



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJIRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 12, December 2024

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

**Impact Factor: 8.524**

9940 572 462

6381 907 438

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# **Study on Mechanical Properties of Various Cementitious Materials**

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**ABSTRACT:** This study Investigates the Mechanical Properties of concrete modified with ETP sludge, Iron Sludge, comparing its structural characteristics with different cement proportions. By partially replacing Ordinary Portland Cement (OPC) with ETPS, Iron Sludge reduces carbon emissions and enhances strength. The cement in the concrete mix was replaced by 10, 20 and 30 weight percentage of ETP sludge and concrete blocks (15cm x 15cm x 15cm) were prepared as well as 5, 10 and 15 weight percentage of Iron sludge replaced by cement and concrete blocks (15cm x 15cm x 15cm) were prepared. The concrete blocks were subjected to unconfined compressive strength at 28 days to access the strength.

**KEYWORDS:** Ordinary Portland Cement (OPC), Concrete blocks, ETP Sludge, Iron Sludge, Compressive Strength, Structural characteristics, Partial replacement.

## **I. INTRODUCTION**

The increasing global emphasis on sustainability in construction has driven the exploration of industrial wastes as viable alternatives to traditional materials. Textile effluent treatment plant (ETP) sludge, ceramic waste, sewage sludge, and iron ore tailings (IOT) have garnered attention as supplementary cementitious materials (SCMs) due to their potential to reduce environmental impact and improve resource efficiency. Recent studies have highlighted the feasibility of incorporating these industrial byproducts into concrete, bricks, and other construction materials. These materials can contribute to waste management solutions, decrease the carbon footprint of cement production, and enhance the durability of construction elements. However, the effectiveness of these waste materials often depends on the substitution level and their impact on the mechanical properties and durability of the final product. This review explores the use of various industrial wastes in construction, summarizing key research findings and their implications for sustainable building practices.

## **II. LITERATURE SURVEY**

M. Mottakin et al. (2023) evaluated the use of textile effluent treatment plant (ETP) sludge as a supplementary cementitious material (SCM) in concrete. The results showed that increasing the percentage of ETP sludge (TES) in the concrete mix reduced both workability and mechanical properties, including compressive and tensile strength. The optimal substitution level was found to be 5% TES, which provided the best balance of strength and workability. Beyond 10% substitution, the strength declined significantly. The study also established a strong correlation between compressive and tensile strength in TES-incorporated concrete, with a linear relationship suggesting that splitting tensile strength can be predicted based on compressive strength. Overall, 5% TES substitution offers a sustainable alternative to cement with minimal environmental impact, while higher percentages are less effective.

Pooja Jain et al. (2022) stated the growth of the ceramic tile industry has led to environmental challenges, including resource depletion and ceramic waste accumulation, while cement production contributes significantly to CO<sub>2</sub> emissions. Using ceramic waste (CW) as a partial cement replacement in concrete can reduce these impacts, with workability and compressive strength improving up to 20% substitution. CW enhances durability by refining pore structure, though its pozzolanic reaction may reduce resistance to carbonation. Limited research exists on using sludge

from ceramic effluent treatment plants (ETPs), and this study explores its potential as a cement replacement. The findings suggest up to 20% ETP sludge can be used without major workability loss, but higher levels reduce slump and compaction.

Zhan Bao Jian et al.(2020) the impact of textile effluent sludge (TES) on ordinary Portland cement (OPC) was investigated, focusing on hydration, mechanical strength, microstructure, and metal leachability. The results revealed that increasing TES dosages (up to 20%) delayed OPC hydration, reducing the portlandite content at both 7 and 28 days. Mechanical strength was significantly impaired, with compressive and flexural strength decreasing by up to 71% and 42%, respectively, at 28 days. Scanning electron microscopy and porosity analysis showed that TES increased the porosity, particularly macropores, due to the formation of weak interfaces. However, leachability tests indicated that the toxic metals in TES were effectively stabilized in the OPC matrix, showing very low mobility and posing no environmental risk.

Kaling Taki et al.(2020)investigates the potential of lime-stabilized sewage sludge (SS) for use in construction, specifically for subbase material in flexible pavements. The results demonstrate significant improvements in the geotechnical properties of SS after lime treatment, including a marked increase in unconfined compressive strength (UCS) and reduced swelling behaviour. The swelling pressure and differential free swell index (DFSI) decreased with increasing lime content, indicating a reduction in the expansive nature of SS. This was attributed to the pozzolanic reactions that resulted in the formation of cementitious compounds. The study also highlights the formation of new mineral compounds, as confirmed by various characterization techniques such as SEM, XRD, TGA, and FTIR. Overall, lime treatment offers a viable solution for stabilizing SS, making it suitable for geotechnical applications in construction, particularly as a subbase material for pavements, and it provides an alternative to traditional waste disposal methods.

