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SUSTAINABLE SOLUTIONS FOR USING PLASTIC WASTES IN THE BUILDING MATERIAL AND CONCRETE INDUSTRY: A COMPRESSIVE TECHNOLOGICAL APPROACH COVERING THE CONCEPT

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Abstract: The urbanization process adds to the increase in solid waste generation, increased environmental impacts, and solid waste management failures. Due to the restricted deployment and proper disposal of solid waste, the environmental implications are a concern. There has been an increase in interest in sustainable practices regarding waste management and recycling, which the civil construction sector has substantially absorbed. Plastic, an omnipresent substance in contemporary life, has turned into a significant environmental concern because of its increasing daily production, restricted biodegradability, and inadequate disposal methods. The current system for handling plastic waste is struggling to address the growing issue, requiring an extensive strategy to promote a more sustainable future. Plastic waste can be recycled and can be used in many applications. One such application is in concrete, for which the recycled–based plastic aggregates or plastic fibres can be partial substituted for natural aggregates, can be employed for fibre incorporation as reinforcement, can be encapsulated in pre–cast blocks or by grout injection techniques or added with other admixtures in concrete. This study concentrates on assessing and studies associated with the recycled plastics in the applications of concrete. This investigation examines an outline of plastic waste management and practice in construction sector and the necessity for developing and implementing sustainable solutions.
Keywords: plastic wastes, concrete, methods & approaches, replacement, reinforcement, encapsulation

INTRODUCTION

Solid waste is one of the many factors that negatively affect the environment. Problems stem from factors such as difficulty of waste recycling and limited reuse. Solid waste is discarded material that is no longer wanted or useful, including household garbage, industrial waste, and construction debris.[1–6] It can be categorized as municipal solid waste (trash), construction and demolition debris, or industrial and hazardous waste, among others.

Proper solid waste management through collection, treatment, and disposal is crucial to prevent environmental contamination, disease spread, and other health risks associated with improper waste disposal.[1–6] Waste management steps focus on segregation by waste type, storage in covered containers, timely handling, and partnership with recycling facilities to maximize diversion from landfills. In short, various waste streams are diverse, requiring targeted segregation, handling, and recycling strategies to mitigate environmental impact, improve sustainability, and support circular use of materials.[1–6]

Opportunities include reusable packaging, pre–demolition audits for better waste sorting, closed–loop recycling of high–value wastes, and development of circular economy models.

Figure 1. Process flow of solid waste management

Plastic is an important type of solid waste with a strong environmental impact.[1–6] The increase in plastic consumption can be linked to its beneficial traits, such as unmatched versatility and the capability to be customized to fulfill precise technical requirements. The surge in plastic usage can be attributed to its advantageous characteristics, including unequalled versatility and the ability to be tailored to meet specific technical needs precisely.[7–18] The increasing volume of plastic waste, particularly plastic packaging, being discarded long after purchase, raises concerns about the growing demand for landfill space.

Apart from their extensive use in packaging and industrial sectors, plastics find wide applications. Additionally, plastics play vital roles in food preservation, household appliances, telecommunications, and the electronics industry, among others.[7–18] Notably, the global annual consumption of plastics continues to surge, and this growing use of different plastic items is a significant challenge for environmental conservation.

Significant amounts of plastic waste and its low biodegradability have a detrimental impact on the environment.[7–18] Every kind of plastic utilized by people in everyday life ultimately turns into waste; many tons of this plastic refuse need extensive land for disposal and cannot be completely recycled at once.[7–18] The disposal of these plastics presents a significant risk to the environment because of their lengthy decomposition times. From various viewpoints, the reuse of waste is significant as it facilitates recycling and energy conservation during production, diminishes environmental pollution, and aids in the preservation of non–renewable natural resources. [7–18] Utilizing plastic waste in the materials sector serves as an ecological approach to reduce the volume of landfills employed in waste incineration.

The escalating global plastic waste crisis has prompted a search for sustainable solutions, particularly in the construction industry. Recycling plastic waste to create sustainable construction materials, such as concrete, has emerged as a promising approach. In light of the increasing environmental issues and the pressing need for sustainable methods in the construction field, there is a rising interest in discovering innovative strategies to tackle the global plastic waste dilemma. With the significant rise in plastic usage, the world confronts the daunting task of handling substantial quantities of plastic waste that threaten the environment, ecosystems, and public health.[7–18] Within this framework, the idea of transforming plastic waste into eco–friendly construction materials, like concrete, has emerged as a viable solution to reduce the negative effects of plastic disposal while simultaneously improving the environmental sustainability of the construction industry. [7–18]

Plastic waste management is a complex global challenge demanding urgent action. Implementing a combination of solutions at various levels, from individual responsibility to policy changes and technological advancements, is crucial to creating a sustainable future.[7–18] By adopting practices that reduce plastic consumption, prioritize sustainable materials, improve waste management infrastructure, and invest in innovative solutions, we can collectively mitigate the environmental impact of plastic.

