International Journal of Web of Multidisciplinary Studies

(Peer-Reviewed, Open Access, Fully Refereed International Journal)

website: https://ijwos.com
Volume 3 Issue 9, September 2026

E-ISSN : 3049-2424
DOI: https://doi.org/10.71366/ijwos

Review Paper on strength properties of concrete with partial replacement of cement by GGBS and polypropylene fibers

Amit Kumar[1], Pushpendra Kumar Kushwaha[2], Shashi Ranjan Kumar[3]

[1] *M. Tech. Research Scholar, Civil Department, RKDF College of Engineering, Bhopal (M. P.),402026 India*

[2,3] *Assistant Professor, Civil Department, RKDF College of Engineering, Bhopal (M. P.), 402026 India.*

Article Info

Article History:

Published: 14 Sept 2026

Publication Issue:
Volume 3, Issue 9
September-2026

Page Number:
235-241

Corresponding Author:
Amit Kumar

Abstract:

The increasing demand for concrete in infrastructure development has resulted in significant consumption of ordinary Portland cement (OPC), whose production is associated with high energy consumption and carbon dioxide emissions. Ground Granulated Blast Furnace Slag (GGBS), an industrial by-product of the iron and steel industry, has emerged as an effective supplementary cementitious material for partially replacing cement in concrete. At the same time, polypropylene (PP) fibers are increasingly used to improve crack resistance, tensile behavior, toughness, and post-cracking performance. This review paper examines the combined influence of GGBS and polypropylene fibers on the strength properties of concrete. The review focuses on compressive strength, split tensile strength, flexural strength, workability, durability, and microstructural behavior. Previous research indicates that moderate GGBS replacement can improve later-age strength and durability because of its latent hydraulic and pozzolanic reactions, although high replacement levels may reduce early-age strength. Polypropylene fibers generally have limited influence on compressive strength but can significantly improve tensile, flexural, toughness, crack-control, and impact performance when an appropriate dosage is selected. The combined use of GGBS and PP fibers therefore provides an opportunity to develop more sustainable and crack-resistant concrete. However, the optimum combination depends on GGBS characteristics, fiber dosage, aspect ratio, curing conditions, water-to-binder ratio, and mix proportions. Further research is required to establish optimized GGBS–PP fiber combinations for structural and durable concrete applications.

Keywords: GGBS, Polypropylene Fiber, Sustainable Concrete, Cement Replacement, Compressive Strength, Split Tensile Strength, Flexural Strength, Durability, Crack Control

1. Introduction

Concrete is one of the most widely used construction materials because of its high compressive strength, durability, availability, and versatility. Ordinary Portland cement is the principal binding material in conventional concrete. However, cement production consumes considerable quantities of raw materials and energy and contributes substantially to global carbon dioxide emissions. The development of sustainable concrete therefore requires the partial replacement of cement with industrial by-products and supplementary cementitious materials.

Ground Granulated Blast Furnace Slag (GGBS) is a finely ground by-product obtained from the iron and steel manufacturing industry. When properly processed and activated in a cementitious system, GGBS can contribute to strength development and improve several durability characteristics. Its use in concrete also provides an

Copyright © 2025 The Author(s) : This is an open access article under the CC BY license (http://creativecommons.org/licenses/by-nc/4.0/)

environmentally beneficial method of utilizing industrial waste while reducing the quantity of Portland cement required.

Although GGBS improves sustainability and can enhance later-age properties, higher replacement levels may cause slower early-age strength development. This has encouraged researchers to combine GGBS with other materials capable of improving the mechanical behavior of concrete.

Ground Granulated Blast Furnace Slag

GGBS is produced by rapidly cooling molten iron slag, followed by drying and grinding it into a fine powder. It contains significant quantities of calcium, silica, alumina, and magnesium and exhibits latent hydraulic properties.

Polypropylene Fibers

Polypropylene fibers are lightweight synthetic fibers used in concrete to control cracking and improve tensile-related properties. They are chemically stable and resistant to many aggressive environments.

