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Strength of Steel Fiber Concrete Using Coal Fly Ash and Silica Fume

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ABSTRACT: In a future where all concrete is recycled, maintaining the properties of recycled concrete is essential. Typically, recycling concrete can lead to a loss of properties, but this is not true for all mixtures. This paper provides an in-depth examination of methods to preserve the properties of recycled aggregate concrete (RAC). Various types of RAC were tested with different replacement ratios in the reviewed literature. The impact of adding steel fibers, silica fume, or fly ash to the mixtures was evaluated both separately and in combination. Specifically, coal fly ash was replaced by 0%, 10%, 20%, and 30%, and silica fume was replaced by 0%, 5%, 10%, and 15% for cement. Initially, concrete specimens with different proportions of coal fly ash and silica fume, without steel fibers, were tested for compressive, flexural, and split tensile strength. Subsequently, sets of specimens with 0.5% and 2% steel fibers were tested under the same conditions. The results indicated that the optimal combination for maximum strength was 15% coal fly ash, 20% silica fume, and 2% steel fiber.

KEYWORDS: Recycled coarse aggregate, steel fiber, silica fume, fly ash, compressive strength, flexural strength.

I. INTRODUCTION

Silica fume, also known as micro silica or condensed silica fume, is used as an artificial pozzolanic admixture. It is produced by reducing quartz with coal in an electric arc furnace during the manufacture of silicon or ferrosilicon alloy. Silica fume contains over 90% silicon dioxide, with other components including carbon, sulfur, and oxides of aluminum, iron, calcium, magnesium, sodium, and potassium. Physically, silica fume particles are about 0.1 to 0.2 microns in diameter, have a surface area of about 30,000 m^2/kg, and a density ranging from 150 to 700 kg/m^3.

Fiber reinforced concrete (FRC) is a cement-based composite material that has gained popularity in recent years due to its excellent flexural-tensile strength, resistance to splitting, impact resistance, and permeability, as well as frost resistance. It effectively increases the toughness, shock resistance, and resistance to plastic shrinkage cracking of mortar. Fibers, which can be circular, triangular, or flat in cross-section, are described by their aspect ratio—the ratio of length to diameter. Many studies have investigated the effects of recycling on the properties of recycled aggregate concrete (RAC), noting variations when using different cement replacement materials and additions like superplasticizers and steel fibers.

For decades, steel fibers have been used to reduce cracks and enhance ductility in concrete. However, few studies have focused on the impact of steel fibers on the durability and compressive strength of RAC containing fly ash and silica fume. This paper reviews scientific findings on recycled aggregate concrete and compares the fresh and hardened properties of different concrete admixtures with those of controlled concrete. It addresses questions about the role and effectiveness of cement replacement materials (fly ash or silica fume) and their impact on the properties of normal and recycled aggregate concrete, as well as the potential improvement in RAC properties with the addition of steel fibers. The use of pozzolanic materials as partial replacements for cement in concrete is becoming increasingly important due to their ability to enhance the long-term durability of concrete and provide ecological benefits. These materials include coal fly ash (a waste product from coal thermal power plants), ground granulated blast furnace slag, silica fume (a by-product of producing silicon or ferrosilicon alloys from high purity quartz and coal in a submerged-arc electric furnace), rice husk ash (a by-product from co-generation power plants burning rice husk), and high reactive metakaolin (HRM). These materials are widely available in India.

Figure 1. Fly Ash (Left) & Silica Fume (Right) Supplement Materials

II. MATERIALS

Silica Fume: Silica fume is a by-product produced during the reduction of high-purity quartz with coal in electric arc furnaces for manufacturing ferrosilicon and silicon metal. This fume, rich in amorphous silicon dioxide and composed of extremely fine spherical particles, is collected by filtering the gases emitted from the furnaces.

Properties of Fresh Silica Fume Concrete:

- Requires more water to achieve the same workability as conventional concrete
- Has low workability
- Exhibits a low slump value
- Low risk of bleeding and segregation
- The mixture is cohesive
- High plastic shrinkage

Figure 2. Silica Fume

Steel Fiber: Steel fibers are typically used to resist cracking and strengthen concrete. In this project, I will test steel fiber reinforced concrete to assess the impact of fibers on its flexural strength. Steel fiber is a type of metal reinforcement, defined as short, discrete lengths with an aspect ratio (length to diameter ratio) ranging from approximately 20 to 100. These fibers have various cross-sections and are small enough to be randomly distributed in an unhardened concrete mixture using standard mixing procedures. Adding a specific amount of steel fiber to concrete can significantly enhance its physical properties, greatly improving its resistance to cracking, impact, fatigue, and bending, as well as its tenacity and durability.

