A Review of the Impact of Textile Sludge Waste on Concrete Properties

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Abstract:

The textile industry generates large quantities of textile effluent sludge (TES) as a by-product of wastewater treatment processes, creating serious environmental and disposal challenges. At the same time, the construction industry faces increasing pressure to reduce cement consumption due to the high energy demand and carbon emissions associated with Ordinary Portland Cement (OPC) production. In this context, the utilization of textile sludge waste as a partial replacement material in concrete has emerged as a promising sustainable solution. This review paper critically examines previous research on the effect of textile sludge waste on the fresh, mechanical, and durability properties of concrete. Emphasis is placed on mix design approaches, processing techniques, and the influence of textile sludge on compressive strength, tensile strength, workability, and durability characteristics. The review indicates that concrete incorporating textile sludge at low replacement levels, typically in the range of 5–10%, can achieve comparable mechanical performance to conventional concrete, particularly when the sludge is properly processed through drying, grinding, or thermal treatment. However, higher replacement levels generally result in reduced strength and workability due to the presence of organic matter and non-cementitious components. The study also highlights key research gaps related to long-term durability, leaching behaviour, and standardization of processing methods. Overall, the findings suggest that textile sludge waste has significant potential for sustainable concrete production when used in controlled proportions, contributing to effective waste management and reduced environmental impact.

Keywords:

Textile effluent sludge, sustainable concrete, cement replacement, industrial waste utilization, compressive strength, tensile strength, durability properties, eco-friendly construction.

1. Introduction

The rapid growth of industrial production and urban expansion has led to a significant increase in construction activities, which in turn demand high volumes of concrete. Ordinary Portland Cement (OPC) manufacturing is known for high energy consumption and CO_2 emissions, accounting for a large share of global greenhouse gas emissions. Simultaneously, the textile industry produces huge amounts of textile effluent sludge (TES) from wastewater treatment processes. TES often contains organic material, colloids, heavy metals, and chemicals, which pose environmental disposal challenges when dumped in landfills or uninhibitedly released into the environment. Integrating textile sludge into cementitious systems presents a promising opportunity to both manage industrial waste and reduce the carbon footprint of conventional concrete [1-33].

Textile effluent sludge (TES) is a semi-solid by-product generated during the treatment of wastewater in textile processing industries, particularly from dyeing, bleaching, and finishing operations. The composition of TES varies depending on the type of textile processed, chemicals used, and treatment methods adopted, but it generally contains a complex mixture of organic matter, fibrous residues, unreacted dyes, surfactants, salts, and trace amounts of heavy metals. Due to its high moisture content and the presence of potentially hazardous constituents, TES poses significant environmental and health risks if not managed properly. Conventional disposal methods such as landfilling and incineration are increasingly restricted due to land scarcity, high costs, and secondary pollution concerns.

Recent research has indicated that, after appropriate processing such as drying, grinding, or thermal treatment, TES can exhibit filler characteristics and limited cementitious or pozzolanic behaviour. When incorporated into cement-based materials in controlled proportions, TES has the potential to enhance waste utilization while maintaining acceptable mechanical and durability performance. However, challenges such as variability in chemical composition, long-term durability, and leaching behaviour necessitate systematic experimental evaluation before large-scale application in concrete. This paper critically synthesizes findings from several experimental investigations on concrete and cementitious mixtures where textile sludge is used as a partial replacement for cement or as an additive. The focus is on mechanical performance, microstructural characteristics, durability aspects, and the implications for practical applications.

2. Development of Textile sludge

The increasing generation of textile sludge waste from textile wastewater treatment plants has drawn significant attention due to its environmental and disposal challenges. Textile sludge, rich in organic matter, fibrous residues, dyes, and chemical additives, is typically landfilled or incinerated, both of which pose serious environmental concerns. In recent years, researchers have explored the feasibility of utilizing textile sludge waste as a partial replacement material in concrete to promote sustainable construction and effective waste management.

Studies have shown that the incorporation of textile sludge in concrete influences its fresh and hardened properties depending on the replacement level and processing method. In the fresh state, workability generally decreases with increasing sludge content due to the high water absorption and irregular particle shape of textile sludge. However, minor replacements have been reported to improve cohesion and reduce segregation. In the hardened state, compressive strength tends to increase at lower replacement levels (typically 5–10%) due to filler effects and improved particle packing, while higher replacement levels often lead to strength reduction caused by dilution of cementitious material and the presence of organic impurities.

