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Combine Effect of Metakaolin, Recycled Steel Fiber and Waste Glass Powder on Mechanical Properties of Concrete

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Abstract

This study investigates the combined effects of metakaolin, recycled steel fiber, and waste glass powder on the mechanical properties of concrete. Specifically, the research explores concrete mixes with metakaolin, crushed glass powder at 9%, 12%, 15%, and 18%, and recycled steel fiber at 0.5%, 1%, 1.5%, and 2% as partial replacements for cement. The primary aim is to identify the optimal mix proportions that enhance the compressive strength, flexural strength, split tensile strength, and durability of M30 grade concrete. In accordance with Indian standards to assess the performance of the concrete mixtures comprehensive laboratory tests were conducted. Various proportions trials were taken to find out a sustainable solution for increased compressive strength. The combination of metakaolin, recycled steel fibers and waste glass powder proved to be a better option in enhancing compressive strength. The findings of this research provide valuable insights into optimizing concrete mixes for improved mechanical properties and sustainability.

Keywords: Metakaolin, recycled steel fiber, waste glass powder, concrete mechanical properties, compressive strength, concrete durability, sustainable construction materials, M30 grade concrete, concrete workability

INTRODUCTION

Concrete, as the cornerstone of modern construction, continues to undergo extensive research and development to meet the evolving demands of sustainability, durability, and performance. In recent decades, there has been a concerted effort within the civil engineering community to explore innovative materials and techniques that not only enhance the mechanical properties of concrete but also minimize its environmental impact.

The present study embarks on this journey by investigating the combined effects of metakaolin, recycled steel fiber, and waste glass powder on the mechanical properties of concrete. Metakaolin, a highly reactive supplementary cementitious material obtained from the calcination of kaolin clay at temperatures ranging from 600°C to 850°C, has garnered significant attention for its pozzolanic properties. When incorporated into concrete mixtures, metakaolin reacts with calcium hydroxide (Ca (OH)2) produced during cement hydration, leading to the formation of additional calcium silicate hydrate (C-S-H) gel. This pozzolanic reaction not only enhances the density and

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microstructure of concrete but also contributes to improved strength, durability, and resistance to chemical attacks.

Metakaolin, a pozzolanic material derived from the calcination of kaolin clay, has shown promising potential in improving the performance of concrete by enhancing its strength, durability, and resistance to chemical attacks. Concurrently, the incorporation of waste materials such as crushed glass powder and recycled steel fiber offers a sustainable solution to mitigate the environmental impact associated with traditional concrete production while addressing the growing challenge of waste management.

The utilization of waste glass powder as a partial replacement for conventional aggregates not only reduces the demand for natural resources but also contributes to the reduction of greenhouse gas emissions associated with the manufacturing process. Furthermore, the inclusion of recycled steel fiber derived from industrial waste streams presents an opportunity to enhance the ductility, toughness, and crack resistance of concrete structures, thereby extending their service life and improving their performance under various loading conditions.

In parallel, the utilization of waste materials such as crushed glass powder and recycled steel fiber presents a compelling avenue for sustainable concrete production. Crushed glass powder, derived from post-consumer or industrial glass waste, offers an environmentally friendly alternative to traditional aggregates. By partially replacing conventional aggregates with waste glass powder, the demand for natural resources can be reduced, while simultaneously diverting significant quantities of glass waste from landfills. Additionally, the incorporation of recycled steel fiber obtained from industrial by-products provides an opportunity to enhance the ductility, toughness, and crack resistance of concrete structures. Unlike traditional steel reinforcement, which is often sourced from virgin materials, recycled steel fiber offers a sustainable solution to strengthen concrete while minimizing the depletion of finite resources.

In the context of this study, the focus lies on the design and optimization of M30 grade concrete mixtures according to Indian standards, wherein metakaolin serves as a constant additive at 5% by weight of cement, while the percentages of crushed glass powder and recycled steel fiber are varied systematically. The objective is to evaluate the combined influence of these supplementary materials on key mechanical properties such as compressive strength, flexural strength, split tensile strength, and durability. By systematically varying the proportions of crushed glass powder (ranging from 3% to 15%) and recycled steel fiber (ranging from 0.1% to 1.2%), a comprehensive assessment of their synergistic effects on the performance of concrete will be conducted.

The outcomes of this research endeavor are expected to yield valuable insights into the optimal utilization of metakaolin, recycled steel fiber, and waste glass aggregate in concrete mixtures, thereby contributing to the advancement of sustainable construction practices.

