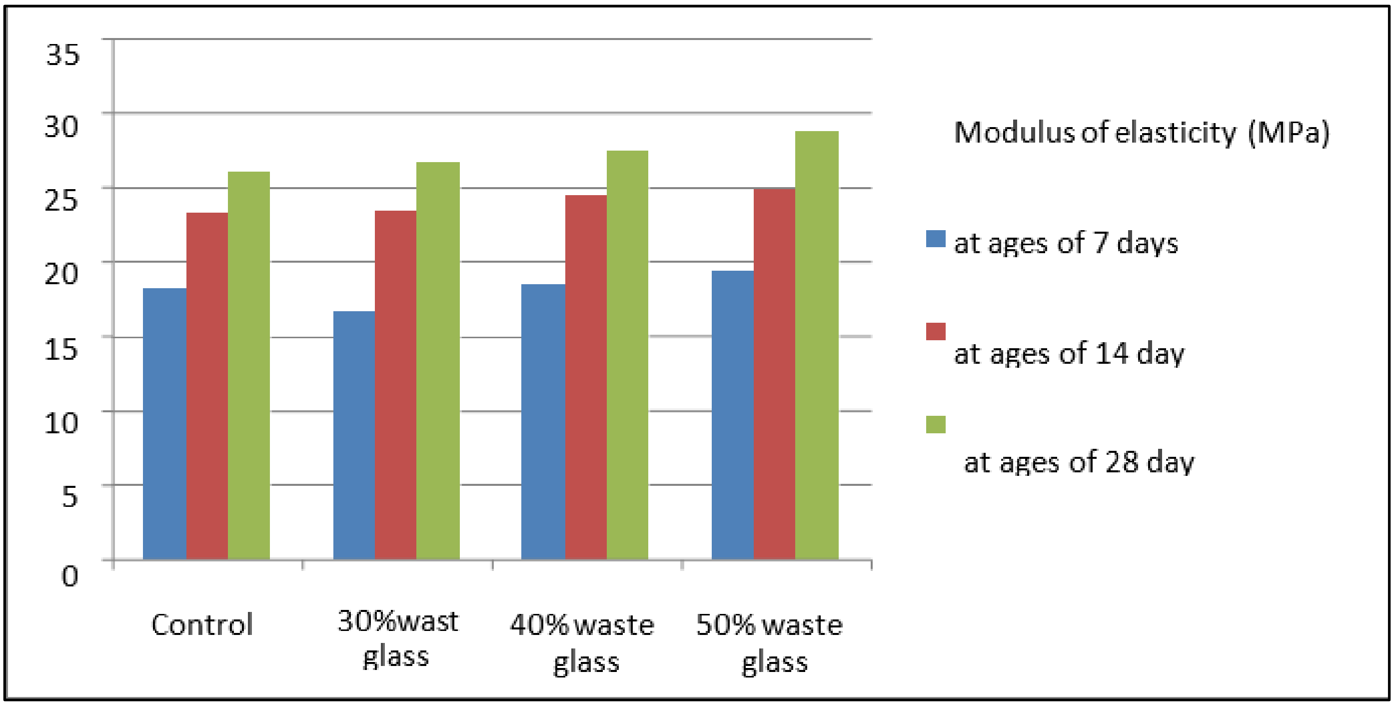

Fig 6 Test Results of Modulus of Elasticity

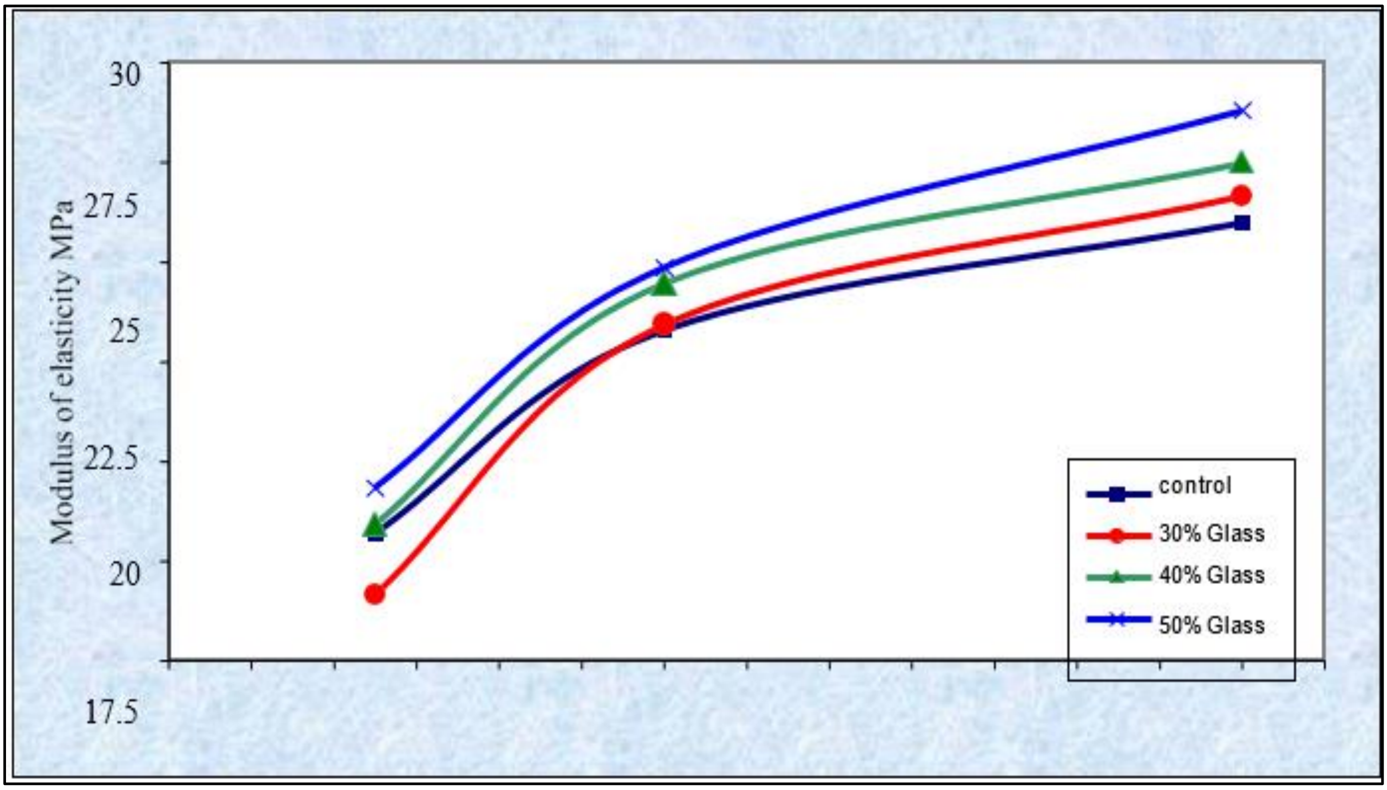

Fig 7 Comparison of Results for different Proportions

➢ *Different Test Results With Addition Of Marble Dust Power*

The experimental results shown in **Error! Reference source not found.** Fig 9 Fig , figure-11 indicate a consistent improvement in the mechanical properties of concrete with the addition of marble dust up to Mix 4. The slump value increased, suggesting enhanced workability. The split tensile strength and compressive strength showed a marked rise at both 7 and 28 days, with Mix 4 achieving the highest strength. Similarly, the modulus of elasticity peaked at Mix 4, confirming improved stiffness. However, Mix 5 displayed a slight reduction in all properties, implying an optimum dosage of marble dust at Mix 4.