The tensile and flexural strengths of concrete containing textile sludge follow trends similar to compressive strength, with optimal performance observed at low replacement percentages. Durability related properties such as water absorption, porosity, and permeability are generally affected by textile sludge content, with moderate additions showing acceptable performance. Some studies have also highlighted concerns related to long-term durability, including sulphate resistance and potential leaching of heavy metals, emphasizing the need for proper sludge treatment and characterization.

Overall, the review indicates that textile sludge waste can be effectively utilized in concrete at controlled replacement levels, contributing to reduced cement consumption and sustainable waste management. However, further research is required to standardize processing techniques, assess long-term durability, and establish clear guidelines for safe and large-scale application in structural concrete.

3. Processing Procedure of Textile Effluent Sludge from the Literature

Textile effluent sludge generated from treatment plants is collected, dewatered, and oven-dried before undergoing stabilization or incineration to reduce organic content and toxicity. The processed material is then ground and sieved for safe utilization in concrete, mortar, or other construction applications. Table 1 imparts the Processing Procedure of Textile Effluent Sludge.

Table 1. Processing Procedure of Textile Effluent Sludge

1	**Collection of Textile Sludge**	Textile effluent sludge is collected from the sludge drying beds or filter press units of textile effluent treatment plants (ETP). The collected sludge is initially in a semi-solid state with high moisture content
2	**Preliminary Drying**	The wet sludge is subjected to sun drying **or** oven drying at 105 ± 5 °C for 24–48 hours to remove free moisture. Drying is essential to prevent excess water interference during concrete mix design.
3	**Crushing and Pulverization**	The dried sludge lumps are crushed manually or mechanically and pulverized using a ball mill or grinder to obtain a fine powder form.
4	**Sieving**	The pulverized textile sludge is sieved through a 90 µm or 75 µm sieve to achieve uniform particle size comparable to cement. Oversized particles are reground and re-sieved.
5	**Optional Thermal Treatment (Calcination)**	To remove organic matter and enhance pozzolanic activity, the sludge may be calcined at 600–800 °C in a muffle furnace for 2–3 hours. This step improves reactivity and reduces odour and harmful constituents
6	**Chemical Stabilization**	In some studies, the sludge is stabilized using lime or cement to reduce leachability of heavy metals and improve compatibility with cementitious systems.
7	**Storage**	The processed textile sludge powder is stored in airtight containers to prevent moisture absorption and contamination prior to use in concrete mixing.
8	**Use in Concrete Mix**	The processed sludge is used as a partial replacement of cement (typically 5–10% by weight) during concrete mix preparation, following standard mix design procedures (IS 10262 / ASTM).

4. Objective and Scope

Objectives:

The objective of this review is to provide a comprehensive overview of research on concrete and cementitious materials partially replaced with textile sludge. Specific aims include:

- Evaluating mechanical properties (compressive strength, tensile strength).
- Evaluating the flexural behaviour of concrete beams partially replaced with textile sludge.
- Identifying research gaps and future directions for sustainable concrete technology.

Scope:

This review covers studies from various sources involving textile sludge replacement of cement and implications for structural applications.

5. Reviews on Mechanical properties of Textile sludge concrete

Balasubramaniam *et al.* (2006) investigated the reuse of textile effluent treatment plant sludge in building materials. The sludge was processed and incorporated into cement-based products. The study reported that compressive strength values remained within acceptable limits at lower replacement levels. The cementitious matrix effectively immobilized harmful constituents, while tensile strength showed marginal reduction at higher sludge contents, attributed to dilution of binding material. The authors concluded that controlled usage of textile sludge is feasible without significantly affecting mechanical performance.

Siddique (2014) reported that industrial sludge-based concrete generally exhibits acceptable compressive strength at low replacement levels. The study noted that tensile strength is more sensitive to sludge content than compressive strength. Minor reductions in tensile strength were observed due to increased porosity, while compressive strength benefited from particle packing effects when sludge was finely processed. Patel and Shah (2018) investigated the use of textile waste sludge powder as a cement replacement material. Experimental results showed optimum compressive and split tensile strength at 5–8% replacement. Beyond this level, strength reduction occurred due to incomplete hydration and organic interference. The authors concluded that textile sludge can be effectively utilized in structural concrete at controlled replacement levels without compromising mechanical performance.

