Utilization of Waste Foundry Sand in Concrete Paver Blocks

Vikram Singh Kurmi[1], Mr. Pankaj Agarwal[2]
[1]M.Tech.Scholar, [2]Professor, Department of Civil Engineering
[1,2]School of Engineering Eklavya University, Damoh, Madhya Pradesh, India

Abstract. *Concrete paver blocks have emerged as a versatile and sustainable alternative to traditional paving materials, offering numerous functional, environmental, and aesthetic advantages. These precast concrete elements are extensively used in a wide range of applications, including residential driveways, public sidewalks, commercial spaces, and heavy-duty industrial pavements. Their modular design, ease of installation, and ability to be customized in various shapes, colors, and patterns make them highly suitable for modern construction needs. The primary aim of this study is to evaluate the feasibility of incorporating Waste Foundry Sand (WFS) into the production of concrete paver blocks. Foundry sand, a byproduct of the metal casting industry, contains high silica content and favorable physical properties, making it a potential partial substitute for natural sand in concrete. This study investigates the effects of WFS on the mechanical and durability characteristics of M40 grade concrete. By replacing natural sand with varying proportions of WFS, the research aims to determine the optimal replacement level that maintains or improves the performance of concrete paver blocks.*

Keywords: Waste foundry sand, materials, concrete, natural sand, compressive strength, flexural strength.

Introduction

Concrete paver blocks have emerged as one of the most innovative and sustainable solutions in the field of modern civil construction. Their widespread use in the development of pathways, driveways, parking zones, footpaths, public spaces, and industrial surfaces has significantly influenced the manner in which infrastructure is designed and implemented. These blocks offer numerous advantages, including high durability, aesthetic flexibility, ease of installation, and low maintenance, making them a preferred choice over traditional paving materials such as asphalt and poured concrete. As urbanization accelerates globally, the demand for cost-effective, eco-friendly, and structurally reliable paving solutions has increased, thereby pushing the boundaries of research and innovation in the area of paver block technology.

Concrete paver blocks are modular units made from high-strength cement concrete, typically manufactured through precast techniques. Their interlocking design provides superior stability and strength, allowing them to distribute loads effectively and prevent cracking. This makes them highly suitable for both light and heavy traffic areas. Additionally, their design versatility allows landscape architects and engineers to use them for aesthetic improvements in both public and private developments.

Historically, the use of block-based pavements dates back to ancient civilizations. The Romans were among the earliest adopters of stone block paving techniques, with enduring examples such as the Appian

Way—constructed around 312 B.C.—still in use today. The modern concept of concrete paver blocks originated in Europe, particularly in the Netherlands and Germany during the mid-20th century. Due to post-war shortages of traditional building materials, these countries explored alternative paving systems that were durable, low maintenance, and reusable. Since then, the technology has evolved significantly and spread worldwide.

In India, the adoption of paver blocks has seen remarkable growth over the past few decades. The country's rapid urban development, coupled with infrastructural demands and increased awareness about sustainable construction practices, has accelerated the implementation of paver block systems in both urban and semi-urban settings. From sidewalks and plazas to bus stops and residential courtyards, concrete paver blocks have become a commonplace feature of the Indian landscape.

Despite the significant benefits of concrete paver blocks, their production relies heavily on natural aggregates, particularly river sand, which is increasingly becoming scarce due to overexploitation. Excessive sand mining has caused severe ecological disturbances, including riverbed degradation, groundwater depletion, and loss of biodiversity. As a result, there is an urgent need to find alternative fine aggregate materials that are sustainable, economical, and technically viable.

One such promising alternative is Waste Foundry Sand **(WFS)**—a byproduct generated in large quantities by the metal casting industry. Foundry sand is used in manufacturing molds for casting metal components. After multiple cycles of reuse, the sand loses its functional properties and is discarded as waste. This discarded sand, known as waste foundry sand, poses a serious disposal challenge for industries and municipalities alike. However, given its high silica content, consistent grain size, and thermal stability, WFS holds considerable potential as a partial replacement for natural sand in concrete applications.