USE OF PLASTIC IN CONSTRUCTION

The solution to the plastic–related problem lies in utilizing plastics in construction. Concrete, as one of the most utilized construction materials worldwide, necessitates a significant quantity of natural aggregates each year. To satisfy this requirement, billions of metric tons of natural aggregates are necessary annually for concrete construction. This growing demand for development resources results in a scarcity of regular assets. [19–41] In any event, to handle this request, experts are responding vigorously by suggesting innovative methods of using alternative materials. Using plastic waste in concrete can lessen reliance on natural aggregates, thus lowering related production and transportation costs. [19–41] Therefore, it allows for the elimination of waste materials without harming the environment.

Although numerous studies have investigated the technical viability and mechanical properties of concrete mixtures that use varying amounts of plastic waste as aggregate replacements, this research seeks to examine the wider consequences of using plastic waste in concrete. It will explore its impact on the general sustainability and eco–friendliness of concrete structures. [19–41]

Different kinds of plastics, including polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polyethylene terephthalate (PET), high–density polyethylene (HDPE), and low–density polyethylene (LDPE), can act as additives in concrete, usually as fibres, particles, or aggregates. Every type of plastic has unique traits that can improve particular features of concrete. [19–41] For example, adding plastic fibres can enhance concrete's strength and durability, whereas using plastic aggregates can lower its weight. Moreover, plastics can help enhance the ductility, impact resistance, and thermal characteristics of concrete. Incorporating plastics into concrete mixtures can enhance performance and sustainability in construction projects.

Plastic wastes are considered wastes, hence their value is low to none. As a result, using plastics in construction materials will avoid the costs associated with traditional building materials, lowering the overall construction cost. Hence, it can be concluded that the recycled based plastic fibres and aggregates can be used successfully substituted for traditional reinforcements or aggregates in concrete without causing long–term deterioration and with adequate strength development qualities.

Plastic wastes, traditionally viewed as environmental burdens, can be effectively repurposed as valuable building materials, turning a waste management challenge into a sustainable resource opportunity. [19–41] Their applications in construction include:

- bricks and blocks made by blending shredded or melted plastics with soil, cement, or other binders.
- insulation boards and panels made from plastic foams.
- composite materials for roofing, wall cladding, and flooring.
- lightweight aggregates replacing natural gravel in concrete.
- innovative products like plastic lumber for decking and fencing.

Several advantages of using plastic waste in building materials are:

- Environmental impact reduction: Diverting plastic waste from landfills and oceans helps reduce pollution and the negative ecological footprint of plastic disposal.
- Resource conservation: Incorporating recycled plastics reduces the demand for virgin raw materials like sand, gravel, clay, and steel in construction, preserving natural resources and minimizing extraction–related harm.
- Energy efficiency and insulation: Plastic–based building components often offer enhanced thermal insulation and waterproofing properties, contributing to energy savings in buildings.
- Lightweight and durable materials: Plastic wastes can produce lightweight construction elements like bricks, panels, and blocks with good durability, toughness, and resistance to weather, chemicals, and corrosion.
- Cost–effectiveness and socio–economic benefits: Utilizing plastic waste lowers material costs, speeds construction, creates new industries and jobs (especially in recycling and manufacturing), and provides affordable housing solutions especially in developing regions.

The importance of plastic–related concrete lies in its potential to address environmental, economic, and performance challenges in construction. The reuse of plastic waste in concrete supports circular economy principles by turning waste into valuable construction materials, promoting sustainable industrial processes and reducing environmental impact.

METHODS FOR USE OF PLASTIC IN CONCRETE

Sustainable solutions for using plastic wastes in the building material and concrete industry focus on recycling and upcycling plastic waste to create eco–friendly, cost–effective, and durable construction materials. Sustainable solutions for using plastic wastes in concrete revolve around recycling plastic as partial replacements for natural aggregates or as reinforcing concrete with plastic fibres, enhancing concrete properties while reducing environmental impacts. [19–41]

PARTIAL REPLACEMENT OF AGGREGATES

The main method for using plastic in concrete is as a partial replacement of natural aggregates (coarse or fine) through mechanical mixing. This method involves substituting a portion of the sand or gravel aggregates (coarse or fine) with processed plastic particles. [19–21]

