

# An Experimental Investigation of Impact of Polypropylene as a Partial Replacement in Concrete

Hinamshu Pathak<sup>1\*</sup>, B.P. Mudgal<sup>2</sup>

## Abstract

India, as a developing nation, will require high-strength and high-performance concrete for future infrastructure projects. Fibrous concrete, which incorporates fibers to enhance structural integrity, is one such material that could meet these demands. With different concrete fibrous materials, shapes, distributions, orientations, and densities, fibrous concrete takes on different characteristics. Polypropylene is a lightweight synthetic fiber that enhances the structural strength of concrete and helps prevent the formation of cracks. In this investigation, various percentages and values of polypropylene fibrous—such as 0%, 0.5%, 1.0%, 1.5%, and 2.0% values—were added, and 1.0% of virgin polypropylene was substituted for cement in the concrete. Workability, split tensile strength, compressive strength, and flexural resistance tests were performed on specimen. Concrete is used by people all over the world as a straightforward, long-lasting, and safe building material. One of the main ingredients in concrete construction is Portland cement. Concerns over the growing use of concrete in building, particularly in developing nations, have led to attempts to create cement alternatives using locally accessible virgin polypropylene. This study's primary goal was to use virgin polypropylene at 0%, 0.5%, 1%, 1.5%, and 2% by weight to investigate the parameters of hardened (splitting tensile strength and compressive strength) and fresh (flowability) concrete. To reach the target strength of 28 N/mm<sup>2</sup>, 90 concrete samples—comprising 45 cubes and 45 cylinders—were prepared, cured, and tested using a UTM at intervals of 7, 14, and 28 days. For each proportion, a set of three concrete specimens were formed in the shapes of cubes and cylinders, respectively, and the average of the three concrete samples was used to determine the outcome. As the amount of polypropylene mixed into the concrete increases, the flowability of fresh concrete diminishes. The findings demonstrated that adding 1.0% polypropylene to the concrete specimens at the 28-day curing stage improved their compressive and tensile strengths by 11.8% and 7.31%, respectively. This study's primary goal was to look at the use of virgin polypropylene in cement composites mixed with concrete.

**Keywords:** Polypropylene, compressive strength, workability, split tensile strength

### \*Author for Correspondence

Hinamshu Pathak  
Email: Him.pathak82695@gmail.com

<sup>1</sup>PG scholar, IPS College of Technology & Management, Gwalior, Madhya Pradesh, India

<sup>2</sup>Professor, IPS College of Technology & Management, Gwalior, Madhya Pradesh, India

Received Date: August 24, 2024

Accepted Date: September 09, 2024

Published Date: September 16, 2024

**Citation:** Hinamshu Pathak, B.P. Mudgal. An Experimental Investigation of Impact of Polypropylene as a Partial Replacement in Concrete. Journal of Construction Engineering, Technology & Management. 2024; 14(3): 1–6p.

## INTRODUCTION

Over human history, concrete has been utilized extensively and everywhere in the world [1]. Sand and crushed rock, or coarse aggregate, are mixed to create concrete using a hardened paste made of hydraulic cement and water [2]. The need for the resources used to make concrete—cement, sand, and gravel—will rise as its use increases. Due to the rapidly rising rate of high-rate concrete ingredients, an unconventional, easily presented, low-cost material that can provide concrete with a similar or higher strength is required [3].

One of the more expensive components of concrete is cement, whose manufacture generates significant emissions of carbon dioxide [4–8]. Producing one tonne of cement consumes about 1.6 tonnes of natural resources and releases nearly one tonne of CO<sub>2</sub> into the atmosphere [9–11]. To reduce costs, waste, and CO<sub>2</sub> emissions, many studies have explored partially replacing cement with agricultural and industrial by-products, such as glass powder, sugarcane bagasse ash, rice husk ash (RHA), blast furnace slag, maize cob ash, millet husk ash, fly ash, and others, especially when these materials are readily available. [9, 12]. RHA is an unwelcome byproduct of agricultural waste [13–15] that is primarily burnt by air [16, 17].