Incorporating waste foundry sand into concrete not only mitigates the environmental issues associated with its disposal but also addresses the scarcity of natural sand. Additionally, it contributes to the circular economy by converting industrial waste into a valuable construction material. Several studies have indicated that WFS, when used in appropriate proportions, can enhance the strength, workability, and durability of concrete. However, the properties of WFS can vary based on the type of metal casting and binder systems used, making it essential to evaluate its performance under controlled experimental conditions.

This study aims to investigate the effects of incorporating waste foundry sand as a partial replacement of fine aggregates in the production of M40 grade concrete paver blocks. The research focuses on evaluating the mechanical properties such as compressive strength, flexural strength, and tensile strength, as well as durability characteristics including water absorption, abrasion resistance, and freeze-thaw behavior. By establishing the optimal percentage of WFS that can be used without compromising performance, this study seeks to promote sustainable construction practices while maintaining or improving the quality of concrete paver blocks.

The motivation behind this research stems from two primary concerns: the environmental impact of natural sand depletion and the underutilization of industrial waste materials like WFS. The construction industry is one of the largest consumers of natural resources and simultaneously one of the biggest producers of waste. Bridging this gap through innovative material replacement strategies has the potential to make construction more sustainable and environmentally responsible.

In addition to technical evaluations, the study also addresses practical aspects such as manufacturing processes, installation techniques, and maintenance requirements of WFS-based concrete paver blocks. The goal is to provide a holistic understanding of how WFS can be effectively used in real-world construction scenarios. The findings of this research can be beneficial for policymakers, construction professionals, environmental engineers, and industry stakeholders interested in adopting green technologies and promoting waste valorization.

This introduction lays the foundation for a comprehensive analysis of concrete paver blocks and their potential enhancement through the incorporation of waste foundry sand. The subsequent chapters of this thesis delve into the literature review, materials and methodology, experimental program, results, and conclusions derived from this study. Ultimately, this research aims to contribute meaningfully to the advancement of sustainable construction materials and promote the adoption of environmentally conscious engineering practices.

Figure 1: Different layers of subgrade for concrete block pavement.

2. Objective of The Work

1. To understand the material composition and structure of concrete paver blocks.
2. To classify different types and applications of paver blocks.
3. To study the manufacturing process and its impact on block quality.
4. To evaluate the environmental benefits of using WFS.
5. To analyze installation methods, best practices, and maintenance requirements.
6. To explore technological innovations and future trends in paver block development.
7. To compare WFS-based paver blocks with traditional ones in terms of cost, performance, and sustainability.

3. Literature Review

Prabhu et al. (2015) conducted a comprehensive study on the mechanical and durability properties of concrete by replacing varying proportions of fine aggregates with Waste Foundry Sand (WFS). The results showed that the highest slump value of 115 mm was recorded for the control mix (0% WFS). As the percentage of WFS increased, slump values declined progressively. At 50% WFS replacement, the slump value dropped significantly to 63 mm. Additionally, after 30 minutes of mixing, the control mix exhibited a slump of 96 mm, while the mix with 50% WFS showed a drastic reduction to 21 mm. After 60 minutes, slump values decreased further across all mixes containing WFS, with the control mix retaining 51 mm and the 50% WFS mix reducing to 0 mm, indicating a notable loss in workability with higher WFS content.

Bilal et al. (2019) explored the effect of WFS on the compressive strength of concrete and found that a 30% replacement yielded the highest strength, showing a 7.82% increase by the 28th day of curing compared to the control mix. Their study also included testing under elevated temperatures using Rapid Cooling Simulation (RCS), where compressive strength decreased as the exposure temperature increased. Notably, the 30% WFS mix consistently outperformed other variations, suggesting that 30% replacement is the optimal level for enhancing strength without compromising performance. Some literature corroborates this finding, highlighting 20%–30% WFS as the effective range for achieving superior mechanical behavior. Furthermore, the inclusion of finer WFS particles contributed to a reduction in concrete density, thereby lowering the overall dead weight of the concrete.