AIM AND OBJECTIVES

The specific objectives of the research are:

- Explore the combined effects of metakaolin, recycled steel fiber, and waste glass powder on the mechanical properties of concrete.
- Determine the optimal mix proportions of metakaolin, recycled steel fiber, and waste glass powder to enhance compressive strength and durability of concrete mixtures.
- Assess the performance of concrete mixtures containing varied percentages of metakaolin, recycled steel fiber, and waste glass powder through comprehensive laboratory testing in accordance with Indian standards for M30 grade concrete.

LITERATURES REVIEW

Ashis Simalti et al. **(January 2021)** investigated the environmental issues related to natural resource depletion and waste material dumping, particularly focusing on waste tires, which pose significant landfill and fire hazards. Their study examined the fresh and hardened properties of self-consolidating concrete (SCC) incorporating recycled steel fiber (RSF) extracted from shredded tires. They prepared seven mixes: one control mix (SCC with no fiber), SCC with manufactured steel fiber (MSF), and SCC with RSF at volume fractions of 0.5%, 1.0%, and 1.5%. Fresh properties were evaluated using slump flow and J-Ring tests, while mechanical properties were assessed through compressive, split tensile, and flexural strength tests. Durability was tested using rapid chloride penetration and ultrasonic pulse velocity tests. The results showed that SCC with 1.5% RSF exhibited the best overall performance compared to SCC with MSF, with good correlations (R2 > 0.7) between fresh, mechanical, and durability properties. Additionally, SCC with RSF demonstrated lower carbon emissions, making it a sustainable and economically viable alternative to SCC with MSF [1].

Mavoori Hitesh Kumar et al. **(19 February 2021)** studied the combined effect of waste glass powder (WGP) and recycled steel fibers (RSF) from waste tires on concrete. WGP was used to replace fine aggregate in varying percentages (0%, 3%, 6%, 9%, 12%, and 15%), and RSF was added in different volume fractions (0%, 0.5%, 1%, and 1.5%). The study examined the compressive, flexural, and split tensile strength of concrete mixes at 7 and 28 days of curing. The mix with 9% WGP exhibited the highest strength across all tests, with mechanical properties improving up to the 9% replacement level before declining. Additionally, increasing RSF content enhanced the compressive and flexural strength of concrete. The optimal mix, consisting of 9% WGP and 1% RSF, showed the best overall performance [2].

M.K. Samarakoon et al. (December 2019) identified the use of steel fibers extracted from tire waste as a sustainable and cost-effective solution for reinforcing concrete, addressing tire recycling challenges. While few studies have explored this approach, there's potential to utilize recycled steel fibers (RF) as an alternative to manufactured steel fibers (SF) in concrete. However, further research is necessary to confirm the structural adequacy of recycled fiber reinforced concrete (RFRC) compared to SFRC. This study focuses on laboratory testing to assess the mechanical properties of RFRC and compare them with SFRC. Additionally, the flexural performance of concrete beams reinforced with RF and SF is evaluated to determine their comparative effectiveness [3].

Arowojolu et al. (August 2018) explored the feasibility of using nano glass powder (NGP) as a partial replacement for cement in concrete, combined with fly ash. Three concrete mixtures were studied, varying the proportions of fly ash and NGP as cement replacements. The first mixture contained 25% class F-fly ash (FA) and 0% NGP, the second had 12.5% class F-FA with 12.5% NGP, and the third had 0% class F-FA with 25% NGP. The water-to-cementitious (w/cm) ratios were kept constant at 0.42 across all mixtures. Fresh properties, including air content and workability, were tested, along with expansion due to potential alkali–silica reaction (ASR), and mechanical properties such as compressive, tensile, and flexural strength were evaluated. It was observed that increasing NGP content beyond 12.5% with 12.5% class F-FA negatively impacted fresh and mechanical properties. However, overall, the addition of NGP improved concrete's mechanical properties, with ASR expansion below 0.1%. This study suggests that partial replacement of cement with NGP has the potential to reduce cement usage, lower global carbon emissions, and decrease the costs associated with recycling and disposing of waste glass materials [4].