Singh and Sharma (2021) assessed textile sludge reuse in cementitious composites from both environmental and mechanical perspectives. Their lifecycle-oriented evaluation demonstrated reduced environmental impact alongside satisfactory strength performance. The study supports industrial sludge valorization as a viable pathway toward sustainable and resource-efficient construction practices. Zhang and Wu (2021) investigated the pozzolanic behavior of thermally treated textile sludge in blended cement systems. Secondary hydration reactions refined pore structure and enhanced long-term strength. Their results confirm that properly processed sludge can function as a supplementary binder, contributing to durable and sustainable cement composites.

Torres and Garcia (2021) performed an environmental assessment of textile sludge reuse in cement-based materials. Their analysis revealed significant reductions in landfill demand and embodied environmental impact. The study emphasizes sludge recycling as an effective circular strategy aligning construction practices with sustainability goals. Rahman and Islam (2021) evaluated blended mortar incorporating industrial sludge ash, focusing on strength development and hydration compatibility. Their findings indicate stable mechanical performance and microstructural refinement at appropriate replacement levels, reinforcing the feasibility of sludge-derived binders in sustainable cement systems.

Silva and Pereira (2022) explored MgO stabilization of textile sludge to improve its suitability for cement mortars. Chemical stabilization reduced harmful constituents and enhanced bonding with hydration products. The study confirmed improved microstructural integrity and mechanical behavior, supporting the safe reuse of industrial sludge as a functional cement replacement material. Patel and Mehta (2022) experimentally evaluated concrete incorporating treated textile effluent sludge. Results indicated that controlled treatment mitigates performance loss while enabling partial cement replacement. The research highlights practical reuse opportunities, demonstrating acceptable strength and workability for non-critical structural and construction applications.

Verma and Kumar (2022) studied structural concrete containing recycled textile wastewater sludge. Strength and durability evaluations showed that optimized incorporation maintained structural reliability. The work demonstrates that waste-derived materials can be engineered into practical concrete mixtures supporting sustainability without compromising performance. Liu et al.,(2025) investigated calcined textile sludge ash as a blended cement component, focusing on hydration kinetics and microstructural evolution. Their findings show enhanced matrix densification through secondary reactions and filler effects. Proper thermal treatment improved compatibility, indicating strong potential for sustainable supplementary cementitious applications without compromising structural performance. Kumar and Gupta (2025) evaluated mortar incorporating textile sludge ash as a partial cement substitute. Mechanical and durability testing revealed that optimized replacement levels preserved compressive strength while refining pore structure. The work demonstrates that treated sludge can enhance sustainability and durability when carefully proportioned within cementitious systems. Table 2 presents the inferences of the literatures related to Mechanical properties of TES

Table 2. Key findings on the mechanical properties of concrete partially replaced with Textile sludge

S. No.	Authors & Year	Focus of Study	Key Findings	Inference
1	Balasubramaniam et al. (2006)	Compressive strength and Tensile strength of Textile sludge concrete	Acceptable compressive strength at lower replacement levels; higher content caused strength reduction due to dilution of cement matrix.	Considering textile sludge ash as a replacement of cement.
2	Singh & Sharma (2021)	Environmental and mechanical assessment of textile sludge in cementitious composites	Lifecycle evaluation showed reduced environmental impact with satisfactory strength performance.	Textile sludge valorization supports eco-efficient construction.
3	Zhang & Wu (2021)	Pozzolanic behaviour of thermally treated textile sludge in blended cement	Secondary hydration reactions refined pore structure and improved long-term strength	Thermal processing enhances reactivity; sludge can act as a supplementary cementitious binder

S. No.	Authors & Year	Focus of Study	Key Findings	Inference
4	Torres & Garcia (2021)	Environmental assessment of sludge reuse in cement-based materials	Significant reduction in landfill demand and embodied environmental impact	Sludge recycling aligns with circular economy and sustainability goals in construction
5	Rahman & Islam (2021)	Blended mortar with industrial sludge ash	Stable mechanical performance and microstructural refinement at optimal replacement levels	Sludge ash is feasible as a partial binder replacement when dosage is controlled
6	Silva & Pereira (2022)	MgO stabilization of textile sludge for cement mortar	Chemical stabilization reduced harmful constituents and improved bonding with hydration products	Stabilization techniques improve compatibility, safety, and mechanical integrity
7	Patel & Mehta (2022)	Concrete incorporating treated textile effluent sludge	Treatment mitigated strength loss; acceptable workability achieved	Proper processing enables practical application in non-critical structural uses
8	Verma & Kumar (2022)	Structural concrete with recycled textile wastewater sludge	Optimized incorporation maintained strength and durability	Engineered sludge mixes can achieve structural reliability while enhancing sustainability
9	Liu et al. (2025)	Calcined textile sludge ash as blended cement component (hydration kinetics & microstructure)	Secondary hydration reactions and filler effects enhanced matrix densification; thermal treatment improved compatibility	Calcination significantly improves reactivity; sludge ash shows strong potential as a sustainable SCM
10	Kumar & Gupta (2025)	Mortar incorporating textile sludge ash as partial cement replacement	Optimized replacement levels preserved compressive strength; refined pore structure and improved durability	Proper proportioning enables strength retention and durability enhancement.