In further studies, Bilal et al. (2019) also reported that concrete mixes without WFS exhibited lower compressive strength compared to those containing 30% WFS. When subjected to temperatures exceeding 500°C, ultrasonic pulse velocity (UPV) values began to decline, with a sharp drop observed beyond 600°C. This reduction in UPV was attributed to the propagation of microcracks and internal fractures in the concrete matrix caused by thermal stress, ultimately reducing the material's velocity and integrity.

Gadhave et al. (2020) discussed the environmental implications of excessive sand mining, which led to stricter regulatory controls across India, impacting the concrete industry both operationally and financially. The authors emphasized the importance of finding sustainable alternatives to natural sand to meet the growing demand for concrete. They pointed out that India recycles less than 60% of its plastic waste, with the remaining 40% accumulating in landfills, posing serious long-term environmental hazards. One proposed solution is to incorporate processed plastic waste as a partial replacement for fine aggregates in concrete. Similarly, WFS—if not properly managed—can cause environmental harm, thus necessitating thorough evaluation of its properties for potential reuse. Their study assessed key performance metrics such as slump, compressive strength, flexural strength, elastic modulus, and splitting tensile strength, all of which are crucial in determining the viability of alternative materials in structural concrete applications.

Mushtaq et al. (2021) emphasized the growing scarcity of natural resources like river sand and gravel, which are extensively used in concrete production—the most consumed construction material globally. The researchers noted that industrial and population growth has led to a surge in waste generation, some of which can be repurposed in concrete. Their investigation focused specifically on the effect of WFS on the mechanical performance of concrete, including compressive strength, splitting tensile strength, workability, and drying shrinkage. WFS was used in varying proportions from 0% to 50%, in 10% increments. The results revealed a marked increase in drying shrinkage with higher WFS content. After 28 days, shrinkage values rose significantly from 16.7% at 10% WFS to 45.18% at 50% WFS. These findings highlight the trade-offs between sustainability and performance when incorporating WFS into concrete and underscore the importance of identifying an optimal replacement percentage that maintains mechanical integrity while promoting environmental responsibility.

4. Materials

Cement

Concrete buildings made using ultra-tech 53-grade cement, which conforms to IS 12269 and has an exceptionally high CS3 (tricalcium giving long-lasting) durability, are required to adhere to IS 15658: 2006. The concrete is made with a very low amount of alkalis chlorides, magnesia, and other harmful substances, making it particularly long-lasting and unstable. Grade 53 Ordinary Portland Cement, in accordance with IS 12269, was used in the experimental work. In accordance with IS: 269/4831, the cement's physical characteristics as determined by the relevant tests.

Figure 2: Grade 53 Ordinary Portland cement Sample.

Foundry Sand

The foundries' founders were Mesopotamians, who settled in Iraq and Syria. Metals like as silver, copper, and gold were shaped using fire pits and clay casting techniques [18]. Working with WFS is a breeze because of its sub-angular to spherical form and incredible thermal conductivity, both of which are useful in the casting and moulding processes. Bentonite clay, that is included in foundry sand in minute amounts and serves as a binder, is another component of the material. Not only that, but foundry sandalso has chemical binders that make sand cores. For metal casting industries, foundry sand is used and recycled several times for mouldings and casting processes. When it reaches its limit of reusability, it is removed from the process and replaced with fresh sand.

Figure 3: Foundry Sand Sample.

Super Plasticizer

High-grade concrete is made or produced using super plasticizers, which are also known as water reducers. Super plasticizers speed up the concrete's curing process and cut the water content by 30%. They successfully enhance the functionality of freshly laid concrete.

Figure 4: Super plasticizer.

Water

The water used to make the paver blocks meets all of the requirements laid forth in IS 456: 2000. Mixing water does not include any harmful levels of oils, acids, alkalis, salts, sugar, organic compounds, or anything else that might damage concrete.