Dhirendra Patel et al. (3 December 2018) investigated the potential of fine glass powder as a pozzolanic material to address environmental concerns and enhance concrete quality. Their study focused on the environmental impact of incorporating glass powder with particle sizes of 12 µm (75–63 µm) at substitution levels of 0–20% for ordinary Portland cement (OPC) paste and mortar. They found that the fineness and morphology of glass powder significantly influenced fresh properties, while hardened properties, including pozzolanic reactivity, were assessed through lime reactivity and compressive strength tests. Results showed that GP63 exhibited higher reactivity than GP75. Additionally, transverse strength, drying shrinkage, and water absorption of control and blended mortar were evaluated. Environmental impact studies indicated a 20% reduction in sustainable environment indexes for glass powder mixtures at 20% substitution compared to control. SEM and EDX analyses confirmed glass powder's role as a filler initially and its pozzolanic nature over time. Overall, mixtures containing 63 μm glass powder showed superior efficiency in replacing cement up to 20% while improving microstructure [5].

D. Harbec et.al (March 2017) investigated based on its high content in amorphous silica (SiO_2 > 70 wt.%), waste glass is an excellent material for valorization into pozzolanic nanoparticles or the so-called ‘‘glass fume” (GF). GF, produced using a scalable radiofrequency induction-coupled-plasma (RF ICP) spheroidization technology, mainly consists in an emulation of silica fume (SF) composed of spherical and amorphous silica-based nanoparticles (dia. of 30–200 nm). To test the impact of GF on the mechanical and durability properties of cement-based materials, compressive strength and rapid chloride ion penetration tests (RCPT) were conducted on high-performance concrete (HPC). Meanwhile, measurements of the resistances to alkali-silica reaction (ASR) and to sulfate attack were performed on mortar bars. As SF, GF increased the compressive strength of HPC at early age (<7 days) by its nucleation and filler effects, but also its high alkali content (11–12 wt.%). At late age (>28 days), GF is characterized by a slower pozzolanic reactivity than SF. However, GF-contained HPC achieve similar compressive strength than SF-contained HPC after 91 days of curing. At early age, GF-contained HPC and mortars yielded lower durability properties (RCPT, ASR and sulfate attack) than SF-contained HPC and mortars due to the slower pozzolanic reactivity of GF. In fact, they yielded similar durability properties compared to the plain cement HPC and mortars (control mixtures). At late age, the alkalinity of the pore solution is reduced and the cement paste is densified by the pozzolanic calcium silicates hydrates (C-S-H) and the durability properties are greatly improved with respect to a control HPC [6].

Sana Gul et al. (2017) highlighted the environmental challenges posed by the disposal of waste rubber tires worldwide, emphasizing the need for sustainable utilization of this waste material. Their study focused on using scrap rubber tires as an alternative to steel fiber in fiber-reinforced concrete. Four concrete mixtures were prepared, including control batches and test batches with 1% and 5% replacement of steel fiber with recycled rubber steel fibers (RRSF) by volume of concrete. Water-to-cement ratios were kept constant to replicate field conditions. Results indicated reduced compressive and split tensile strength, with reductions of up to 20% and 14%, respectively, for 1% replacement of RRSF, and reductions of 38% and 42% for 5% replacement. However, samples with RRSF exhibited ductile behavior, showing potential benefits for structures requiring impact resistance. The study recommended using such concrete for lightweight concrete construction [7].

Kamali et al. (November 2015) investigated the mechanical strength and durability behavior of cementitious materials modified with two types of glass powders and class F fly ash at various levels of cement replacement. Their study included compressive strength and flexural strength tests for mechanical evaluation and alkali-silica-reactivity, electrical resistivity, chloride permeability, and porosity assessments for durability characteristics. Results showed that cementitious materials modified with glass powders exhibited improved compressive and flexural strengths compared to control concrete at later stages of curing. Addition of glass powders reduced alkali-silica reaction expansions and enhanced resistance to chloride permeability and electrical resistivity. These enhancements were attributed to microstructure improvements resulting from the pozzolanic property of the glass powders [8].

B.B. Sabir et al. (December 2001) investigated the utilization of calcined clay, specifically metakaolin (MK), as a pozzolanic material for mortar and concrete. The study focused on minimizing Portland cement (PC) consumption, which is environmentally damaging, by incorporating industrial by-products. MK, as a partial pozzolanic replacement for cement, enhances the durability properties of mortar and concrete. Literature review indicated that MK effectively improves the pore structure and enhances the concrete's resistance to harmful solutions. This research contributes to the growing interest in sustainable construction practices by utilizing pozzolanic materials to improve concrete performance and reduce environmental impact [9].