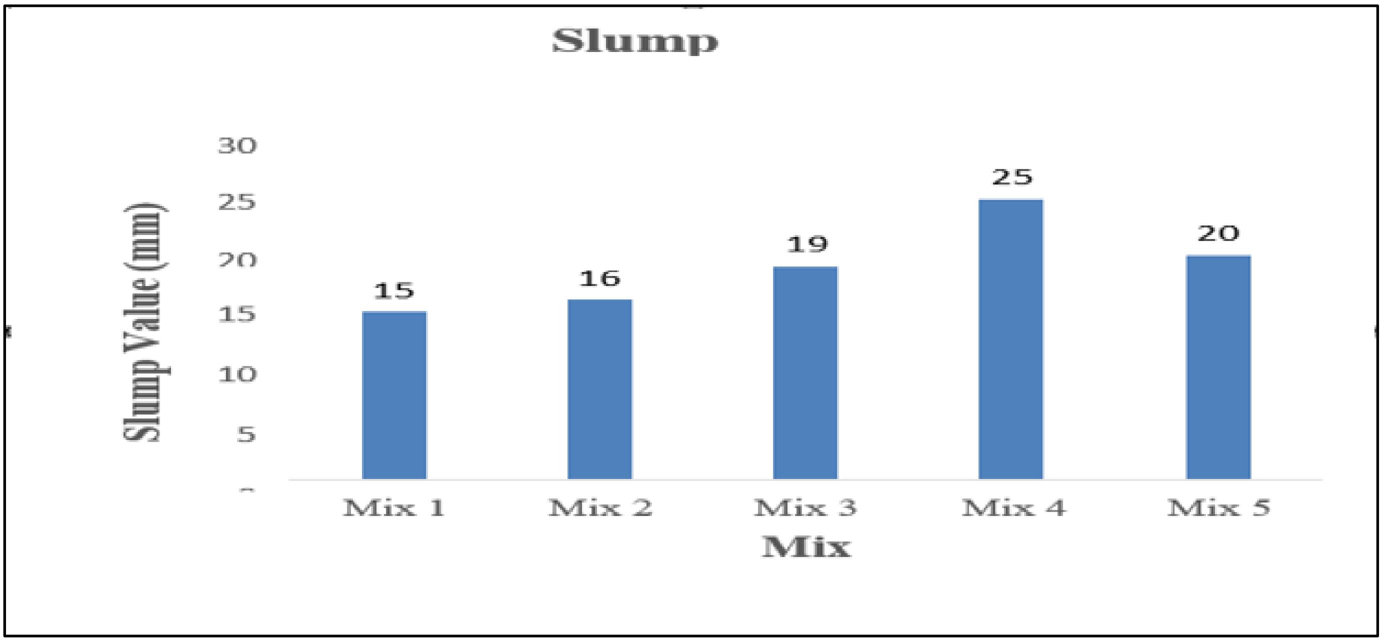

Fig 8 Slump Test Result with Addition of Marble Dust

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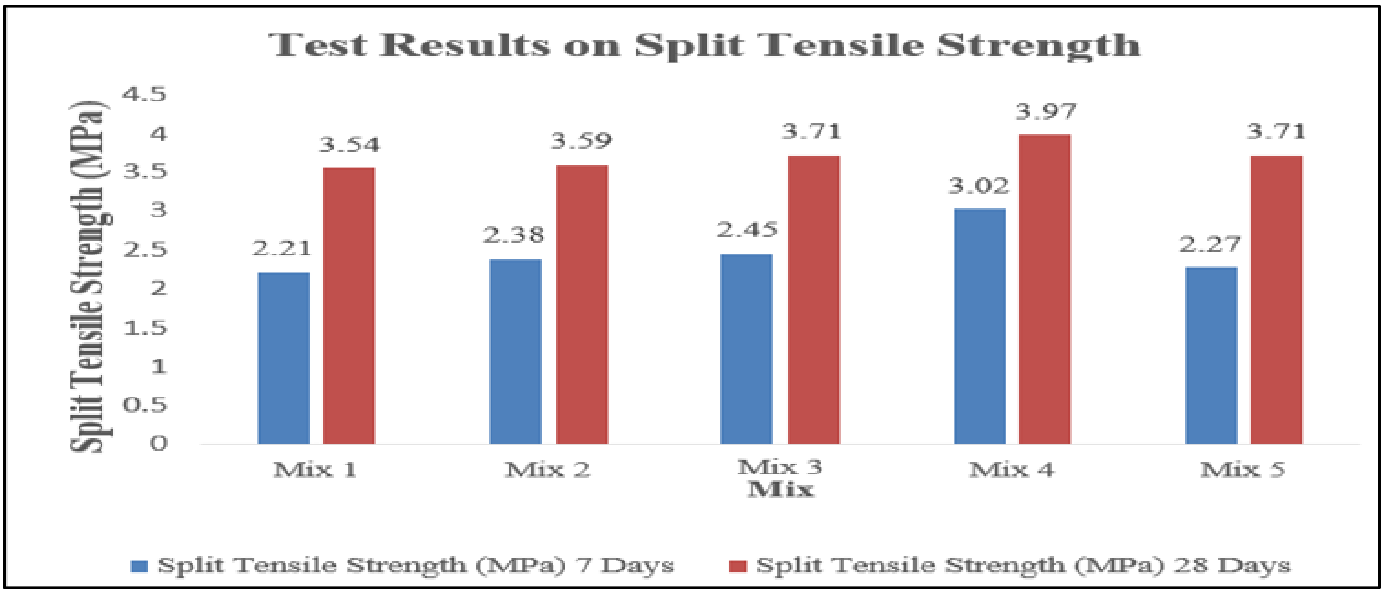