Almost 70–80% portion of concrete is composed of AGGREGATES. The workability of concrete is highly dependent on the type of aggregate. Their shape, size, texture, and other properties counted for their suitability while using it in a concrete mixture.[19–29] COARSE AGGREGATES like crushed stone and gravel are essential ingredients in construction materials such as concrete. Coarse aggregate resources used in concrete contain a composite blend of stones and gravel particles across a range of sizes and proportions adequate enough to deliver specified strength and durability capabilities. These are obtained from naturally occurring sources such as river gravels, crushed stones (granite, basalt, limestone), and quarry blasting. They are usually angular or rounded particles. Coarse aggregates compose 60–80% of concrete volume, control strength, workability, water demand, and dimensional stability, and determine the bonding quality of the cement paste. On another hand, the most common FINE AGGREGATE are derived from riverbeds, beaches, or pits. It consists mostly of silica and is valued for its rounded shape and smooth texture, which improve workability. The manufactured sand (crushed stone sand) is produced by crushing hard rocks like granite, basalt, or limestone. Manufactured sand is angular and rougher than natural sand, providing better bonding but potentially increasing water demand.[19–29] Crushed gravel or crushed stone fines are particles obtained as by–products from crushing larger aggregates. These can serve as fine aggregates, especially when natural sand is scarce. Properties such as particle size distribution (grading), shape, texture, and water absorption influence the workability, strength, shrinkage, and durability of concrete.

Figure 2. Natural aggregates (coarse or fine)

Plastic wastes are first cleaned, shredded, and sized to appropriate dimensions to behave similarly to natural aggregates in concrete. The prepared plastic particles are mixed with conventional concrete ingredients (cement, water, sand, coarse aggregates) either as partial replacements for coarse aggregate or fine aggregate based on the particle size. This mixture is mechanically mixed to distribute the plastic particles uniformly within the concrete matrix.[19–29] The following approaches are commonly utilized:

- Flakes or chips: Various plastics are shredded into small, irregular flat flakes, typically ranging from 2 to 10 mm in size. These flakes can partially replace fine aggregates and improve workability due to their smoother texture and spherical shape. Can be used as partial replacement of fine or coarse aggregates.
- Granules: Produced by grinding or granulating plastics into small, uniform pellet–like particles. Larger plastic pieces, usually between 5 and 20 mm, can be obtained by crushing various plastic waste sources. More uniform size and shape help improve mixing and particle packing. These can replace coarse aggregates but require careful optimization to avoid compromising strength and ensure proper interlocking within the concrete matrix.
- Melted aggregates: Plastic waste is melted and formed into new aggregate pellets or coated on traditional aggregates. Melting certain plastics allows them to be moulded into specific shapes resembling conventional aggregates. This approach offers greater control over the size and shape but requires additional energy consumption and might not be cost–effective for large–scale applications. Can be used as coarse aggregate replacement.

In brief, shredded flakes are simplest but weakest for structural use, granules balance ease of production and properties, while melted plastic aggregates offer potentially better mechanical performance but require higher processing energy and safety considerations. [19–29]

Figure 3. Plastic wastes prepared for use in concrete

Therefore, shredded, grinded, granulated or melted plastic can be used to partially replace several components of concrete, mainly:

— COARSE AGGREGATE REPLACEMENT (gravel or crushed stone): The plastic content is optimized often within 10–30% by volume or weight of the replaced coarse aggregate. Higher amounts tend to reduce strength due to poor plastic–cement bonding, so specific mix designs are necessary to maintain structural performance. Typical replacement percentages range from 5% to 15% with some decrease in compressive strength at higher replacement levels. This replacement reduces concrete density and plastic waste simultaneously.

— FINE AGGREGATE (SAND) REPLACEMENT: Plastic waste shredded into smaller sizes can substitute fine aggregate (sand) partially. Replacing sand (fine aggregates) with shredded plastic in concrete has been studied as an environmentally beneficial alternative to reduce sand consumption and plastic waste. Shredded plastic replaces sand effectively, though plastic particles do not bond to cement paste as strongly as sand. Around 10% replacement of fine aggregate (sand) with shredded plastic can be achieved without compromising concrete strength and longevity. This limits the replacement percentage but still provides cost savings and reduces environmental impact and this replacement can save millions of tonnes of sand annually. In summary, shredded plastic as a partial sand replacement in concrete is a viable, sustainable option that balances mechanical performance, cost, and environmental benefits. The typical replacement percentage for good results is around 4–10% by volume. Overall, shredded plastic as partial sand replacement offers a sustainable and effective alternative for concrete in construction, particularly in regions with high plastic waste and construction demand.