Coarse Aggregates

The materials that passed through a 4.75 mm IS sieve are known as coarse aggregates. Coarse aggregates might be either uncrushed gravel or stone that has naturally broken down into smaller pieces, or crushed gravel or stone that has been compressed into smaller pieces. The use of coarse aggregates in paver blocks is validated by IS 383. Used crushed or semi-crushed aggregates will be prioritized.

Figure 5: Coarse aggregates of 10 mm size Sample.

Fine Aggregates

Aggregate that has been passed through a 4.75 mm sieve and contains the smallest amount of coarser material allowed is called fine aggregate. Fine aggregate can be generated in a few different ways: first, by crushing hard stones; second, by crushing natural gravel; and third, by utilizing natural sand that has been deposited by streams or glaciers

Figure 6: Sand Sample.

5. Manufacturing of paver blocks

1. Size of the paver blocks

We need to determine the size of the paver block before we can begin building it. The manufacturer recommends the following dimensions:

General form: Part I. Dimension: 200 mm × 160 mm Size: 80 millimeters

The value of the aspect ratio (L/T) is 2.5 < 4.0, according to IS 15658: 2006.

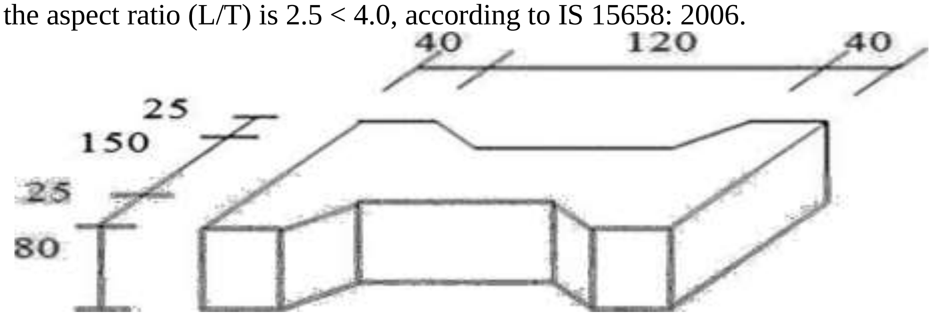


Figure 7: Dimension of Paver Blocks.

2. Casting

Paver block Moulds

Paver blocks are made using a rubber mould. When completed and ready for use, its dimensions and internal faces must be correct within the following limitations, and its construction must allow for the safe removal of the moulded specimen. The mould's height and the spacing between its faces must be the given dimensions plus or minus 0.2 millimetres in accordance with IS: 516: 1959. The mould's top and bottom planes, as well as the interior faces that are next to each other, must form an angle of 90 degrees, or 0.5 degrees. The mould's inside surfaces must be flat and within a tolerance of 0.03 mm. A metal base plate with a flat surface must be supplied with each mould. It is preferred to use a spring or screws to secure the base plate to the mould, and its proportions should be such that they hold the mould without leaking when filling.