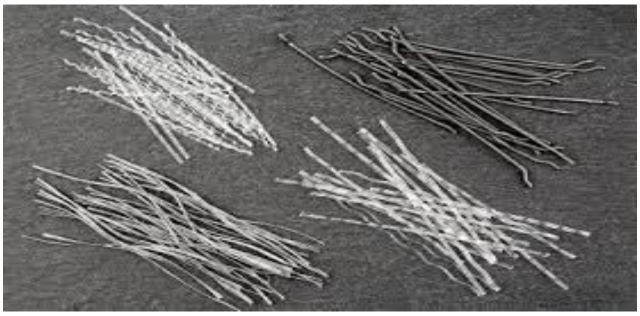


Figure 3. Steel Fibers

Types of Steel Fibers and Their Use in Concrete:

To enhance concrete properties, various types of fibers are used in both construction practice and research. These fibers can be made from plastic, glass, carbon, or steel (Fig. 4). Steel fibers are small pieces of metal reinforcement with varying aspect ratios (length to diameter), up to 100 mm in length, and come in different forms and ends (straight, crimped, stranded, hooked, and twisted). There are five groups of steel fibers based on their shape and production process: mill cut, melt-extracted, cut sheet, cold-drawn wire, and modified cold-drawn wire. The primary benefits of using steel fibers in concrete include reducing the number of surface cracks, increasing resistance to high temperatures and external impacts, and improving other properties such as bending capability, durability, toughness, and fatigue resistance.

Figure 4. Fibers commonly used to Reinforce Concrete

Steel Fibers in Ultra-High-Performance Concrete (UHPC):

In various civil engineering applications such as bridge construction, decks, slabs, and industrial pavements, steel fibers play a crucial role. Brandt's study [7] focuses on the development of ultra-high-performance concrete (UHPC) and highlights that steel fibers can reduce the cement content in concrete, thereby lowering its carbon footprint and environmental impact.

Steel Fibers in Lightweight Concrete (LWC):

Research indicates that even a small amount of fibers can enhance the composition of lightweight concrete, preventing brittle failure. The influence of steel fibers on flexural strength surpasses their direct effect on stress or compression.

Steel Fibers in Self-Compacting Concrete (SCC):

Ramesh et al. [10] studied different percentages of steel fibers (0.3%, 0.6%, 0.9%, 1.2%) in self-compacting concrete mixes to evaluate their impact on workability and strength properties. Results showed improvements in flexural and split tensile strength after 7 days for SCC with steel fibers compared to control concrete, with more significant enhancements (15-21%) observed by the 28th day.

The Necessity of Recycled Coarse Aggregate (RCA):

Concrete, a primary construction material, offers significant advantages but also contributes to environmental impact through CO_2 emissions. Zhang et al. [13] noted global concrete production amounts and emphasized the high usage of aggregate (49%) and water (16%) annually.

Using Silica Fume:

Cakir and Sofyanli investigated the impact of silica fume (SF) on recycled concrete quality by replacing Portland cement with 0%, 5%, and 10% SF. Concrete specimens substituted natural aggregates with recycled aggregates, revealing enhanced mechanical and physical properties with 10% SF in recycled aggregate concrete (RAC).

Using Steel Fiber:

Gao et al. explored the durability of steel fiber reinforced recycled coarse aggregate concrete (SFRRAC) through carbonization, freeze-thaw, and chloride penetration tests. They varied coarse aggregate replacements (0%, 30%, 50%, 100%) and steel fiber ratios (0%, 0.5%, 1%, 1.5%, 2%), finding improvements in carbonation resistance, freeze-thaw durability, and chloride permeability.