Nowadays, getting rid of industrial and agricultural waste is a big issue. Rice husk is one of these agricultural wastes. In paddy fields, approximately 120 million tonnes of rice husk are produced annually [17–19]. After rice is processed, the husk is either burned or disposed of. At a specific temperature, rice husk is burned in an environment. RHA has an 85% silica content, also referred to as non-crystalline silica, and it can be used as a material to partially replace cement [20–24]. RHA can be used to concrete as an extra material to lessen environmental problems because it is measured as a highly pozzolanic substance [25–29].

### LITERATURE STUDY

In this investigation, concrete samples were mixed at a 1:2:4 ratio with a water-to-cement ratio of 0.45, 0.50, and 0.60. The samples were then cured and examined after 7, 14, and 28 days. The tensile and compressive strengths rose by 10.71% and 14.51%, respectively, at 0.45 water-cement ratio when 1.0% polypropylene was added to concrete and allowed to cure for 56 days, according to the data.

When compared to regular cement concrete, polypropylene helps lower the temperature of the concrete, according to authors in [29]. Researchers in [30] studied the hardened characteristics of concrete mixed with 5%, 10%, 15%, and 20% weight of cement and other polymeric substance. The concrete samples were cured for seven and twenty-eight days, with a target strength of 25N/mm<sup>2</sup>. When 1.0% of polypropylene was added to concrete at 28 days, the crushing strength increased by 15.74% [28].

Polypropylene is a crucial component in cementitious materials [29]. Concrete's characteristics are enhanced by the shredded plastic particles' thicker size compared to OPC [30].

As the shreds of plastic are only about 55 microns in size, polypropylene can serve as an essential filler in cement [22]. Up to 2.0% of the weight of the concrete was combined with polypropylene in this experimental investigation.

### RESEARCH METHODOLOGY

Concrete's fresh and hardened properties were studied using varying percentages of polypropylene (0%, 0.5%, 1.0%, 1.5%, and 2.0%) used as a cement substitute. A total of 90 concrete samples—comprising 45 cubes and 45 cylinders—were prepared and cured for 7, 14, and 28 days to achieve the target strength of 28 N/mm<sup>2</sup>. Many trial mixes are made with different amounts of water, fine, coarse, and variable cement (binder) to achieve the best possible mix. To get the desired mix, polypropylene was substituted for cement to test the concrete specimens' features and strength. Afterward, the India Standard (BIS) code was followed when testing the concrete specimens on a UTM.

Concrete cylinders were produced for splitting tensile strength and cubes for compressive strength in this investigation. For each proportion, a set of three concrete examples were cast, and the final result was the average of the three specimens from the set of nine. The work was finished in the concrete laboratory of the IPS College of Technology, & Management, Gwalior Department of Civil Engineering.

## MATERIALS USED

### Cement

Ultratech PPC cement is easily and extensively available in the market; it was utilized during the trial job and it was collected from stack which was free from any moisture and the bag of cement does not carry any lumps.

### Fine Aggregates

The fine aggregates of Zone-II, which passed through Sieve No. 4 (4.75mm) and satisfied the BIS code readings, were obtained from the Sindh River. Fine aggregates have a specific gravity of 2.60, a fineness modulus of 2.61, and water absorption of 1.8% and these values are obtained after carrying out various tests.

### Coarse Aggregates

The coarse aggregates used were 20mm in size and were available in the local market. The coarse aggregates had a water absorption rate of 1.4% and a specific gravity of 2.73.