6. Results

1. Compressive Strength test

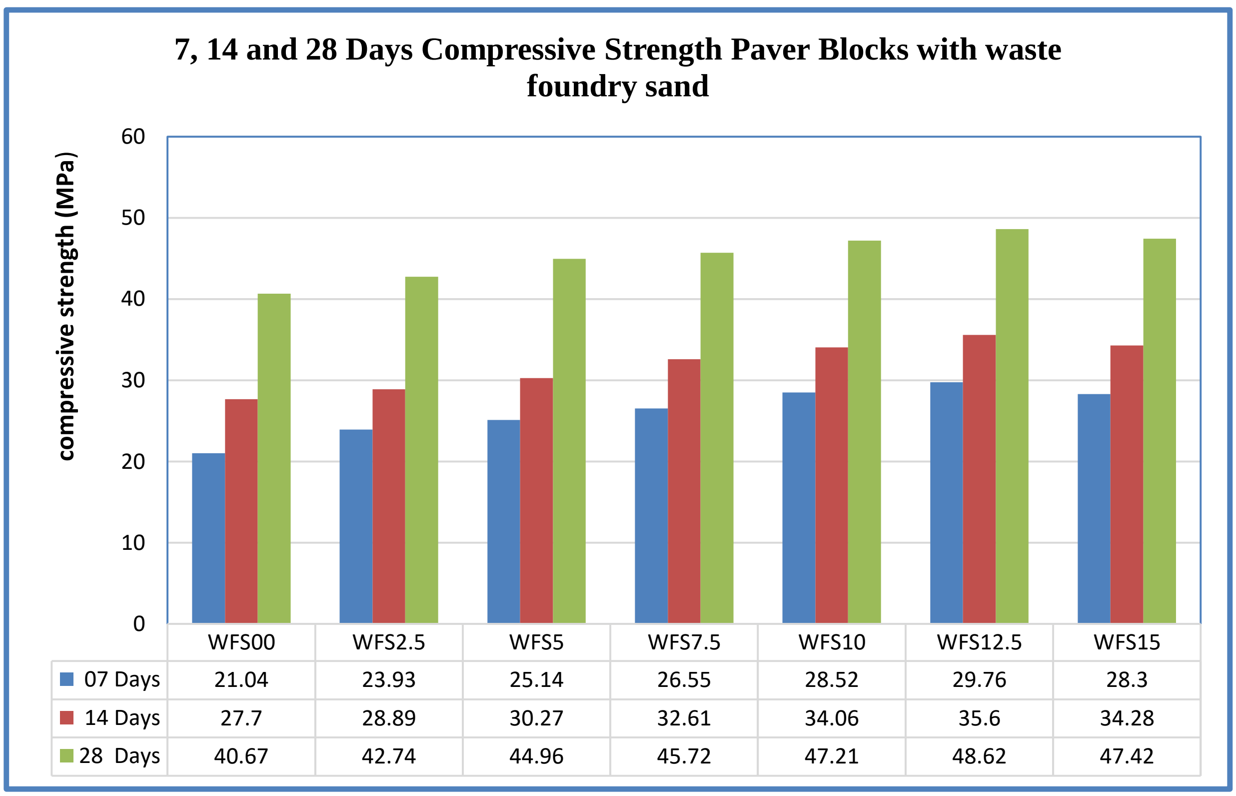
For accurate compressive strength testing of concrete paver blocks, the testing machine must be equipped with two high-strength steel bearing blocks. These blocks are essential to ensure uniform load distribution during testing. Each block must have a minimum thickness of 25 mm and a hardness of not less than 60 HRC (Rockwell Hardness C scale) to withstand repeated loading without deformation. The upper bearing block must be spherically seated, ensuring that no eccentric or lateral forces are transmitted to the specimen. This design allows self-alignment during loading and guarantees that only axial compressive force is applied. The lower block must be rigidly fixed, and the test specimen should be placed with a tight, stable fit to prevent any movement during testing. In cases where the bearing area of the paver block specimen is smaller than that of the machine's steel bearing blocks, two steel bearing plates conforming to the same material and hardness specifications must be inserted between the specimen and the machine's bearing blocks. These intermediary plates ensure uniform stress distribution and prevent localized stress concentrations, which could affect the accuracy of the test results.

Compressive Strength of Paver Blocks with waste foundry sand

The compressive strength test results show that the mix produces the best paver block. Data from the compressive strength test may be found in tables

Table 1: 7, 14 and 28 Days Compressive Strength of Paver Blocks with waste foundry sand.