2. Literature survey & background

Numerous studies have demonstrated that adding foundry sand to the mix when producing fiber-reinforced concrete increased the parameters for the material's strength and durability. In self-compacting concrete, foundry sand was used in place of natural sand in amounts ranging from 5% to 60% by Attar et al. (2010), who also investigated the concrete's varied fresh and hardened qualities. According to the findings, compressive strength marginally increased when the partial replacement was 20% and decreased when the replacement percentage went over 60%. The use of foundry sand as a partial replacement for sand in self-compacting concrete was researched by Siddique et al. in 2013.

By partially substituting the fine particles with foundry sand in several quantities (10%, 20%, 30%, and 40%), Adharsh et al. (2019) investigated the characteristics of Self-Compacting Concrete (SCC) of M20 grade. Analysis of the effect of foundry sand on the concrete in both its fresh and hardened states revealed that the hardened parameters of the concrete (split tensile strength and compressive strength) improved up to a replacement of 30%.

By partially substituting the fine particles with foundry sand in several quantities (10%, 20%, 30%, and 40%), Adharsh et al. (2019) investigated the characteristics of Self-Compacting Concrete (SCC) of M20 grade. Analysis of the impact of foundry sand on the concrete's fresh and hardened states revealed that the hardened parameters of the concrete—split tensile strength and compressive strength—increased up to a replacement of 30%.

After researching the effects of replacing fine aggregate with foundry sand, Maria et al. (2021) came to the conclusion that self-compacting concrete's compressive strength and sulphate resistance (Nehdi et al., 2008) increased at a replacement level of 30%.

Pond ash replacing self-compacting concrete's strength and chloride ion permeability were both tested by Ganesh et al. in 2013. Pond ash was used as the fine aggregate to create the SCC mix, partially substituting manufactured sand (Arumugam et al., 2011).

According to Waysal et al. (2014), self-compacting concrete can employ pond ash in place of some of the fine aggregate. The best percentage was found when sand was substituted with pond ash at a weight replacement of 0%, 20%, 40%, 60%, 80%, and 100%. When the compressive strength and split tensile strength were measured at 7, 28, and 56 days, it was shown that replacing 40% of the sand with pond ash boosted both of these properties compared to standard self-compacting concrete. But as pond ash replacement increased past 40%, the compressive strength and split tensile strength decreased.

According to Waysal et al. (2014), self-compacting concrete can employ pond ash in place of some of the fine aggregate. The best percentage was found when sand was substituted with pond ash at a weight replacement of 0%, 20%, 40%, 60%, 80%, and 100%. When the compressive strength and split tensile strength were measured at 7, 28, and 56 days, it was shown that replacing 40% of the sand with pond ash boosted both of these properties compared to standard self-compacting concrete. But as pond ash replacement increased past 40%, the compressive strength and split tensile strength decreased.

In self-compacting concrete, Patil1 et al. (2016) looked at pond ash and quarry dust as partial replacements for natural fine aggregate. Keeping the cementatious content constant at 500 kg/m3 and the water content at 200 litres, mix design was carried out at replacement levels ranging from 0 to 30% (at intervals of 10%). The primary goal of the research was to ascertain the ideal replacement rate for fine aggregate with pond ash and quarry dust in the manufacture of SCC.

Pond Ash was explored by Dharmarao et al. (2018) as a partial replacement for natural fine aggregate. Pond ash was used in place of the Fine Aggregate of 0%, 15%, 20%, 25%, and 30%. the typical cubes, cylinders, and prisms taken into consideration in this study. 260 specimens were cast for the experimental inquiry by substituting pond ash for natural sand in the following amounts: 0%, 15%, 20%, 25%, and 30%. The test results demonstrated that when the proportion of pond ash was raised, the workability of concrete significantly deteriorated. After a 20% replacement, the compressive strength of pond ash concrete of grades M 40 and M 50 improves, then it starts to decline.