### Polypropylene

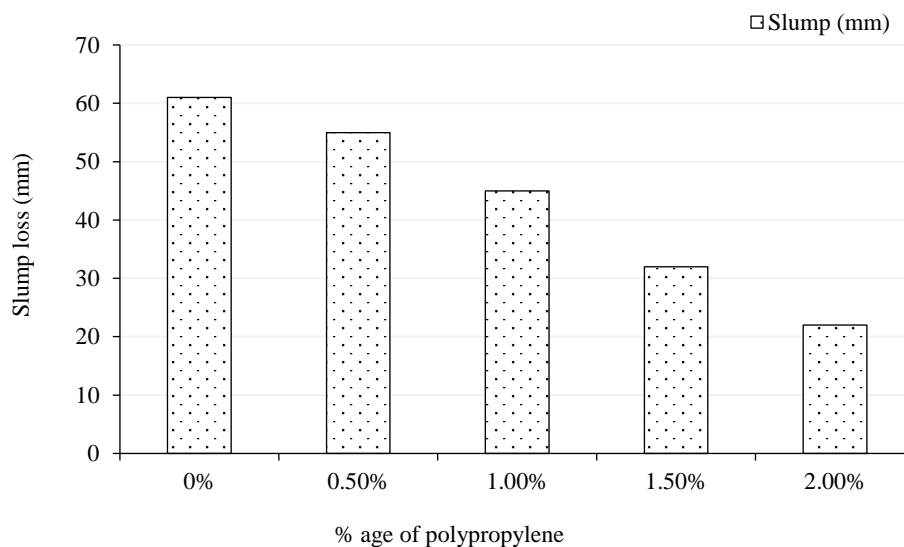
After being removed from the plastic park situated at “Bilaua” and “Antri” region nearby to Gwalior city and, virgin polypropylene was allowed to air dry. For experimental reasons, colourless polypropylene was torn into little pieces to facilitate easy mixing with the liquid.

### Water

The potable water available in the institute was taken for experimental investigation and before using directly the TDS of water has been checked to make sure that it was free from any impurities.

## RESULTS AND DISCUSSION

The slump cone test was used to measure the flow of fresh concrete. It had three dimensions: a top diameter of 10 cm, a bottom diameter of 20 cm, and a height of 30 cm. It was filled with four layers of varied percentages of polypropylene addition in accordance with Indian standard, and it was rammed with 35 blows. The lowest value of workability was 25mm at 2.0% polypropylene by weight, while the maximum flow of fresh concrete was 65mm when utilizing 0% polypropylene as a substitute material for cement in the concrete. It was observed that as the amount of polypropylene added to the concrete increases, the flow of the fresh concrete decreases. The results of the experiment are shown in Figure 1.



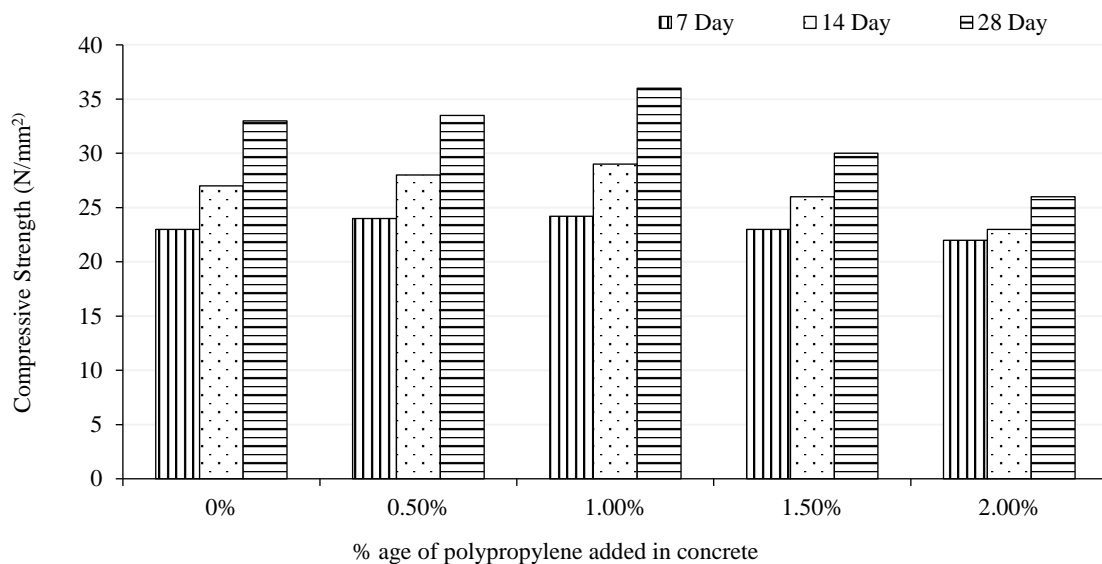
**Figure 1.** Impact of slump on the addition of polypropylene.