Mix Designation	Average compressive strength (MPa)	Average compressive strength (MPa)	Average compressive strength (MPa)
WFS00	21.04	27.70	40.67
WFS2.5	23.93	28.89	42.74
WFS5	25.14	30.27	44.96
WFS7.5	26.55	32.61	45.72
WFS10	28.52	34.06	47.21
WFS12.5	29.76	35.60	48.62
WFS15	28.30	34.28	47.42

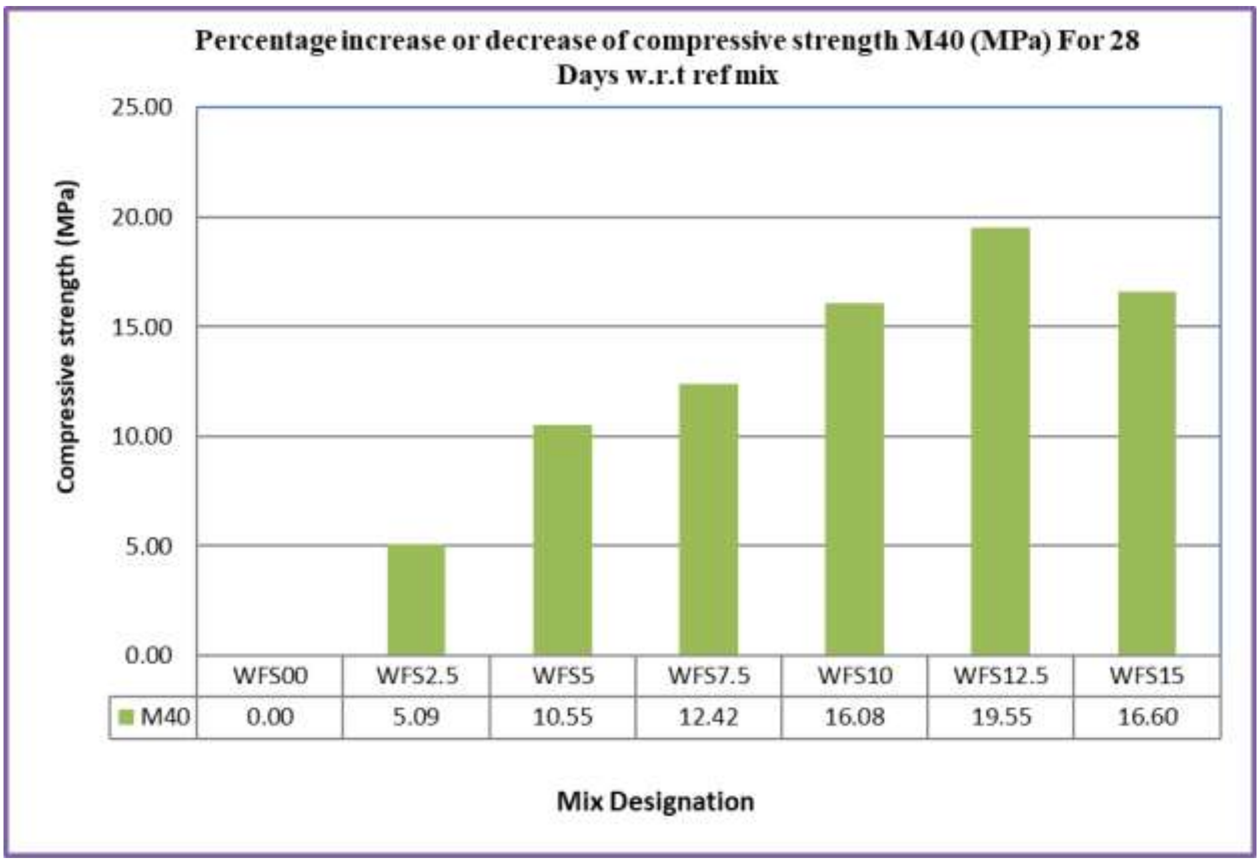


Graph 1: 7, 14 and 28 Days Compressive Strength of Paver Blocks with waste foundry sand Corrected Compressive Strength of Nylon Fiber Paver Blocks.

Table and graphs show the results of correcting the compressive strength of paver blocks according to IS 15658.

Table 2: Percentage increase or decrease of compressive strength of Paver Blocks with waste foundry sand M40 (MPa) For 28 Days w.r.t ref mix.