S. No.	Authors & Year	Focus of Study	Key Findings	Inference
11	Siddique (2014)	Industrial sludge-based materials	Acceptable compressive strength at lower replacement levels; higher content caused strength reduction Tensile strength more sensitive; minor reductions observed due to increased porosity	Movement toward positioning textile sludge ash as a functional SCM rather than just a waste filler
12	Gupta & Tiwari (2018)	Partial replacement in concrete	Characterized textile sludge and incorporated it in concrete. Strength decreased at higher replacement levels due to increased porosity and weak bonding.	Textile sludge can be used in limited proportions; higher percentages negatively affect strength and durability.
13	Hasan et al. (2022)	Replacement of fine aggregate in concrete	Mechanical performance acceptable at low replacement levels. Workability and compressive strength decreased with increasing sludge content.	Optimal replacement percentage is essential to maintain structural performance.
14	Jadhav & Patil (2017)	Cement mortar (partial replacement)	Achieved satisfactory compressive strength at controlled replacement levels. Particle fineness influenced hydration and strength gain.	Proper processing and fineness control improve performance in mortar applications.
15	Kasaw et al. (2021)	Incinerated sludge as cement replacement	Thermal treatment improved pozzolanic activity and reduced organic impurities.	Pre-treatment (incineration) enhances strength and durability performance.

6. Reviews on Mix design of Textile sludge waste concrete

Zhan *et al.* (2023) investigated concrete where textile sludge was used to replace cement (up to 20 %). Mix proportions were designed with control of slump using superplasticizer and drying shrinkage was evaluated. It was found that 10% sludge replacement improved later-age compressive strength, while higher levels reduced strength due to dilution of cementitious content.

Igor V Fernandes *et al.,(*2025) designed concrete mixes using calcined textile sludge as a supplementary cementitious material (SCM). The study focused on fineness and activation to enhance pozzolanic activity, promoting strength gain in no-slump concrete mixes and better hydration characteristics. Shubham Rai *et al*.,(2025) incorporated textile sludge alongside steel slag and polypropylene fibers. Multiple waste products were proportioned with fibers to optimize compressive and flexural strengths, showing an effective sustainable mix for M35 grade concrete.

Tiwari & Richariya (2023) stabilized textile ETP sludge was incorporated as a partial cement replacement (5–15%) in mortar mix design. The optimized mix with stabilized sludge improved compressive performance versus raw sludge mixtures, showing that stabilization can influence mix design outcomes. Harpreet Kaur and Dr Jaspal Singh (2019) designed the Concrete mixes with textile mill sludge replacing cement up to 35%. Workability decreased and compressive strength dropped with higher sludge content; mixes beyond 25% failed to meet structural criteria, stressing limits on sludge percentage in mix design. RAJ and Vasudevan (2016) mixed Textile and tannery sludges in various proportions in M15 grade concrete. Optimal compressive strength was found at around 15% sludge replacement, indicating proper mix ratio selection is crucial to performance. Cheng et al. modified mix designs by combining textile sludge with fiber reinforcement, adjusting proportions to improve strength and microstructure. Such hybrid mixes show how mix design strategies can compensate for potential sludge-induced weaknesses. Table 3 Presents the inferences collected from literatures related to the Mix design of TES concrete.