Cement:

Cement, known for its cohesive and adhesive properties in water, primarily comprises silicates and aluminates of lime from limestone and clay. Ordinary Portland cement (OPC), available in 33, 43, and 53 grades, offers rapid strength development. Portland slag cement, blending Portland cement clinker, gypsum, and granulated blast furnace slag, features lower heat evolution, enhanced durability, and suitability for mass concrete production. Oxide compositions of lime, silica, alumina, and iron oxide in cement kilns form complex compounds, influencing cement properties, aided by cooling rates.

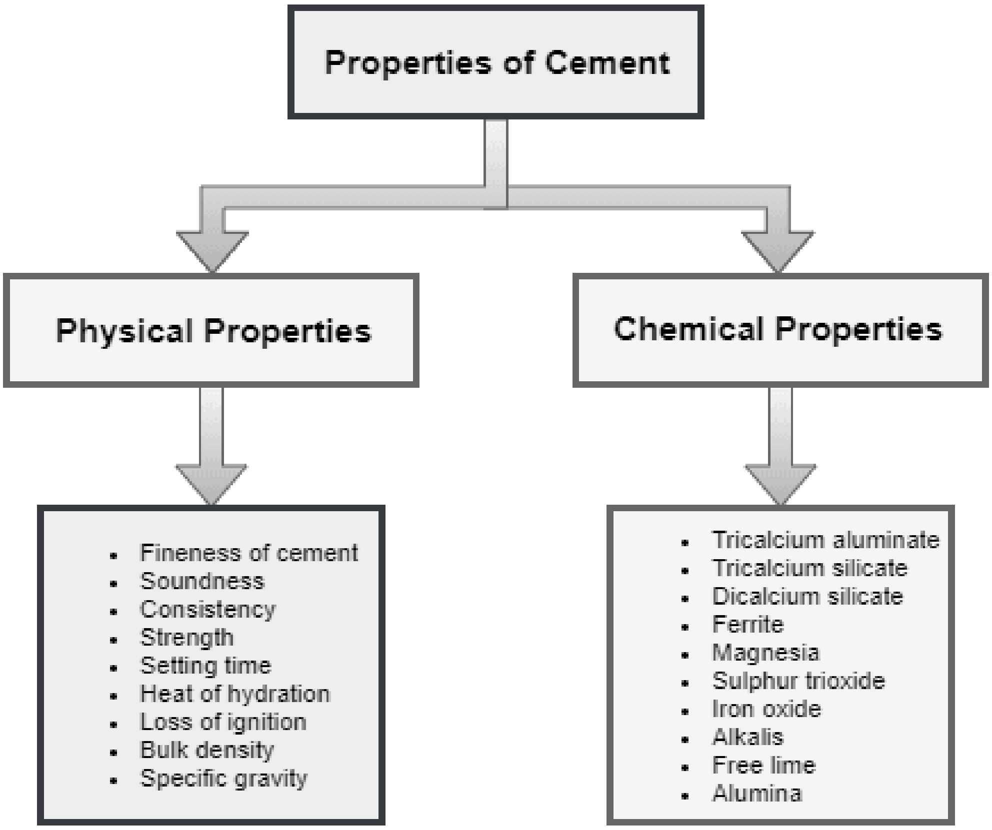


Figure 5. Properties of Cement

Table 1. Influence of Rate of Cooling on Compressive Strength

Type of cement	Cooling Conditions	Compressive Strength MPa		
		3 days	7 days	28 days
Normal Cement	Quick	9.9	15.3	26
	Moderate	9.7	21	27
	Slow Very slow	9.7	19.3	24
		8.7	18.7	23
High early strength cement	Quick	10.2	18.8	29
	Moderate	14.2	26.7	33
	Slow Very Slow	10.2	21	29
		9.1	18.1	28

Fly Ash: Coal fly ash is a finely divided residue generated from the combustion of powdered coal, transported by flue gases, and collected through electrostatic precipitation. In the U.K., it is known as pulverized fuel ash (PFA). Coal fly ash is the most commonly used pozzolanic material globally. It was first utilized on a large scale in the construction of the Hungry Horse Dam in America, where it comprised approximately 30% of the cement by weight. Subsequently, it was used in the construction of Canyon and Ferry dams. In India, coal fly ash was incorporated in the Rihand Dam construction, replacing up to 15% of the cement.