Duna Samson et al. **(December 2016)** investigated the impact of metakaolin (MK) on the compressive strength of concrete containing glass powder (GP). They produced plain mixes, binary mixes with 10% GP by weight of cement, and ternary mixes with 10% GP and 5%, 10%, 15%, and 20% MK by weight of cement. These mixes were cured for various durations (7, 14, 28, 56, and 90 days) and tested for compressive strength. Results indicated a general decrease in compressive strength with increasing MK content, but strength improved with longer curing periods. Concrete cubes containing 10%-20% MK and cured for 56 and 90 days achieved the 28-day target strength of 25 N/mm^2. The optimum replacement level was observed at 10% GP and 15% MK, cured for 90 days. Regression analysis and analysis of variance (ANOVA) in MINITAB 16 software showed a highly significant model predicting compressive strength based on curing period and MK content. The model exhibited a high coefficient of determination (R^2 = 90.44%), indicating a strong correlation between response and predictor variables [10].

SYSTEM DEVELOPMENT

The present research work is based on experimental study oriented and requires preliminary investigations in a methodological manner.

Materials and Grade of Control Mix

- Selection of materials and grade of control mix, mix design, trial mixes, final mix proportions.
- Estimating total quantity of concrete required for the whole experimental work.
- Estimating quantity of cement, fine aggregate, metakaolin, crushed glass powder, recycled Recycle steel fibers, Precipitated silica, water, superplasticizer required for the work.

Production of Mixes

- Production of control mix in the laboratory is carried out by using appropriate designed proportions from paper.
- Production of concrete with different percentage of crushed glass powder such as 9%, 12%, 15%, 18% including 5% of metakaolin.
- Production of concrete with different percentage of Recycle steel fiber such as 0.5%, 0.1%, 1.5%, 2%.

MATERIAL USED IN EXPERIMENTAL WORK

Cement

The ingredients of concrete i.e. cement, fine, sand are tested before using them in work. The various tests have been conducted according to relative standard code of practice. The cement used in this experimental work is “Ultra-tech 53 grade Ordinary Portland Cement”. All properties of cement were tested by referring IS 12269 - 1987 Specification for 53 Grade Ordinary Portland cement [11].

Coarse Aggregate

The coarse aggregate used were single-sized crush angular coarse aggregates used between 40mm to 4.75mm size confirmed from the sieve analysis. Specific gravity of coarse aggregate is 2.74.

Fine Aggregate

Locally available river sand is used. As per IS 2386 (part 1) it was confirmed that sand utilized belong to Zone II and specific gravity is 2.68.

Metakaolin

Metakaolin (MK) is available in dry powder form and was ordered from AJ Corporation, Mumbai. It is available in 40Kg bags, it is white in colour. The chemical & physical properties of MK are shown in Table 1.

Table 1. Properties of metakaolin.

S.N.	Properties	Result
1.	Particle size	0.03-0.3μm
2.	Colour	White
3.	Silica content	5 %
4.	Specific gravity	2.30

Table 2. Properties of glass powder.

S.N.	Properties	Result
1.	Presentation	Finally divided dry powder
2.	Colour	white green
5.	Particle size	1 μm-0.5 mm
6.	Particle shape	Irregular

Table 3. Physical properties of recycle steel fibers.

S.N.	Properties	Value
1.	Diameter	0.8 mm
2.	Length of fiber	50 mm
3.	Average aspect ratio	62.5
4.	Deformation	Straight
7.	Specific Gravity	7.8

Glass Powder

Used glass bottles from scratch shops of same properties were used. Glass bottles were manually crushed till the fine particles are created Table 2.

Recycle Steel Fibers

Recycled steel fibers of aspect ratio 62.2 with 50 mm length and 0.8 mm diameter were extracted from waste tires and utilized as a reinforcing element in concrete mix. Properties of Recycle steel fibers are described here Table 3.

METHODOLOGY

Mix proportions for grade of M-30 grade were designed by replacing cement and fine aggregate with metakaolin, glass powder and by adding recycled steel fibers respectively in different variations. Mix design was designed as per IS 10262:2019 with water cement ratio of 0.45, to achieve a target strength of 38.6 N/mm2.

16 different proportions were designed where **A, B, C, D** states the percentage of cement replaced with 5% metakaolin, 9 % sand replacement with glass powder and adding recycled steel fiber with percent varying from 0.5% to 2%. Four different sets of proportions were made with a total of 16 variations, 4 variations in each set Table 4.