Table 3. Mix Design of Concrete Partially Replaced with Textile Sludge

S. No.	Authors & Year	Mix Design Approach	Key Findings
1	Zhan et al. (2023)	Cement replaced with textile sludge (up to 20%); slump controlled using superplasticizer; drying shrinkage evaluated.	10% replacement improved later-age strength; higher levels reduced strength due to cement dilution
2	Igor V. Fernandes et al. (2025)	Calcined textile sludge used as SCM; fineness and activation optimized; no-slump concrete	Enhanced pozzolanic activity improved hydration and strength gain. Thermal activation and fineness control are key to transforming sludge into effective SCM
3	Shubham Rai et al. (2025)	Textile sludge combined with steel slag and polypropylene fibers in M35 concrete	Optimized proportions improved compressive and flexural strength. Inclusion of fibre can compensate for sludge weaknesses and enhance structural performance
4	Tiwari & Richariya (2023)	Stabilized ETP sludge used as 5–15% cement replacement in mortar	Stabilized sludge improved compressive strength compared to raw sludge. Chemical stabilization significantly improves compatibility and strength performance

S. No.	Authors & Year	Mix Design Approach	Key Findings
5	Harpreet Kaur & Dr. Jaspal Singh (2019)	Cement replaced with textile mill sludge up to 35%	Workability decreased; strength dropped beyond 25%; high replacement failed in structural criteria
6	Raj & Vasudevan (2016)	Combined textile and tannery sludge in M15 concrete	Optimal strength achieved at 15% replacement. ; moderate replacement ensures acceptable performance
7	Cheng *et al.*(2023)	Hybrid mix design with textile sludge and fiber reinforcement	Mix design modification with fibers is an effective performance-enhancing strategy .Improved strength and microstructure through fiber compensation

7. Behaviour of RC Beams Partially Replaced with Textile Sludge Composition

The behaviour of Reinforced Concrete (RC) beams incorporating textile sludge as a partial replacement of cement is strongly influenced by the chemical and physical composition of the textile sludge. Textile sludge generally consists of organic matter, fibrous residues, inorganic salts, and trace heavy metals, which collectively affect hydration, microstructure, and load-carrying performance of RC beams (Table 4).

Flexural Behaviour

Experimental studies indicate that R.C. beams with low percentages of textile sludge replacement (typically 5–10%) exhibit flexural behavior comparable to conventional beams. The inorganic fraction of textile sludge contributes to micro-filling, improving matrix density and bond between concrete and reinforcement. Beams at optimal replacement levels show similar first-crack loads, yield loads, and ultimate loads to control specimens. However, higher sludge content increases organic interference, leading to delayed hydration and reduced flexural capacity.

Crack Pattern and Crack Width

Textile sludge composition influences cracking behaviour by altering tensile strength and stiffness of concrete. At low replacement levels, crack spacing and crack width remain within permissible limits, showing distributed cracking patterns similar to normal RC beams. Increased organic content at higher replacement levels results in early crack initiation, wider cracks, and reduced tension stiffening effect.

Load–Deflection Behaviour

RC beams containing optimally processed textile sludge demonstrate ductile load–deflection behaviour with gradual stiffness degradation after cracking. The presence of fibrous residues may slightly enhance post-cracking energy absorption. Conversely, beams with higher sludge proportions exhibit increased deflection at lower loads due to reduced modulus of elasticity and weakened interfacial transition zone.

Bond and Steel Concrete Interaction

The mineralogical composition of treated textile sludge enhances particle packing, leading to improved steel concrete bond at low replacement levels. Untreated sludge with high organic content may weaken the bond, causing slip and reduced stress transfer between steel reinforcement and concrete.

Failure Mode

Control beams and beams with up to 10% textile sludge replacement predominantly fail in flexural tension mode, characterized by yielding of tensile reinforcement followed by concrete crushing in compression. Beams with higher sludge content may show premature cracking and brittle failure due to reduced compressive and tensile strength.

Table 4. Reviews on the flexural behaviour of beams partially replaced with Textile sludge

Sl. No.	Author(s)	Behavioural Inference on R.C. Beams
1	Balasubramaniam *et al.(*2006)	R.C. elements with low textile sludge content exhibited flexural behaviour comparable to control beams; higher organic content caused early cracking and stiffness reduction.
2	Siddique(2014)	Sludge-based concrete beams exhibited reduced modulus of elasticity; however, properly processed sludge ensured adequate ductility within service load limits.
3	Patel & Shah(2018)	Optimum sludge replacement (5–8%) controlled crack width and ensured gradual flexural failure; higher replacement widened cracks and reduced moment capacity.
5	Tiwari & Richariya(2023)	Stabilized textile ETP sludge improved flexural strength and reduced crack width compared to raw sludge, indicating composition modification is critical.
6	Zhan *et al.*(2023)	Calcined textile sludge enhanced microstructural density, enabling R.C. beams with up to 10% replacement to achieve flexural behaviour comparable to control beams.