Recently, the significance and use of coal fly ash in concrete have increased to the point where it has become a standard ingredient, especially for producing high-strength and high-performance concrete. Extensive research worldwide has explored the benefits of using coal fly ash as a supplementary cementitious material. High-volume coal fly ash concrete is currently a topic of global interest.

Coal fly ash

III. PROBLEM STATEMENT

From the above literature review, the following conclusions can be drawn:

1) Using self-compacting concrete instead of a normal mix slightly increases the shear capacity of beams.
2) The characteristic strength of concrete increases up to a certain optimal value, after which it decreases.
3) Split tensile strength and flexural strength also increase, while water absorption capacity decreases.
4) Replacing cement with metakaolin and silica fume in various proportions results in a slight increase in the characteristic strengths.

IV. CONCLUSIONS

The study on the effect of steel fibers with coal fly ash remains promising due to the ongoing need to address concrete brittleness and the disposal of coal fly ash from power plants. The following conclusions can be drawn from the present investigation:

1) The density of concrete increases as the percentage of steel fibers rises, with 10% coal fly ash content.
2) A superplasticizer agent is required to produce a workable mix.
3) For small quantities of coal fly ash (10% and 20%), the compressive strength is higher with 1.0% steel fibers.

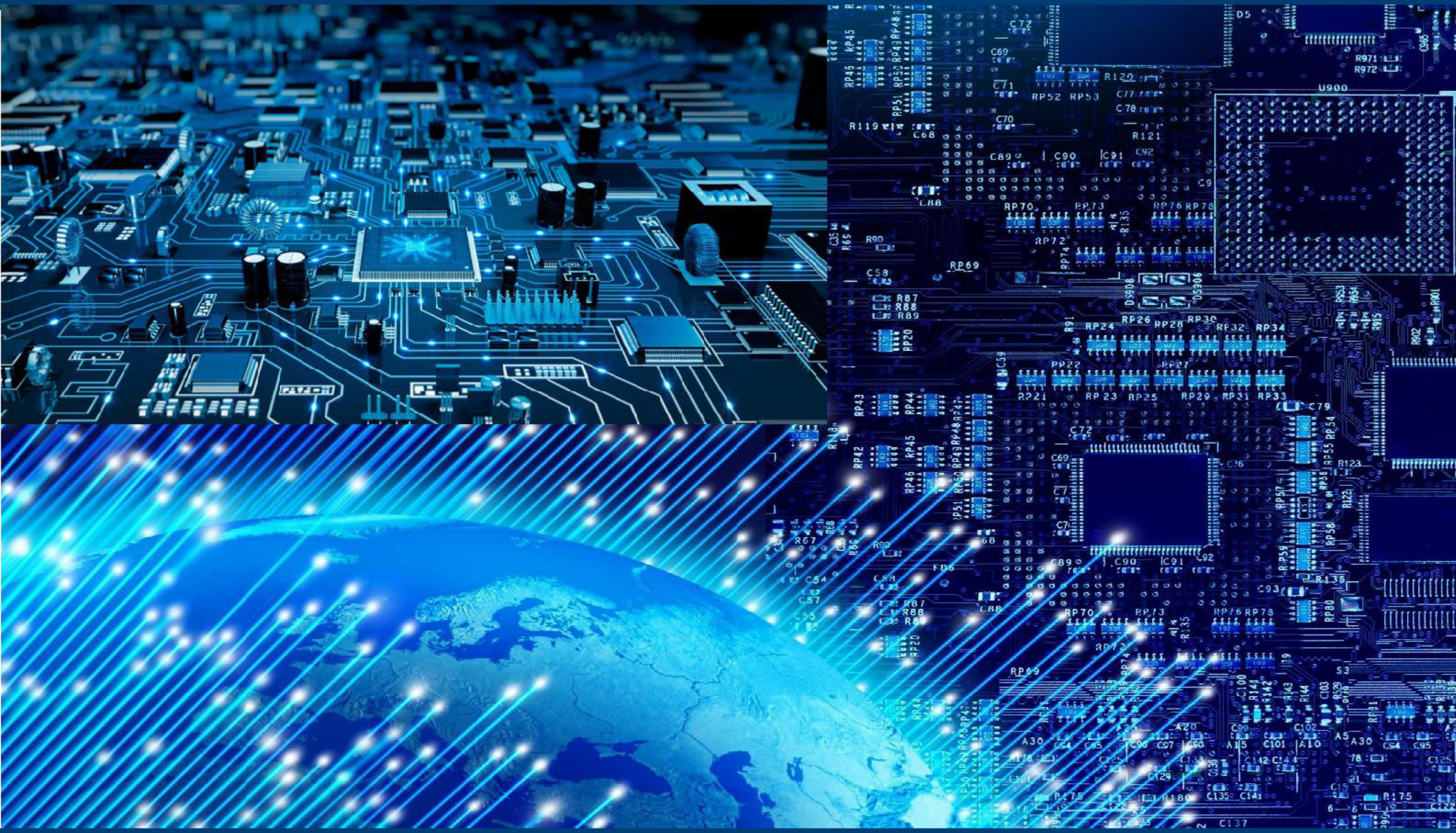
Additional findings include:

1) The maximum strength of the specimen after 28 days is 127.0 tons for 1% steel fibers.
2) A 15% increase in strength is observed when 1% steel fibers are added to the mix. Strength increases up to 1% fiber content, but further increases in fiber content lead to a reduction in strength.
3) Using metakaolin and silica fume as cement replacements helps reduce energy consumption in cement manufacturing.

REFERENCES

1. Babar Ali , Erol Yilmaz , Ahmad Raza Tahir,Fehmi Gamaoun, Mohamed Hechmi El Ouni, Nd Syed Muhammad Murtaza Rizvi1(November 2021) "The durability of high-strength concrete containing waste tire steel fiber and coal fly ash" hindawi advances in materials science and engineering volume 2021, article id 7329685, 19 pages https://doi.org/10.1155/2021/7329685
2. G.H.L.S.Sai Kumar, M.Jugal Kishore (2021) "experimental study of fly ash based steel fiber reinforced self compacting concrete" the authors. Production and hosting by elsevier b.v. on behalf of king saud university. this is an open access article under the cc by-nc-nd license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
3. Hemn Qader Ahmed , Dilshad Kakasor Jaf, And Sinan Abdulkhaleq Yaseen (January 2020) "Comparison Of The Flexural Performance And Behaviour Of Fly-Ash-Based Geopolymer Concrete Beams Reinforced With Cfrp And Gfrp Bars" hindawi advances in materials science and engineering volume 2020, article id 3495276, 15 pages https://doi.org/10.1155/2020/3495276 department of civil engineering, salahaddin university-erbil, erbil, Iraq correspondence should be addressed to hemn qader ahmed; hemn.ahmed@su.edu.krd received 4 april 2019; revised 25 november 2019; accepted 26 december 2019; published 11 january 2020
4. Esakkiraj. P, Sreesha. S, Sreevidya. V, Antony Jeyendran. S (July 2020) "Development of high volume fly ash concrete incorporating steel fibre" international journal of recent technology and engineering (ijrte) issn: 2277-3878 (online), volume-9 issue-2, july 2020 426 published by: blue eyes intelligence engineering & sciences publication retrieval number: b3567079220/2020©beiesp doi:10.35940/ijrte.b3567.07922 journal website: www.ijrte.org
5. Anil Kumar, Mr. Rohit Kumar, Dr.Partima Kumar (September-2018) "A review paper about steel fiber and fly ash based concrete" international journal for technological research in engineering volume 6, issue 1, september-2018 issn (online): 2347 - 4718 www.ijtre.com copyright 2018.all rights reserved. 4754
6. Shyam, A. Anwar, Syed Aqeel Ahmad (March 2017) "A Literature Review on Study of Silica fume as Partial Replacement of Cement in Concrete" DOI:10.24001/IJAEMS.3.3.18Corpus ID: 55118118 Published 1 March 2017 Materials Science, Engineering International Journal of Advanced engineering, Management and Science
7. Irfaz Ur Rahman Najar , Jagdish Chand Kambooj (2016) "Combine effect of silica-fume, fly-ash and steel fibre on reinforced concrete, a review" hindawi publishing corporation advances in materials science and engineering volume 2016, article id 1638419, 7 pages http://dx.doi.org/10.1155/2016/1638419
8. Khadake S.N., Konapure C.G. (Nov-Dec. 2012), "an investigation of steel fiber reinforced concrete with fly ash" iosr journal of mechanical and civil engineering (iosr-jmce) issn: 2278-1684 volume 4, issue 5 (nov-dec. 2012), pp 01-05 www.iosrjournals.org www.iosrjournals.org 1 | page
9. B.R. Phanikumar, A. Sofi (November 2014) "Effect of pond ash and steel fibre on engineering properties of concrete" received 1 july 2014; revised 26 november 2014; accepted 12 march 2015 available online 20 april 2015 the cc by-nc-nd license (http://creativecommons.org/licenses/by-nc-nd/4.0/). ain shams engineering journal (2016) 7, 89–99
10. Bissonnette, B., Pierre, P. and Pigeon, M., 1999. Influence of key parameters on drying shrinkage of cementitious materials. Cement and Concrete Research, 29(10), pp.1655-1662.
11. Verma, P., Dhurvey, P., & Sundramurthy, V. P. (2022). Potential Assessment of E - Waste Plastic in Metakaolin Based Geopolymer Using Petrography Image Analysis. Advances in Materials Science and Engineering, 2022(1), 7790320.
12. Kim, J.K. and Lee, C.S., 1998. Prediction of differential drying shrinkage in concrete. Cement and Concrete Research, 28(7), pp.985-994.
13. Verma, P., Dhurvey, P., & Sundramurthy, V. P. (2022). Structural Behaviour of Metakaolin Geopolymer Concrete Wall - Type Abutments with Connected Wing Walls. Advances in Materials Science and Engineering, 2022(1), 6103595.
14. Fujiwara, T., 2008. Effect of aggregate on drying shrinkage of concrete. Journal of Advanced Concrete Technology, 6(1), pp.31-44.
15. Verma, P., Dhurvey, P., & Gour, C. P. (2023). Utilization of E-Waste as Coarse Aggregates in Geopolymer Concrete. In Sustainable Approaches and Strategies for E-Waste Management and Utilization (pp. 224-238). IGI Global.
16. Li, J. and Yao, Y., 2001. A study on creep and drying shrinkage of high performance concrete. Cement and Concrete Research, 31(8), pp.1203-1206.
17. Sahu, B., Dhurvey, P., Verma, P., Raheem, J., & Bhargava, A. (2022, November). Behaviour Analysis of Layered Beam Using ANSYS. In International conference on Advances in Materials and Manufacturing (pp. 135-142). Singapore: Springer Nature Singapore.