Figure 4. Replacement aggregate with plastics

The simplest, most widely used method to incorporate plastics in concrete is as partial replacements for natural aggregates mixed thoroughly into the cement matrix. This approach requires careful control of replacement ratios and mix design parameters, including the use of suitable admixtures, to balance sustainability benefits with structural performance.

The main replacement components for shredded plastic in concrete are coarse aggregate and fine aggregate (sand). These substitutions promote sustainability by reducing natural resource consumption and plastic waste, while maintaining workable, durable concrete. Optimal replacement percentages depend on plastic type, size, and concrete design. Replacing aggregates reduces the environmental burdens related to sand mining, including ecosystem disruption. Overall, aggregate (coarse or fine) replacements improve sustainability, cut costs, and reduce environmental impacts over the full lifecycle of concrete applications.

Using shredded plastic as a partial replacement for cement in concrete is generally limited due to the weak bonding between plastic particles and cement paste. Most research focuses on plastic as aggregate or fibre replacement rather than substituting cement itself. Plastic particles are hydrophobic and do not contribute to the cement hydration process, which is critical for concrete strength development.

Research suggests that plastic waste in concrete is best used as partial aggregate or fibre replacement to improve sustainability while maintaining acceptable mechanical performance. In fact, shredded plastic is not typically used as a direct cement replacement in concrete due to fundamental material incompatibility, but rather as partial replacement for aggregates or as reinforcement fibres.

FIBRE REINFORCEMENT

Fibre reinforcement with plastics in concrete involves adding synthetic plastic fibres to the concrete mix to improve its mechanical properties, durability, and crack resistance. This technique is an effective complement or partial alternative to traditional steel reinforcement, especially in applications where corrosion resistance, lightweight, and ease of handling are priorities. [30–36] In fact, plastic fibre reinforcement is a versatile, corrosion–resistant solution that enhances concrete durability and crack resistance, especially suitable for non–structural and moderately loaded applications, contributing to sustainable and efficient construction practices. [30–36]

Figure 5. Fibre reinforcement with plastics in concrete

This method involves dispersing plastic fibres throughout the concrete mix. [30–36] The following types of fibres are commonly used.

- Microfibres: These are very fine fibres, typically less than 1 mm in diameter and several centimetres long. They are generally well–distributed within the matrix and primarily enhance crack resistance and ductility.
- Macrofibres: These are larger fibres, ranging from 5 to 25 mm in length and diameter. They contribute to improved tensile strength and can bridge larger cracks, providing additional structural reinforcement.

Figure 6. Types of fibres are commonly used

Fibres act by bridging microcracks that develop during concrete curing and service life, preventing crack propagation. They improve post–crack behaviour (post–fracture toughness), meaning the concrete can carry loads even after initial cracking. [30–36] Also, plastic fibres increase the durability of concrete by reducing microcracking and mitigating shrinkage–related damage.

Several techniques can be employed for fibre incorporation in concrete to enhance its mechanical properties, durability, and sustainability:

- MANUAL MIXING, as direct mixing method: This involves adding the fibres directly to the concrete mix during mixing. However, consistent distribution can be challenging, especially for larger fibres. Fibres are dispersed uniformly by mixing machinery to avoid clumping or balling. This is the most common and straightforward method for fibre reinforcement. In smaller or site–mixed batches, fibres may be introduced gradually and mixed thoroughly by hand or small mixers to ensure uniformity.
- COLLATION, or PRE–MIXING WITH AGGREGATE: Fibre can be pre–collated with a small amount of cementitious material to form small bundles. Fibres are first mixed with coarse or fine aggregates before adding cement and water. This improves dispersion and reduces clumping during mixing. In fact, this method enhances even distribution and reduces fibre clustering in the mix.
- SPRAYING, or RAPID DISPERSION: Fibres may be added to concrete mixes sprayed onto surfaces (shotcrete). Specialized equipment can spray the fibres onto the concrete mix during casting, ensuring a more uniform distribution. Plastic fibres may be chemically or physically treated to improve adhesion with the cement matrix. In spraying, fibres must be well–dispersed beforehand to avoid nozzle blockages.

These fibre incorporation techniques aim to maximize fibre dispersion and bonding within the cement matrix, essential for realizing the mechanical and durability benefits of plastic fibre–reinforced concrete. [30–36] Fibres are often combined with plasticizers or superplasticizers to improve workability since fibres tend to reduce slump. Admixtures help maintain flow and compaction quality of fibre–reinforced mixes.