Fig 9 Split Tensile Strength Test Results

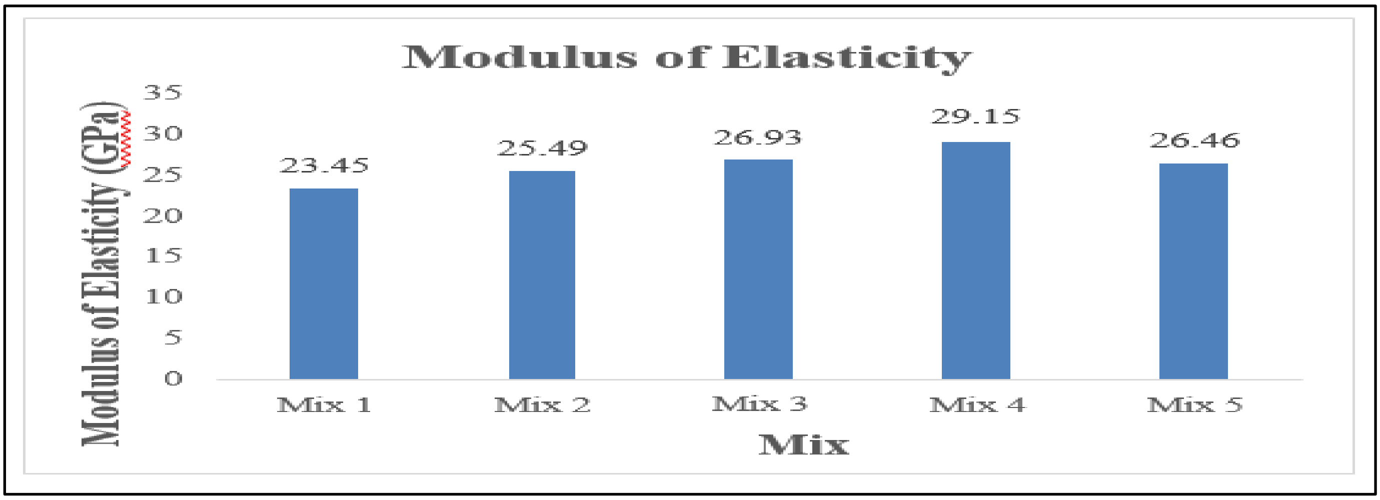

Fig 10 Test Results of Modulus of Elasticity

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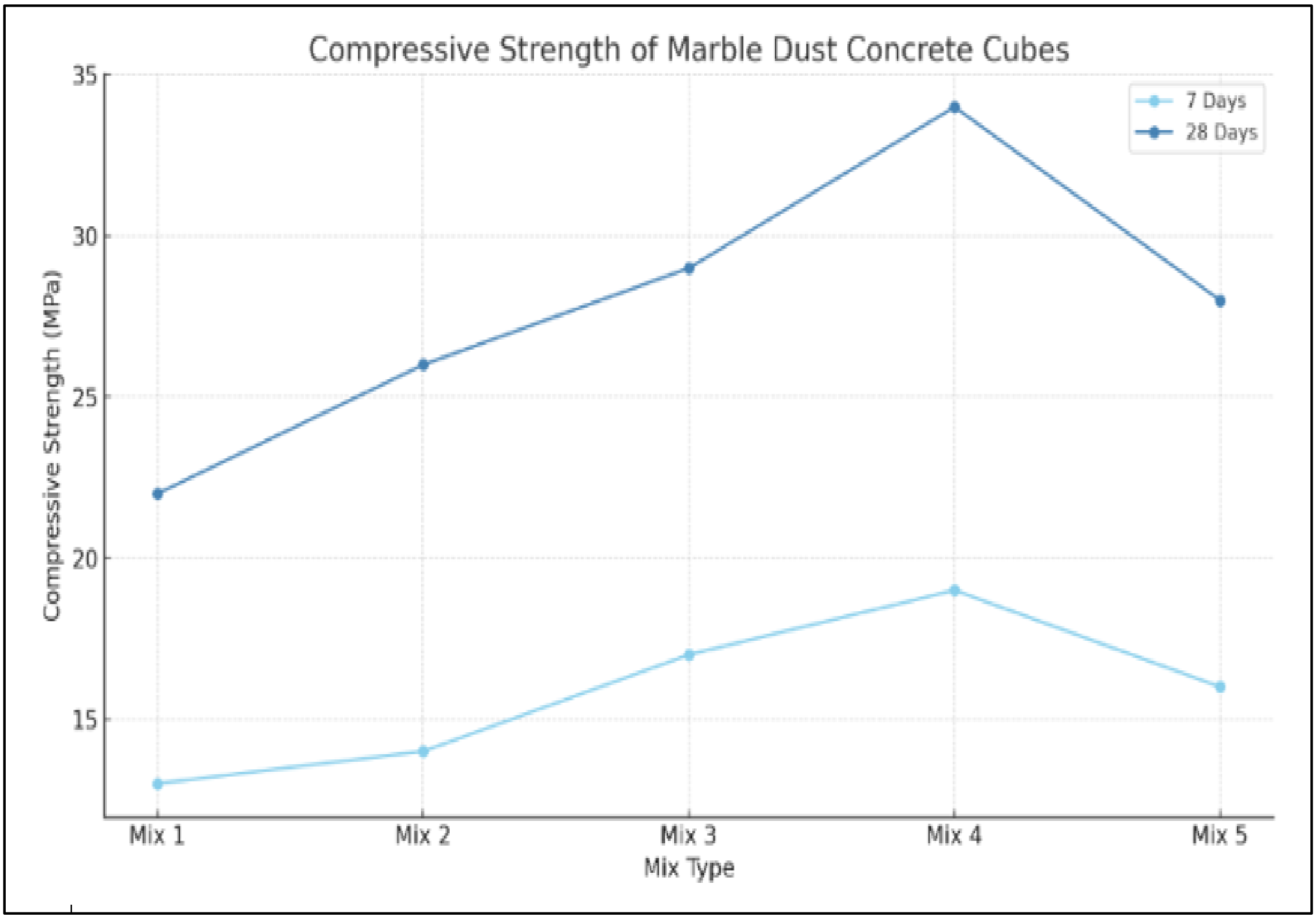

Fig 11 Compressive Strength Test Results

V. CONCLUSION

➢ *Key Findings Based on Experimental Results:*

- The droop that took the place of the fine aggregate decreased as the quantity of excess glass grew. The workability of mixtures encompassing glass aggregate is tranquil decent even however their slump values have decreased. Slump values fall by 18.7%, 29.4%, and 35%, respectively, when natural fine aggregate is substituted with 5%, 15%, and 20% of the mix instead of the control mix.

- When some of the sand was substituted with finely crushed waste glass, the concrete's compressive strength increased as the waste glass increment ratio increased.When mixed with glass fragments, later-aged concrete has a greater compressive strength. Compared to controlled concrete, the compressive strength of 20% crushed waste glass is 5.28% higher thansand.

- The 20% replacement rate of sand with superbly ground waste glass that, after 28 days, yields the greatest standards of compressive, flexural, and tensile strengths.