## COMPRESSIVE STRENGTH

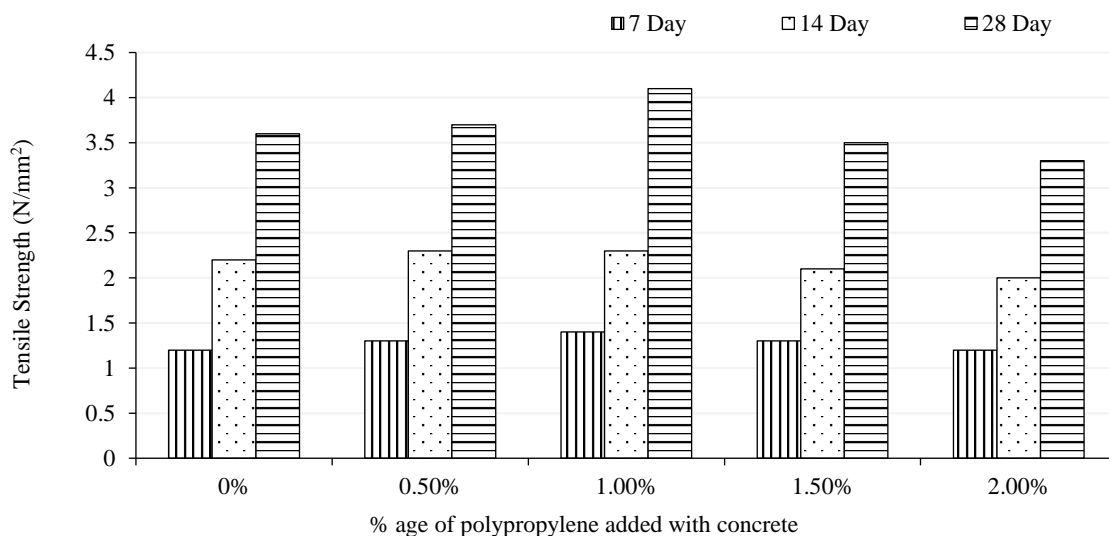
Cubes measuring  $150 \times 150 \times 150 \text{ mm}^3$  were subjected to compressive strength tests with varying percentages of polypropylene mixture. Three concrete specimens were cast for each proportion, with the final result being the average of these three specimens. When virgin polypropylene is added to concrete as a cement substitute, the maximum compressive strength is reached at 1.0%, and the minimum is reached at 2.0% after 7, 14, and 28 days of curing. Figure 2 presents the findings.

## Splitting Tensile Strength

Testing for splitting tensile strength was done on 150 mm diameter by 300 mm height cylinders that had been combined with different amounts of virgin polypropylene and cured for 7, 14, and 28 days, respectively. For every proportion, three concrete samples were cast, and the average was determined as the outcome. Concrete's minimum splitting strength was reported at 2.0%, while its maximum splitting tensile strength was recorded at 1.0% for polypropylene specimens. A universal testing equipment with a 5kN capacity and a speed range of 0.5 to 500 mm/min was used to test the cylinders. Figure 3 displays the results of the experimental study.