EXPERIMENTAL ANALYSIS

Fresh concrete was prepared and was poured in the cube specimen of 150mm*150mm*150 mm. 3 specimens for 7 days and 3 specimens for 28 days for each variation were casted and cured. In total 96 specimens were casted. Automated CTM was used for testing the specimens. The compressive strength was calculated using the formula:

$$fc=P/A$$

Where, fc= Compressive strength (N/mm2) P=Maximum Load (N)
A=cross section of sample (mm2)

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Table 4. Shows the variations with their full forms and percent replacements.
The proportions were as follows:

S.N.	Variations abbreviations	Percent variations
1	A1	Glass powder 9%, RSF 0.5%, 5% MK
2	A2	Glass powder 9%, RSF 1%, 5% MK
3	A3	Glass powder 9%, RSF 1.5%, 5% MK
4	A4	Glass powder 9%, RSF 2%, 5% MK
5	B1	Glass powder 12%, RSF 0.5%, 5% MK
6	B2	Glass powder 12%, RSF 1%, 5% MK
7	B3	Glass powder 12%, RSF 1.5%, 5% MK
8	B4	Glass powder 12%, RSF 2%, 5% MK
9	C1	Glass powder 15%, RSF 0.5%, 5% MK
10	C2	Glass powder 15%, RSF 1%, 5% MK
11	C3	Glass powder 15%, RSF 1.5%, 5% MK
12	C4	Glass powder 15%, RSF 2%, 5% MK
13	D1	Glass powder 18%, RSF 0.5%, 5% MK
14	D2	Glass powder 18%, RSF 1%, 5% MK
15	D3	Glass powder 18%, RSF 1.5%, 5% MK
16	D4	Glass powder 18%, RSF 2 %, 5% MK

Table 5. Readings of 7 days and 28 days compressive strength of A variations.

Mix proportions	7 days strength in N/mm^2	28 days strength N/mm^2
A1	22.32	34.18
A2	22.84	34.69
A3	23.61	34.88
A4	23.97	35.16

RESULT AND DISCUSSIONS

16 different variations were casted and were tested for compressive strength of 7 days and 28 days. cubes for each variation were casted for 7 days and 28 days. Results were obtained with different percent combinations of replacing cement and sand with metakaolin, glass powder and by adding recycled steel fiber respectively. The observations and readings of the different proportions are given below:

The first set of proportions were taken of 5% replacement of cement with metakaolin, 9 % sand replacement with glass powder and adding recycled steel fiber with percent varying from 0.5% to 2%.

Table 5 shows the readings of 7 days and 28 days compressive strength of the above variations. Figure 1 depicts comparison of compressive strengths for 7 days and 28 days of 5% replacement of cement with metakaolin, 9 % sand replacement with glass powder and adding recycled steel fiber with percent varying from 0.5% to 2%.

The second set of proportions were taken of 5% replacement of cement with metakaolin, 12 % sand replacement with glass powder and adding recycled steel fiber with percent varying from 0.5% to 2%.

Table 6 shows the readings of 7 days and 28 days compressive strength of the above variations. Figure 2 depicts comparison of compressive strengths for 7 days and 28 days of 5% replacement of cement with metakaolin, 12 % sand replacement with glass powder and adding recycled steel fiber with percent varying from 0.5% to 2%.