REFERENCES

[1]. Al-zubaidi, a. b. & tabbakh, a. a. a.-. 2016. Recycling Glass Powder and its Use as Cement Mortar Applications. International Journal of Scientific & Engineering Research, 7, 555-564.

[2]. Aniket S. Mulmuley, Dr.Anant N. Dabhade; © 2023 IJCRT | Volume 11, Issue 4 April 2023 |ISSN: 2320-2882

[3]. Awham Jumah Salman, Zahraa Fakhri Jawad, Fatima Waad , Zahraa Rafea , Abed Alrazaq Ahmed . Journal of University of Babylon for Engineering Sciences, Vol. (28), No. (2): 2020

[4]. Bashar,T. and Nounu,G. (2007), Properties of concrete contains mixed colour waste recycled glass as sand and cement replacement, Construction and Building Materials, vol 22, pp. 713– 720

[5]. Caijun, S. and Keren, Z.(2007), A review on the use of waste glasses in the production of cement and concrete, Resources, Conservation and Recycling, Elsevier Ltd, pp 234– 247.

[6]. Fahmida Munim Ani.; Md. Altaf Hossain, and Raha Nadoal Shahril; European Journal of Engineering and Technology Research.

[7]. Ghadeer Jabbar Kassed; Dr. Sura Karim Ali; Journal of Engineering journal homepage: www.joe.uobaghdad.edu.iq Number 8 Volume 27 August 2021

[8]. Hathaichanok Warnphen, Nuta Supakata, and Vorapot Kanokkantapong; ENGINEERING JOURNAL Volume 23 Issue 5

[9]. Ilangovana, r., mahendrana, n. & nagamanib, k. 2008. strength and durability properties of concrete containing quarry rock dust as fine aggregate. arpn journal of engineering and appliedscience, 3, 20-26.

[10]. Metwally, I.M. (2007), Investigations on the performance of concrete made with blended finely milled waste glass, Advances in Structural Engineering 10 (1), 47–53.

[11]. Özkan, Ö. and Yüksel, I. (2008), Studies on mortars containing waste bottle glass and industrial by-products, Construction and Building Materials , vol 22, pp.1288–1298.

[12]. Pilegis, M., Gardner, D. & Lark, R. 2016. An investigation into the use of manufactured sand as a 100% replacement for fine aggregate in concrete. Materials, 9, 440.

[13]. Qaidi, S.; Najm, H.M.; Abed, S.M.; Özkılıç, Y.O.; Al Dughaishi, H.; Alosta, M.; Sabri, M.M.S.; Alkhatib, F.; Milad, A Fahmida Munim Ani.; Md. Altaf Hossain, and Raha Nadoal Shahril; Concrete Containing Waste Glass as an Environmentally Friendly Aggregate: A Review on Fresh and Mechanical Characteristics. Materials 2022, 15, 6222.

[14]. Sudarshan Upreti , Dr Bharat Mandal; International Research Journal of Modernization in Engineering Technology and Science; Volume:03/Issue:02/February-2021

[15]. Taha, B. and Nounu, G. (2008), Properties of concrete contains mixed colour waste recycled glass as sand and cement replacement, Construction and Building Materials 22(2008) p.p.713–720.

[16]. Topçu, Í.B., Bag, A. , Bilir, T. (2008), Alkali-silica reactions of mortars produced by using waste glass as fire aggregate and admixtures such as fly ash and Li2CO3,Waste Management 28 (5), pp. 878–884.

[17]. Vieira, d. r., calmon, j. l. & coelho, f. z. 2016. Life cycle assessment (LCA) applied to the manufacturing of common and ecological concrete: A review. Construction and Building Materials, 124, 656-666.

[18]. Aruntas H.Y., Guru M., Dayı, M. and Tekin, I., (2010), Utilization of waste marble dust as an additive in cement production. Materials & Design, 31(8), pp.4039-4042.

[19]. Aliabdo, A.A., Abd Elmoaty, M. and Auda, E.M., (2014), Re-use of waste marble dust in the production of cement and concrete, Construction and building materials, 50, pp.28-41.