**Figure 2.** Variation of compressive strength after the addition of polypropylene.



**Figure 3.** Variation of tensile strength after the addition of polypropylene.

## CONCLUSION

When utilizing zero percent polypropylene as a cement substitute material in concrete, the flow of fresh concrete was seen to be at its maximum. The lowest observed workability value was 2.0% when polypropylene was combined with concrete. It was determined that when polypropylene is added to concrete, the flow of fresh concrete diminishes. After 7, 14, and 28 days, the greatest compressive strength was achieved at 1.0% Polypropylene mixed with concrete, while the minimum was found at 2.0% Polypropylene mixed with concrete. At 7, 14, and 28 days, respectively, the minimum splitting strength was recorded at 2.0% Polypropylene added with concrete, while the maximum splitting tensile strength was detected at 1.0% Polypropylene added with concrete.

## REFERENCES

1. Aggarwal, P., Aggarwal, Y & Gupta, S.M 2007, "Effect of Bottom Ash As Replacement of Fine Aggregates in Concrete" Asian Journal of Civil Engineering (Building and Housing), vol. 8, no. 1, pp. 49-62.
2. Ahmet Raif Boga & Ilker Bekir Topçu 2012, "Influence of fly ash on corrosion resistance and chloride ion permeability of concrete", Construction and Building Materials, vol. 31, pp. 258-264.
3. Alireza Naji Givi, Suraya Abdul Rashid, Farah Nora A. Aziz & Mohamad Amran Mohd Salleh 2010a, "Contribution of Rice Husk Ash to the Properties of Mortar and Concrete: A Review", Journal of American Science, vol. 06, no. 03, pp. 157-165.
4. Alireza Naji Givi, Suraya Abdul Rashid, Farah Nora A. Aziz & Mohamad Amran Mohd Salleh 2010b, "Assessment of the effects of rice husk ash particle size on strength, water permeability and workability of binary blended concrete", Construction and Building Materials, vol. 24, pp. 2145-2150.
5. Andres E. Idiart, Carlos M. Lopez & Ignacio Carol.(2021) "Chemo mechanical analysis of concrete cracking and degradation due to external sulphate attack", Cement and Concrete Composites, vol. 33, no. 3, pp. 411-423.
6. Andri Kusbiantoro, Muhd Fadhil Nuruddin, Nasir Shafiq & Sobia Anwar Qazi. (2022) "The effect of microwave incinerated rice husk ash on the compressive and bond strength of fly ash based geopolymer concrete" Construction and Building Materials, vol. 36, pp. 695- 703.
7. Aydin, S, Yazici, H, Yigiter, H & Baradan, B.(2017) "Sulfuric acid resistance of high volume fly ash concrete" Build Environ vol. 42, pp. 717-721.
8. Binu Sukumar, Nagamani, K & Srinivasa Raghavan, R.(2018) "Evaluation of strength at early ages of self-compacting concrete with high volume fly ash" Construction and Building Materials, vol. 22, no.7, pp. 1394-140.
9. Bouzoubaa, N, Zhang, M.H & Malhotra, V.M.(2019) "Mechanical properties and durability of concrete made with high-volume fly ash blended cements using a coarse fly ash" Cement and Concrete Research, vol.31, no. 10, pp. 1393-1402.
10. Chindaprasirt, P & Rukzon, S.(2023) "Strength, porosity and corrosion resistance of ternary blend Portland cement, rice husk ash and fly ash mortar", Construction and Building Materials, vol. 22, no. 8, pp. 1601- 1606.
11. Chindaprasirt, P, Chareerat, T, Hatanaka, S & Cao, T. (2019), "High- Strength Geopolymer Using Fine High-Calcium Fly Ash", ASCE, vol. 23, no. 3, pp. 264-270.
12. Chindaprasirt, P, Homwuttiwong, S & Jaturapitakkul, C.(2022) "Strength and water permeability of concrete containing palm oil fuel ash and rice husk-bark ash", Construction and Building Materials, vol. 21, no. 7, pp. 1492-1499.
13. Chindaprasirt, P, Homwuttiwong, S & Sirivivatnanon, V. (2021) "Influence of fly ash fineness on strength, drying shrinkage and sulphate resistance of blended cement mortar", Cement and Concrete Research, vol.34, no. 7, pp. 1087-1092.
14. Chindaprasirt, P, Kanchanda, P, Sathonsaowaphak, A & Cao, H.T. (2020) "Sulfate resistance of blended cements containing fly ash and rice husk ash", Construction and Building Materials, vol. 21, no. 6, pp.1356-1361.