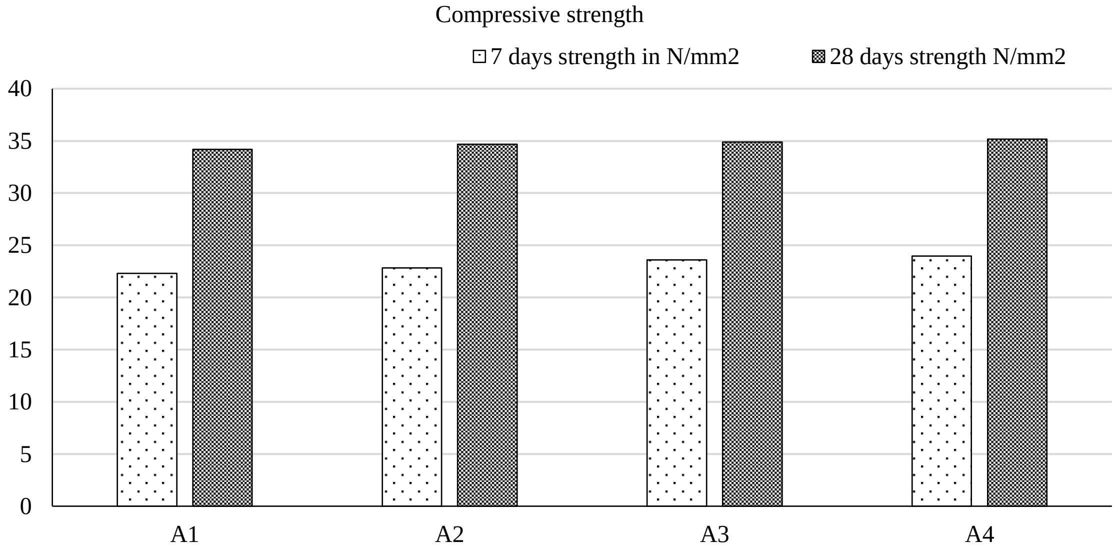

Figure 1. Comparison of 7 days and 28 days strength of Set A variations.

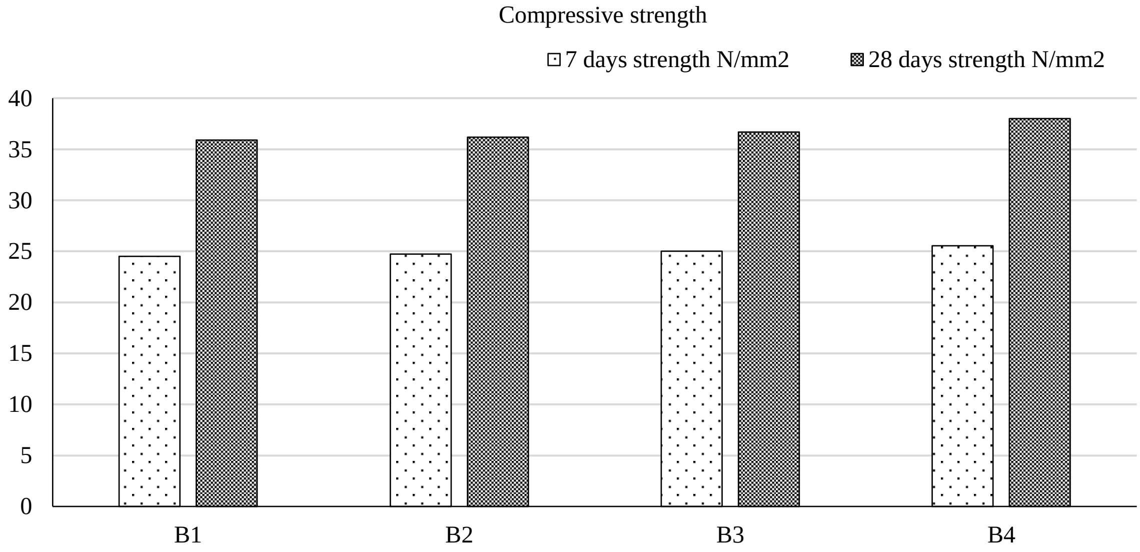

Figure 2. Comparison of 7 days and 28 days strength of set B variations.

Table 6. Readings of 7 days and 28 days compressive strength Set B variations.

Mix proportions	7 days strength N/mm^2	28 days strength N/mm^2
B1	24.51	35.89
B2	24.72	36.17
B3	25.01	36.68
B4	25.53	37.99

The third set of proportions were taken of 5% replacement of cement with metakaolin, 15 % sand replacement with glass powder and adding recycled steel fiber with percent varying from 0.5% to 2%.

Table 7 shows the readings of 7 days and 28 days compressive strength of the above variations. Figure 3 depicts comparison of compressive strengths for 7 days and 28 days of 5% replacement of cement with metakaolin, 15 % sand replacement with glass powder and adding recycled steel fiber with percent varying from 0.5% to 2%.

The fourth set of proportions were taken of 5% replacement of cement with metakaolin, 18 % sand replacement with glass powder and adding recycled steel fiber with percent varying from 0.5% to 2%.

Table 8 shows the readings of 7 days and 28 days compressive strength of the above variations. Figure 4 depicts comparison of compressive strengths for 7 days and 28 days of 5% replacement of cement with metakaolin, 18 % sand replacement with glass powder and adding recycled steel fiber with percent varying from 0.5% to 2%.

Table 7. Readings of 7 days and 28 days compressive strength Set c variations.