8. Important Recommendations collected from the Literature Review

Optimum replacement levels for textile sludge in concrete typically range between 5–10%.Compressive strength is less sensitive to textile sludge addition compared to tensile strength. Tensile strength is influenced by sludge content, particle morphology, and interfacial bonding. Excess replacement (>20–25%) leads to dilution of cementitious content and strength reduction Proper pre-treatment (drying, grinding, calcination) significantly improves mechanical performance. Pre-treatment (drying, stabilization, calcination) is critical for consistent performance. Mix designs often require water or chemical admixture adjustment**.** Textile sludge concrete is best suited for low to moderate strength applications**,** unless enhanced with treatment or supplementary materials. Organic content governs cracking behaviour and stiffness degradation. Calcination or stabilization significantly improves flexural performance. Failure mode remains flexural tension-controlled at optimum replacement levels. Proper processing is essential for structural applicability of textile sludge concrete. Thermal/chemical stabilization significantly enhances pozzolanic reactivity. Hybrid systems (slag + fibers + sludge) can offset mechanical deficiencies. Proper control of workability (superplasticizers), fineness, and activation is essential in mix design.

Recent research trends indicate a clear transition toward positioning textile sludge ash as a functional supplementary cementitious material (SCM) rather than merely a waste filler. Emphasis has shifted to comprehensive lifecycle and environmental impact assessments to validate its sustainability benefits alongside mechanical performance. Studies increasingly incorporate thermal and chemical stabilization techniques to enhance pozzolanic reactivity, reduce harmful constituents, and improve compatibility with cement hydration products. In addition, durability and long-term performance analyses such as shrinkage, permeability, and microstructural evolution are being prioritized to ensure service life reliability. Collectively, these advancements support the integration of treated textile sludge into structural-grade concrete, demonstrating its potential as a technically viable and environmentally responsible material in modern construction practice.

9. Research Gap Identified

Although several studies have explored the use of textile sludge as a partial replacement material in concrete, systematic investigations on full-scale RC beams remain limited**,** particularly under flexural loading conditions. Most existing research focuses on compressive strength and material-level properties, while the structural behaviour of beams**,** such as load–deflection response, crack propagation, stiffness degradation, and failure modes, is insufficiently examined. Furthermore, a direct comparative assessment between untreated and treated textile sludge in RC beams is largely absent, restricting clear understanding of the role of sludge processing on flexural performance.

Another significant research gap lies in the long-term durability behaviour of textile sludge–based RC beams, including resistance to carbonation, chloride ingress, sulphate attack, and shrinkage-induced cracking. The influence of textile sludge on bond behaviour between steel reinforcement and concrete**,** which governs crack control and serviceability performance, has received minimal attention. Additionally, limited studies address serviceability limit state parameters**,** such as deflection control and crack width, in accordance with IS 456 provisions**.**

Moreover, codal design recommendations for incorporating textile sludge in structural concrete are currently unavailable, making practical implementation challenging. Hence, comprehensive experimental studies on full-scale R.C. beams are required to establish performance benchmarks and support the development of IS 456–based design guidelines for sustainable structural applications.

10. Conclusions

According to the reviewed literature, when employed in controlled amounts, textile sludge exhibits promising potential as a partial replacement material in reinforced concrete. The mechanical and flexural behaviour of textile sludge based concrete is similar to that of regular concrete at low replacement levels, especially between 5 and 10%. At these levels, the flexural performance RC beam is still tension-controlled, with tolerable load-deflection characteristics and a slow rate of crack formation.

Untreated organic and fiber components in textile sludge, however, can negatively impact steel concrete bond, stiffness, and hydration, resulting in wider fractures and more deflections. Research continuously shows that appropriate treatment techniques, including calcination, stabilization, or ash conversion, greatly increase microstructural density and improve attributes related to flexural strength, crack resistance, and durability..

Despite these promising results, the majority of the research to date has focused on material size or small scale specimens, and there is a lack of information regarding the behaviour, long-term durability, and serviceability performance of R.C. beams at full scale. Furthermore, structural adoption is constrained by IS 456's absence of codal requirements. In order to create trustworthy design guidelines and encourage the safe, sustainable use of textile sludge in structural concrete applications, more experimental and analytical research is therefore necessary.

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