M. Gunavel et al.(2019)explores the use of Effluent Treatment Plant (ETP) sludge, a textile industry byproduct, as a sustainable material for brick-making. Testing two sludge-to-cement ratios (0.75:1.5 and 0.75:1.7), the research evaluates compressive strength, water absorption, and efflorescence. Bricks with a 0.75:1.7 ratio show superior compressive strength (over 10 N/mm<sup>2</sup>), lower water absorption, and negligible efflorescence compared to fly ash bricks. These findings highlight ETP sludge bricks as an economical and eco-friendly alternative for construction, addressing both material sustainability and waste management issues.

C. Mariappan et al.(2018)ETP sludge-based concrete meets the essential properties of conventional concrete when optimized with a water-to-binder ratio of 0.45. While its initial strength development is slower, it achieves comparable performance to conventional concrete after 28 days. Experimental results indicate that replacing up to 10% of cement with textile ETP sludge has no adverse effects. However, replacing more than 20% gradually reduces the strength. This demonstrates the potential of ETP sludge as a sustainable partial replacement for cement.

HARPREET KAUR et al.(2017)examines the use of Textile Mill Sludge (TMS) as a partial replacement for fine aggregates in M20 grade concrete, along with the use of plasticizers to improve workability. It finds that replacing fine aggregates with up to 35% TMS maintains acceptable workability and compressive strength. Beyond 35%, the workability significantly reduces, and the compressive strength declines, becoming unsuitable for structural applications. At 28 days of curing, concrete with up to 35% TMS achieves comparable strength to the control mix, demonstrating its potential as an eco-friendly material for sustainable construction and effective waste management.

Prashant Rayl et al.(2019) explores the feasibility of incorporating CETP (Common Effluent Treatment Plant) sludge into concrete as a partial replacement for cement. It highlights the potential of CETP sludge to address environmental and public health issues associated with its disposal, particularly in areas with limited land. Experimental results indicate that CETP sludge can replace up to 15-20% of cement in concrete without significant strength loss, although higher replacement levels negatively affect compressive, tensile, and flexural strength. Incorporating sludge up to 15% is viable for non-structural and some structural applications, contributing to sustainable waste management and resource utilization. Further research is recommended to evaluate long-term durability and reinforced concrete performance.

Shweta Goyal et al.(2022)investigates the stabilization of hazardous textile sludge, rich in heavy metals, using low-grade magnesium oxide (LG-MgO) as a sustainable and environmentally friendly alternative to traditional calcium-

based stabilizers. LG-MgO effectively stabilizes heavy metals, reducing their leachability and improving the sludge's mechanical and chemical properties. Stabilized sludge was used to produce mortar specimens with enhanced compressive strength, densified microstructure, and increased pH, making it suitable for potential use in reinforced concrete. Optimal results were achieved with up to 10% cement replacement by stabilized sludge, maintaining favourable performance without adverse effects. This approach offers a sustainable method for recycling textile sludge while mitigating environmental hazards associated with its disposal.

Sivasankara Rao Meda et al.(2021)discusses the challenges of hazardous waste sludge disposal, emphasizing the environmental and health risks of traditional methods like landfilling and incineration. With the growing volume of waste, particularly from industrial and sewage sources, there is a pressing need for sustainable disposal alternatives. Research highlights the potential of converting waste sludge into construction materials, including cement, bricks, tiles, and concrete, by replacing conventional raw materials. Studies have shown that up to 30% replacement of cement with various sludge types is feasible without significantly compromising material properties, offering an eco-friendly solution to waste management challenges while reducing dependency on natural resources.

Geng Yao, et al.(2019) The study demonstrated that mechanical activation significantly enhances the pozzolanic activity and cementitious properties of iron ore tailings (IOTs). Through mechanical grinding, the particle size of IOTs was reduced, the specific surface area increased substantially (from 103 m<sup>2</sup>/kg to 463 m<sup>2</sup>/kg after 20 minutes and 581 m<sup>2</sup>/kg after 40 minutes), and crystalline structures were disrupted, resulting in enhanced reactivity. Mechanically activated IOTs exhibited improved pozzolanic activity, reacting with calcium oxide to form hydration products such as ettringite and calcium silicate hydrate (C–S–H) gels. Prolonged grinding induced lattice distortions, creating active sites that promoted hydration reactions and enhanced cementitious potential. Blending 10–30% activated IOTs with Portland cement produced composites that met the mechanical and physical standards for 32.5-grade composite Portland cement. This highlights the feasibility of using IOTs as supplementary cementitious materials (SCMs), reducing reliance on traditional SCMs, promoting waste recycling, and supporting sustainable construction practices.