Mix proportions	7 days strength N/mm^2	28 days strength N/mm^2
C1	27.63	38.41
C2	28.21	40.07
C3	28.79	40.18
C4	29.21	40.69

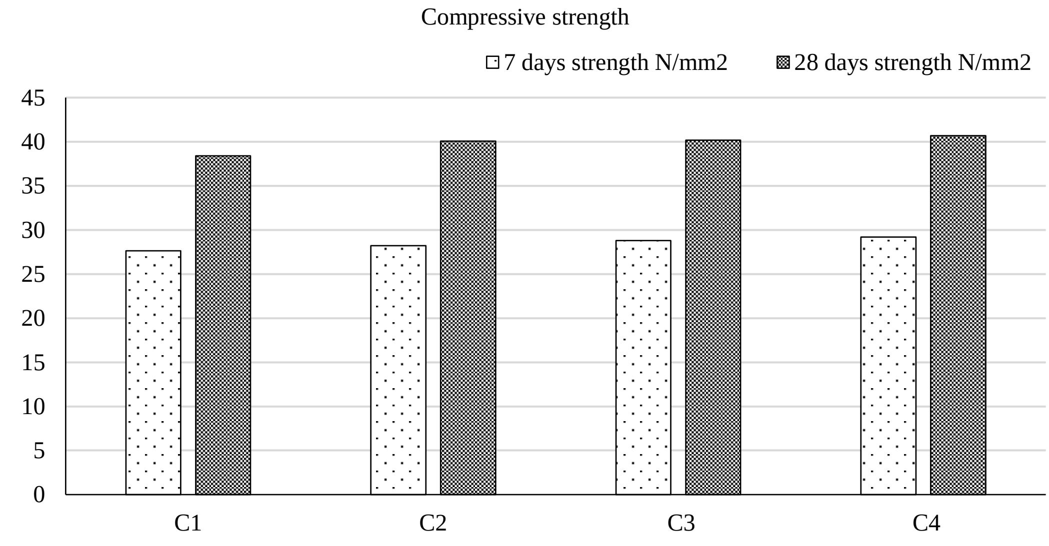

Figure 3. Comparison of 7 days and 28 days strength of Set C variations.

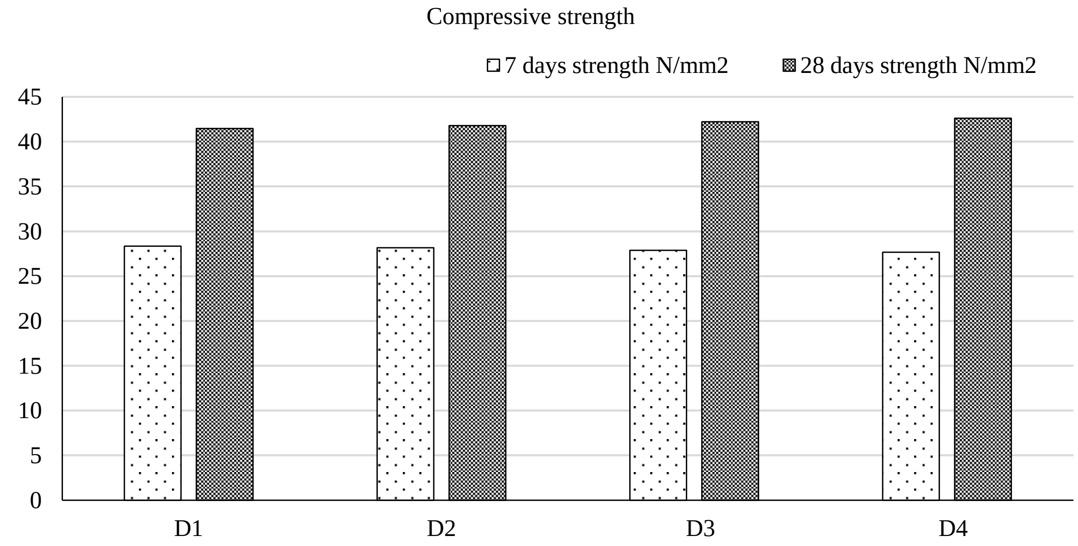

Figure 4. Comparison of 7 days and 28 days strength of Set D variations.

Table 8. Readings of 7 days and 28 days compressive strength Set D variations.