18. Shariq, M., Prasad, J. and Abbas, H., 2016. Creep and drying shrinkage of concrete containing GGBFS. Cement and Concrete Composites, 68, pp.35-45.
19. Dhurvey, P., Panthi, H., Verma, P., & Gaur, C. P. (2023). Utilization of Waste Ceramic Tiles as Coarse Aggregates in Concrete. In Waste Recovery and Management (pp. 291-302). CRC Press.
20. Maruyama, I. and Sugie, A., 2014. Numerical study on drying shrinkage of concrete affected by aggregate size. Journal of Advanced Concrete Technology, 12(8), pp.279-288.
21. Kioumarsi, M., Azarhomayun, F., Haji, M. and Shekarchi, M., 2020. Effect of shrinkage reducing admixture on drying shrinkage of concrete with different w/c ratios. Materials, 13(24), p.5721.
22. Yuan, J., Lindquist, W.D., Darwin, D. and Browning, J., 2015. Effect of slag cement on drying shrinkage of concrete. American Concrete Institute.
23. Hooton, R.D., Stanish, K., Angel, J.P. and Prusinski, J., 2009. The effect of ground granulated blast furnace slag (slag cement) on the drying shrinkage of concrete–a critical review of the literature. Slag Cement Concrete, pp.79-94.
24. Abdalhmid, J.M., Ashour, A.F. and Sheehan, T., 2019. Long-term drying shrinkage of self-compacting concrete: Experimental and analytical investigations. Construction and Building Materials, 202, pp.825-837.
25. Benboudjema, F., Meftah, F. and Torrenti, J.M., 2005. Interaction between drying, shrinkage, creep and cracking phenomena in concrete. Engineering structures, 27(2), pp.239-250.
26. Almudaiheem, J.A., 1992. An improved model to predict the ultimate drying shrinkage of concrete. Magazine of concrete research, 44(159), pp.81-85.



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