Mix Designation	28 Days	Percentage of increase or decrease
WFS00	40.67	0.00
WFS2.5	42.74	5.09
WFS5	44.96	10.55
WFS7.5	45.72	12.42
WFS10	47.21	16.08
WFS12.5	48.62	19.55
WFS15	47.42	16.60



Graph 2: Percentage increase or decrease of compressive strength of Paver Blocks with waste foundry sand M40 (MPa) For 28 Days w.r.t ref mix.

Conclusion

The findings revealed that the concrete mixtures for M-40 consisting of natural sand, exhibited significant increases in compressive strength throughout the duration of the testing process, indicating a hardened nature of the mixtures. The compressive strength tests on M-40 Mix Designs over 07, 14, and 28 days, altering the fine aggregate mix of Natural sand and WFS, revealed significant strength gains. For M-40, positive trends persisted with increases up to 19.55% at WFS 12.5 mix. These consistent findings underscore the positive impact of WFS on concrete strength across various mix designs and timeframes.

References

1. Research published in Materials (Basel) in August 2019 by H. Bilal et al., "Performance of foundry sand concrete under ambient and elevated temperatures," has the DOI 10.3390/ma12162645.Adv. Mater. Sci. Eng., 2015, vol. 2015, doi: 10.1155/2015/161753,
2. G. Ganesh Prabhu, J. W. Bang, B. J. Lee, J. H. Hyun, and Y. Y. Kim, "Mechanical and Durability Properties of Concrete Made with Used Foundry Sand as Fine Aggregate."
3. Siddique investigated the microstructure and characteristics of concrete. This sentence is paraphrased from a publication by J. M. Khatib, B. A. Herki, and S. Kenai titled
4. "Capillarity of concrete incorporating waste foundry sand." The article was published in 2014 and may be accessed online at doi: 10.1016/j.conbuildmat.2013.12.051.
5. In a 2013 study published in the journal Constr. Build. Mater. S. Monosi, F. Tittarelli, C. Giosuè, and M. L. Ruello examined the impact of two distinct sources and washing treatment on the characteristics of UFS by-products used in mortar and concrete production.
6. The study's DOI is 10.1016/j.conbuildmat.2013.02.029. 23. In their article titled "Properties of concrete using metallurgical industrial by-products as aggregates," Etxeberria, Pacheco, Meneses, and Berridi discuss the use of these materials in manufacturing concrete.
7. "Properties of Self-Compacting Concrete Incorporating Waste Foundry Sand," by R. Siddique and R. Kaur SANDHU, published in 2013 in the Journal of Materials Science and Civil Engineering, volume 25, issue 4, pages 484-490, with the DOI 10.1061/(ASCE)MT.1943-5533.0000521.105–124 December 2013 p.n.The Leonardo Journal of Sciences (ISSN: NO. 1583-0233)
8. "An Experimental Investigation on Partial Replacement of Waste Foundary Sand in Plane Concrete," published in 2017, by H. Vardhan, M. Mallikarjuna, N. Venkata, H. Reddy, and K. Gayathri, was published in volume 2, issue 2, and ran from pages 705-711.
9. In a 2016 article published in the ACI Materials Journal, N. Ghafoori, I. B. Batilov, and M. Najimi examined the sulphate resistance of mortars containing nanosilica and microsilica. The research was carried out using the DOI number 10.14359/51688989
10. The study "Micro-structural and metal leachate analysis of concrete made with fungal treated waste foundry sand" was published in January 2013 in the journal Constr.
11. Build. Mater. And was co-authored by G. Kaur, R. Siddique, and A. Rajor. The article can be read online at doi: 10.1016/j.conbuildmat.2012.07.112. 30.In 2020,
12. Akshay T. Gadhave and colleagues published an article in the International Research Journal of Engineering and Technology (IRJET). The article may be found online at www.irjet.net with the following DOI: 2395-0056. The issue number is 12.