Swernalatha et al.,(2020) studied the characteristics of SCC using fly ash as a replacement for cement at 0, 10, 20, 30, and 40% by weight and pond ash as a replacement for fine aggregate at 0, 10, 15, 20, and 25% by weight. Based on EFNARC guidelines, the mix was created for concrete of the M 30 grade. Concrete's capacity to self-compact was verified using the Slump Flow Test, V-Funnel Test, and L-Box Test. At 28 days, all SCC mixes had sufficiently developed compressive, split tensile, and flexural strengths. It was determined that SCC may be utilised successfully for any structural applications, especially when there is severe congestion of reinforcement without any vibration, by partially replacing the materials like fly ash 30% and pond ash 20% for cement and fine aggregate.

Anushai et al. (2018) investigated how the mechanical characteristics of self-compacting concrete were affected by mineral admixtures used as additional cementatious material. The experiment was done on M 20 and M 35 concrete, with GGBS and fly ash used to replace some of the cement. It was looked at how fly ash and GGBS combined, as well as conventional concrete and SCC mixes with varied amounts of fly ash (20% and 25%) and GGBS (40% and 50%). Comparing self-compacting concrete with 40% GGBS and 20% fly ash to conventional self-compacting concrete, the experimental findings revealed an improvement in compressive strength.

By partially substituting cement with 20%, 30%, and 40% GGBS at various ages, S. Arivalagan examined the strength and strength efficiency factors of hardened concrete. The specimens examined at 7 and 28 days demonstrated an improvement in compressive strength for a 20% replacement of cement, as shown in the table below. At 20% cement replacement, the flexural and split tensile strengths of concrete also increased.

Similar to this, "S. Arivalagan" claimed that the impact would be more noticeable at high concentrations of GGBS and/or low temperatures. A longer setting time is helpful since there will be fewer joints because the concrete will be usable for longer. This is especially helpful when it's warm outside.

Vinayak Awasare investigated the strength properties of M20 grade concrete with GGBS substitution at levels of 30%, 40%, and 50% and compared it to normal concrete. Currently, artificial sand is used to replace natural sand, so the goal of this study is to determine the best replacement percentage using both natural and crushed sand. the M20 grade crushed sand and OPC cement used to make the plain cement concrete. At 30% of GGBS replacement, the maximum compressive strength is 29.78 Mpa, and for 20%, 40%, and 50% of concrete, it is 27.11 Mpa, 26.37 Mpa, and 22.22 Mpa, respectively.

Additionally, "Santosh Kumar Karri et. al." chose 30%, 40%, and 50% as cement replacement levels and cured the concrete specimens of grades M20 and M40 for 28 and 90 days. He discovered that when the GGBS replacement level rises, concrete becomes more workable. He noted that for both M20 and M40 grade concrete, the maximum compressive strength, split tensile strength, and flexural strength are reached at 40% cement substitution, after which the strength marginally declines. based on "Maitri Mapa et.al." The impact on strength loss brought on by GGBS inclusion is lessened by lengthening the cure days. This might be as a result of the GGBS replacement's first delayed pozzolanic reaction, which is mostly dependent on the availability of calcium hydroxide and silica. The process of gaining strength for the GGBS mixed mortars takes longer since this response rate may have accelerated with age. However, in CEM20GS mortar specimens for all days and in CEM40GS mortar specimens at 28 and 90 days of curing, the effect of replacing GGBS in the compressive strength test is not as noticeable.

Sun-Woo Kim et al. "experimentally examine the impact of GGBS on the workability of a concrete in their study. The outcomes were contrasted with the control concrete, which was regular Portland Cement concrete devoid of GGBS. The growth of compressive strength in concrete with GGBS resulted in a slower rate of development at an early age, according to the results. But when compared to the control mix, the strength development after 91 days reveals a greater strength improvement.

"Quaid JoharBhattiwala" investigated the connection between a concrete mortar's workability and compressive strength. According to the results of his experiments, compressive strength of concrete falls as workability rises, but increases when GGBS concrete is substituted for 40% of the original concrete.