Mix proportions	7 days strength N/mm^2	28 days strength N/mm^2
D1	28.33	41.48
D2	28.16	41.78
D3	27.88	42.23
D4	27.67	42.62

CONCLUSIONS AND FINDINGS

The present study examines the influence of 5% metakaolin in fixed proportion, crushed glass powder 9, 12, 15, 18 % and recycled steel fiber 0.5, 1, 1.5, 2% in concrete mixes. The main aim of this research work is exploring the combined effects of metakaolin, recycled steel fiber, and waste glass aggregate on the mechanical properties of concrete. the optimal mix proportions of metakaolin, recycled steel fiber, and waste glass powder to enhance compressive strength and durability of concrete mixtures. the performance of concrete mixtures is assessed containing varied percentages of metakaolin, recycled steel fiber, and waste glass powder through comprehensive laboratory testing in accordance with Indian standards for M30 grade concrete. The 5% metakaolin was constant in all proportions of concrete. The conclusions drawn from the analysis of the experimental results are explained below:

1. 1.The workability was reduced by incorporating metakaolin in concrete, hence more water is required to maintain uniform slump.
2. Compressive strength increases gradually for 7 days till the replacement of glass powder 15% with recycled fiber with 2%.
3. This trend is not observed in case of replacement of glass powder 18% with recycled fiber with 0.5 %to 2%.
4. Compressive strength for 28 days increases continuously for all the mix proportions.
5. Maximum compressive strength for 7 days was with the replacement of glass powder 15% with recycled fiber with 2%.
6. Similarly, maximum compressive strength for 28 days was with the replacement of glass powder 18% with recycled fiber with 2%.

REFERENCES

1. Ashish Simalti, A.P Singh, "Comparative study on performance of manufactured steel fiber and shredded tire recycled steel fiber reinforced self- consolidating concrete" Elsevier, Construction and Building Materials, Volume 266, Part B, 10 January 2021, 121102.
2. Mavoori Hitesh Kumar, Nihar Ranjan Mohanta, Sandeep Samantaray, Nagarampalli Manoj Kumar, "Combined effect of waste glass powder and recycled steel fibers on mechanical behavior of concrete", Springer, S N Applied Science, Volume 3, article number 350, 19 February 2021.
3. S.M Samindi M.K Samarakoona, Pal Rubena, Jorgen Wie Pedersena, Luis Evangelista, "Mechanical performance of concrete made of steel fibers from tire waste" Elsevier, Case Studies in Construction Materials, Volume11, December 2019, e00259.
4. Olaniyi Arowojolu, Jennifer Fina, Ana Pruneda, Ahmed Ibrahim, Enad Mahmoud, "Feasibility Study on Concrete Performance Made by Partial Replacement of Cement with Nanoglass Powder and Fly Ash" Springer, International Journal of Civil Engineering, Volume 17, 16 August 2018, pages 1007-1014.
5. Dhirendra Patel, R.P. Tiwari, R. Shrivastava, R.K. Yadav, "Effective utilization of waste glass powder as the substitution of cement in making paste and mortar", Elsevier, Construction and Building Materials, Volume199, February 2019, pages 406-415.
6. D. Harbec, A. Zidol, A. Tagnit-Hamou, F. Gitzhofer, "Mechanical and durability properties of high-performance glass fume concrete and mortars", Elsevier, Construction and Building Materials, Volume134, 1 March 2017, pages 142-156.
7. Sana Gula, Sohaib Naseerb, "Concrete Containing Recycled Rubber Steel Fiber", Elsevier, Procedia Structural Integrity, Volume 18, 2019, pages 101-107.

ISSN: 2249-4723 (Online), ISSN: 2347-7253 (Print)

8. Mahsa Kamali, Ali Ghahremaninezhad, "Effect of glass powders on the mechanical and durability properties of cementitious materials", Elsevier, Construction and Building Materials, Volume 98, 15 November 2015, pages 407-416.
9. B.B. Sabir, S. Wild, J. Bai, "Metakaolin and calcined clays as pozzolans for concrete: review", Elsevier, Cement and Concrete Composites, Volume 23, Issue 6, December 2001, pages 441-454.
10. Duna Samson, Musa Abdullahi, Mohammed Abba-Gana, "Effect of metakaolin on compressive strength of concrete containing glass powder", International Journal of Research in Engineering and Technology, Volume 5, Issue 12, December 2016.
11. Morsli, Chaid, Molez, Diouri, "Effect of glass addition on the properties of cements", ResearchGate, Journal of Building Material and Structures ,18 April 2018, 5, page no 65-73 .