15. Chindaprasirt, P, Rukzon, S & Sirivivatnanon. V (2008) "Resistance to chloride penetration of blended Portland cement mortar containing palm oil fuel ash, rice husk ash and fly ash", *Construction and Building Materials*, vol. 22, no. 5, pp. 932-938.
16. N. D. Bheel, S. L. Meghwar, S. A. Abbasi, L. C. Marwari, J. A. Muger, R. A. Abbasi.(2023) "Effect of rice husk ash and water-cement ratio on strength of concrete", *International Civil Engineering Journal*, Vol. 4, No. 10, pp. 2373-2382.
17. M. Akhter.(2021) "Experimental study on effect of wood ash on strength of concrete" *International Research Journal of Engineering and Technology*, vol. 4, no. 7, pp. 1252–1254.
18. N. Bheel, A. Awoyera, and D. Olalusi.(2021) "Engineering properties of concrete with a ternary blend of fly ash, wheat straw ash, and maize cob ash," *International Journal of Engineering Research in Africa*, vol. 54, pp. 43–55.
19. S. Rukzon, P. Chindaprasirt, and R. Mahachai, "Effect of grinding on chemical and physical properties of rice husk ash," *International Journal of Minerals, Metallurgy and Materials*, vol. 16, no. 2, pp. 242–247, 2009.
20. Indian Standard 516. (2002). "Methods of tests for strength of concrete "Bureau of India standards" New Delhi, India.
21. Indian Standard 5816. (1999). "Splitting tensile strength of concrete- method of test". Bureau of India Standards, New Delhi, India.
22. Indian Standard 8112. (1990). "43 grade ordinary Portland cement – specification". Bureau of India Standards, New Delhi, India.
23. Indian Standard 9103. (1999). "Concrete admixtures – specification". Bureau of India Standards, New Delhi, India.
24. Khan, R., Jabbar, A., Ahmad, I., Khan, W., Khan, A.N., and Mirza, J. (2018). "Reduction in environmental problems using rice-husk ash in concrete." *Construction and Building Materials*, 30, 360-365.
25. Mazaheripour, H., Ghanbarpour, S., Mirmoradi, S.H., and Hosseinpour, I. (2011). "The effect of polypropylene fibrous on the properties of fresh and hardened lightweight self-compacting concrete". *Construction and Building Materials*, 25, 351-358.
26. Nili, M., and Afrouhsabet, V. (2010). "The effects of silica fume and polypropylene fibrous on the impact resistance and mechanical properties of concrete." *Construction and Building Materials*, 24, 927-933.
27. Indian Standard 516. (2002). "Methods of tests for strength of concrete". Bureau of India Standards, New Delhi, India.
28. Bosnjak, J., Ozbolt, J., and Hahn, R. (2023). "Permeability measurement on high-strength concrete without and with polypropylene fibrous at elevated temperatures using a new test setup." *Cement Concrete Research*, 53, 104- 111.
29. Medina, N.F., Barluenga, G., and Olivares, F.H. (2022). "Enhancement of durability of concrete composites containing natural pozzolan blended cement through the use of polypropylene fibrous". *Composites-Part B*, 61, 214-221.
30. Khan, R., Jabbar, A., Ahmad, I., Khan, W., Khan, A.N., and Mirza, J. (2024). "Reduction in environmental problems using rice-husk ash in concrete." *Construction and Building Materials*, 30, 360-365.