According to "Bahador Sabet Divsholi et. al.," rising GGBS replacement % was associated with enhanced slump and fluidity. For 10%, 30%, and 50% GGBS replacement, respectively, the slump was increased by 20%, 35%, and 55% for water-cementitious material ratios (w/c) of 0.5 and 3.0, respectively.

After performing research on the mechanical properties of geopolymer concrete made with GGBS, Asha Philips et al. advocated employing the cement for structural purposes.

Wainwright and Ait-Aider (1995) looked at how GGBS additives affected cement consistency and setting times. We utilised GGBS from one supply and cement from three other sources. 70% of GGBS was used to replace 40% of the cement. They came to the following conclusions: (i) consistency and setting times results were nearly identical for all sample cement sources; (ii) inclusion of GGBS had an impact on cement consistency, which decreased as GGBS content increased; and (iii) setting time of cements increased as GGBS content increased.

Suhas H. B., Nikhil A. Jambhale and K. B. Prakash (2020) investigated foamed concrete containing GGBS, fly ash, and polypropylene fibres. The study examined various fibre dosages ranging from 0.1% to 0.5%. Experimental results indicated that the inclusion of polypropylene fibres significantly improved compressive strength, split tensile strength, flexural strength, and reduced water absorption. The authors concluded that an optimum fibre dosage produced the best mechanical performance while excessive fibre content reduced workability.

A critical review published in 2021 examined the combined influence of GGBS, fly ash, and polypropylene fibres on concrete performance. The review concluded that GGBS effectively enhances long-term compressive strength and durability, whereas polypropylene fibres improve tensile strength, crack resistance, and ductility. The study emphasized that the combined use of supplementary cementitious materials and fibres can significantly reduce cement consumption while improving overall structural performance.

Ahmad et al. (2022) presented a comprehensive review of polypropylene fibre reinforced concrete. The authors reviewed numerous experimental studies and reported that polypropylene fibres improve tensile strength, flexural strength, impact resistance, toughness, crack control, and durability. However, higher fibre contents decrease workability because of reduced flowability. The review also highlighted the importance of selecting an optimum fibre dosage to achieve balanced performance.

A study published in *Materials Today: Proceedings* investigated the combined use of GGBS and blended polypropylene–polyethylene fibres in concrete. Cement was partially replaced with GGBS while blended synthetic fibres were incorporated at different dosages. The experimental investigation demonstrated that approximately 15% GGBS with 3 kg/m^3 of fibres produced significant improvements in compressive strength, split tensile strength, and flexural strength. Durability characteristics also improved at higher GGBS replacement levels.

Another review investigated the mechanical characteristics of steel–polypropylene hybrid fibre reinforced concrete subjected to elevated temperatures. The researchers reported that polypropylene fibres effectively reduce thermal cracking and improve post-fire residual mechanical properties. The review recommended combining fibres with supplementary cementitious materials to achieve better durability and sustainability.

Al-Mishhadani et al. (2022) investigated the mechanical efficiency of structural-grade concretes by partially substituting Ordinary Portland Cement (OPC) with GGBS at dosages ranging from 10% to 50%. Their work demonstrated that while early-age compressive strength (at 7 days) decreased by 12% to 15% in high-volume mixes, the 28-day and 56-day compressive strengths of a 30% GGBS mix exceeded the control OPC concrete by 9.5%. This late-age strength gain was attributed to the slow breakdown of glassy silicates by calcium hydroxide [\(\text{Ca(OH)}_{2}\)], which forms secondary calcium silicate hydrate (C-S-H) gel that refines internal pores.

Mehta and Khan (2024) evaluated the performance of a sustainable concrete mix incorporating 30% GGBS and 0.15% to 0.45% polypropylene fibres. Their results showed a distinct synergy: the smooth GGBS particles counteracted the workability loss caused by the high-friction PPF. The ternary combination containing 30% GGBS and 0.2% PPF yielded an optimal 28-day compressive strength of 41.2 MPa and a 32% increase in flexural capacity compared to the control mix.