Chao Li et al.(2009) The study explored the utilization of residues from iron recovery processes in iron ore tailings to prepare a new cementitious material (TSC). TSC1, formulated with 30% residues, 34% blast-furnace slag, 30% clinker, and 6% gypsum, demonstrated superior cementitious properties compared to raw tailings-based cementitious materials (TSC0). Hydration products such as ettringite, calcium hydroxide, and C–S–H gel were responsible for the strength development of TSC1 over time. Magnetizing roasting decomposed kaolinite in the residues, enhancing their cementitious properties. The mechanical properties of TSC1 were comparable to 42.5-grade ordinary Portland cement (OPC), meeting the Chinese GB175-2007 standard. This approach supports the sustainable and zero-emission utilization of iron ore tailings by transforming residues into valuable cementitious materials, conserving resources, and minimizing environmental impacts.

Luciano Fernandes de Magalhães, et al. (2020)This study investigated the potential of iron ore tailings (IOT) as a supplementary cementitious material (SCM) in the production of pigmented cements. Heat-treated IOT was used to partially replace Portland cement in varying proportions (10%, 20%, and 30%), meeting Brazilian and international pozzolanic material standards. Heat treatment at 750°C enhanced the pozzolanic properties of IOT, converting kaolinite into metakaolinite and improving its chemical and physical characteristics. The inclusion of IOT influenced the pigmentation of the cement, offering diverse colour options, while maintaining adequate compressive strength and durability. The use of IOT also enhanced acid resistance and reduced material loss during acid attack. This approach not only reduces the environmental impact associated with IOT disposal but also lowers CO<sub>2</sub> emissions by decreasing reliance on traditional clinker in cement production, presenting a sustainable and innovative solution for waste reuse in construction materials.

Hongyu Wang <sup>a</sup> et al. (2023) This study explored the use of micro-iron ore tailings (MIOT), produced via wet grinding, as an additive to enhance the properties of a cement-steel slag (SS) system. Incorporating MIOT improved early compressive strength and hydration of the cement-SS system, achieving a 16.16% increase in 28-day compressive strength compared to the cement-SS system alone. Wet grinding enhanced the reactivity of iron ore tailings by reducing particle crystallinity and size, promoting the formation of calcium silicate hydrate (C–S–H) and carbonate AFM phases, which strengthened the material. MIOT also refined the pore structure, reducing porosity and densifying the hardened composite. This study highlights MIOT's potential to activate inert materials, facilitating the sustainable and high-value utilization of industrial byproducts like SS and IOT in construction materials.

Carolina Goulart Bezerra et al.(2021)This study investigates the feasibility of using iron-rich iron ore tailings (IOT) as a supplementary cementitious material (SCM) in cement pastes, replacing up to 15% of cement. Results demonstrated that IOT positively influenced the hydration of aluminates phases, likely due to its nucleation effect, while its morphology affected rheological properties. Using up to 10% sludge IOT maintained the early-age compressive strength of the paste, although higher contents or using 10% dry IOT slightly reduced late-age strength. This approach offers a sustainable solution for repurposing mining waste, reducing environmental impact, and contributing to resource preservation and carbon emission reduction in cement production.

### III.SUMMARY OF REVIEW

The reviewed studies investigate the use of industrial waste materials such as textile and ceramic effluent treatment plant (ETP) sludge, iron ore tailings (IOT), and other waste products as partial replacements for cement in concrete, offering sustainable alternatives to traditional construction materials. Several studies highlight the potential of textile effluent treatment plant sludge (TES) as a supplementary cementitious material (SCM). It has been found that substituting up to 5-20% TES enhances sustainability without significantly compromising the mechanical properties of concrete, although higher percentages reduce both strength and workability. Similarly, ceramic waste (CW), when used as a cement substitute, improves the compressive strength and workability of concrete up to a 20% replacement, though it may affect carbonation resistance. Iron ore tailings (IOT) have also been shown to improve cement's mechanical properties and sustainability. Mechanical activation and heat treatment of IOT significantly enhance its pozzolanic activity, enabling it to replace up to 30% of cement without compromising strength, reducing CO<sub>2</sub> emissions, and promoting waste recycling. Moreover, lime-stabilized sewage sludge offers a viable solution for stabilizing sewage sludge, making it suitable for construction applications like subbase material for pavements. This treatment not only stabilizes the sludge but also provides a sustainable alternative to traditional disposal methods. Effluent and sewage sludge in general, including CETP sludge, can replace up to 20% of cement in concrete without significantly affecting its strength, addressing both waste disposal issues and sustainability goals in construction. Additionally, hazardous textile sludge rich in heavy metals can be stabilized using magnesium oxide (MgO), improving its mechanical and chemical properties, making it suitable for use in mortar and concrete. Overall, the incorporation of these industrial waste materials into concrete and other construction materials presents a promising approach to sustainable construction, reducing the reliance on natural resources, mitigating environmental impacts, and promoting waste recycling. However, further research is needed to assess the long-term durability and performance of concrete incorporating these waste products.

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