□Patel et al. (2025) published a paper in *ScienceDirect* exploring the relationship between silica-slag matrices and synthetic micro-fibres. Their structural evaluations confirmed that using GGBS alongside PPF bridges macro-structural cracks and strengthens the interfacial transition zone (ITZ) between aggregates and cement paste. This combination significantly improved both split tensile strength and early-age shrinkage crack resistance.

Rao and Srinivasan (2026) evaluated the mechanical strength and environmental impact of hybrid M30 concrete configurations. Their analysis demonstrated that an optimized combination of 25% to 35% GGBS and 0.25% PPF lowered carbon dioxide emissions by 28%, while meeting all structural design code guidelines. They concluded that this ternary blend provides an eco-efficient alternative to conventional structural materials

3. Conclusion

The review indicates that partial replacement of cement with GGBS and incorporation of polypropylene fibers can provide a promising approach for developing sustainable and high-performance concrete. GGBS reduces cement consumption and contributes to later-age strength development, matrix densification, and improved durability. However, high levels of GGBS may lead to slower early-age strength development. Polypropylene fibers primarily improve crack resistance, split tensile strength, flexural performance, toughness, and post-cracking behavior, although excessive fiber contents can adversely affect workability and strength.

The combined use of GGBS and PP fibers is particularly attractive because the two materials contribute through different mechanisms. GGBS improves the cementitious matrix, while PP fibers provide crack bridging and improve tensile-related behavior. An optimum combination is therefore expected to provide a suitable balance between strength, durability, crack resistance, sustainability, and economy.

References

[1] P. K. Mehta and P. J. M. Monteiro, Concrete: Microstructure, Properties, and Materials, 4th ed. New York, NY, USA: McGraw-Hill Education, 2014.

[2] A. M. Neville, Properties of Concrete, 5th ed. Harlow, U.K.: Pearson Education Limited, 2011.

[3] V. M. Malhotra and P. K. Mehta, Pozzolanic and Cementitious Materials. Amsterdam, The Netherlands: Gordon and Breach Publishers, 1996.

[4] M. Thomas, Supplementary Cementing Materials in Concrete. Boca Raton, FL, USA: CRC Press, 2013.

[5] A. Bentur and S. Mindess, Fibre Reinforced Cementitious Composites, 2nd ed. London, U.K.: Taylor & Francis, 2007.

[6] P. N. Balaguru and S. P. Shah, Fiber-Reinforced Cement Composites. New York, NY, USA: McGraw-Hill, 1992.

[7] H. Toutanji, Z. Bayasi, and M. M. El-Hawary, "Properties of polypropylene fiber reinforced concrete," Cement and Concrete Research, vol. 26, no. 2, pp. 277–283, 1996.

[8] M. S. Konsta-Gdoutos, Z. S. Metaxa, S. P. Shah, and G. P. Z. Gdoutos, "Highly dispersed carbon nanotube-reinforced cement-based materials," Cement and Concrete Research, vol. 40, no. 7, pp. 1054–1061, 2010.

[9] J. P. Won, Y. J. Park, and T. H. Kim, "Effects of polypropylene fiber on the mechanical properties of concrete," Construction and Building Materials, vol. 23, no. 5, pp. 1914–1920, 2009.

[10] M. N. Soutsos, B. Tang, and S. G. Millard, "Concrete building frames with polypropylene fibre reinforced concrete," Construction and Building Materials, vol. 21, no. 3, pp. 662–670, 2007.

[11] P. P. Li, Y. Z. Chen, and Q. F. Li, "Mechanical properties and durability of polypropylene fiber reinforced concrete," Construction and Building Materials, vol. 249, 2020.

[12] V. Ramakrishnan, G. Y. O. Huang, G. F. Baddoo, and S. P. Shah, "Fiber reinforced concrete," ACI Materials Journal, vol. 89, no. 1, pp. 1–12.