Plastic fibres are usually added during mixing, with dosages ranging from around 0.2% to 2% by volume depending on the application and fibre type.[30–36] Optimal fibre content balances improved mechanical properties with acceptable workability and compaction. Designing concrete with 1.5–2.0% plastic fibres requires optimizing the mix ratio—adjusting water content, admixtures, and aggregate grading—and adopting careful compaction practices to ensure homogeneity and maximize strength and durability benefits without sacrificing workability.[30–36] This balance enables successful utilization of plastic fibre reinforcement in practical concrete applications. When incorporating 1.5–2.0% plastic fibres by volume in concrete, mix proportions and compaction practices should be adjusted for optimal performance. Therefore, carefully adjusted mix proportions and controlled compaction compensate for plastic fibres' effects, maintaining workability while leveraging fibres' mechanical benefits.

Fibres can be incorporated into concrete through direct mixing, pre–mixing with aggregates, spraying for shotcrete applications, and continuous mixing in precast production. Spraying (shotcrete) methods require well–dispersed fibres and specific mix designs to avoid workability issues and ensure effective fibre reinforcement for crack control.

ENCAPSULATION IN PRE–CAST BLOCKS

ENCAPSULATION OF PLASTICS IN CONCRETE refers to a method where waste plastics are immobilized or mechanically bound within a cementitious matrix, effectively "encapsulating" the plastic particles inside the solid concrete material. This approach allows the incorporation of high volumes of plastic waste into concrete, creating composite materials known as encapsulated plastic concrete. The plastics are physically enclosed within the cement matrix, reducing environmental contamination risk from plastic debris.[37–41] Encapsulation involves immobilizing or binding waste plastics within cementitious materials to form a solid monolith, often referred to as encapsulated plastic concrete.[37–41] Encapsulation helps to mitigate some environmental and mechanical challenges of using loose plastic aggregates directly. Thus, encapsulation serves as a complementary method to using processed plastic particles in concrete, enhancing environmental safety and broadening potential applications of plastic waste concrete

This method effectively surrounds plastic particles within the cement matrix, which can improve handling and durability.[37–41] In essence, encapsulating plastics within concrete creates a composite material that leverages waste plastics for sustainability while providing functional performance for non–structural or lightweight construction uses. Encapsulated plastic concrete typically exhibits lightweight properties with densities ranging from approximately 1400 to 1700 kg/m³ and porosity from 8.9% to 21.2%. The method supports sustainability by effectively immobilizing plastic waste in civil engineering applications while avoiding the direct exposure of plastic to the environment. Applications include lightweight construction elements, concrete fills, landscaping, structural formwork, sandwich panels, boundary walls, and pervious concrete for drainage and flood defence. Durability is improved relative to loose plastic waste; encapsulated plastic concrete shows resistance to frost, sulphate attack, and moderate heat (up to about 150°C). [37–41] Limitations include low tensile strength and potentially lower workability, which can be mitigated by mechanical mixing and reinforcement (e.g., mesh).

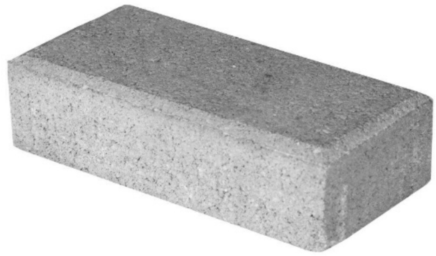

Figure 7.Pre–cast blocks

ENCAPSULATING PLASTICS IN PRE–CAST CONCRETE BLOCKS involves immobilizing plastic waste within the concrete matrix during the block manufacturing process, creating composite precast elements with environmental and functional benefits. [37–41] Plastic waste is compacted and encased in pre–cast concrete blocks. This method offers a potential solution for hazardous plastic waste management but requires a dedicated production process and may not be suitable for large–scale waste diversion. [37–41] Methods of encapsulating plastics in precast blocks are:

- Mechanical mixing: Plastics in shredded, pelletized, or aggregate form are mixed directly with cement, sand, and aggregates to produce a plastic–filled concrete mix. This mix is poured or molded into precast block forms and cured. Mechanical mixing ensures plastics are uniformly dispersed and encapsulated within the hardened concrete.
- Use of mineral admixtures: Incorporating mineral powders such as pulverized fly ash or silica fume alongside plastics helps improve bonding and reduce voids in the composite, enhancing strength and durability of the precast blocks.
- Layer or sandwich construction: Precast blocks can be made in layers with an inner core containing encapsulated plastic concrete and outer layers of conventional heavier concrete. This approach provides insulation benefits from the plastic core while maintaining surface durability.
- Reinforcement integration: Depending on application, mesh or fibres may be included

to compensate for plastics' low tensile strength and enhance block structural integrity.

Plastics are encapsulated in precast block production by integrating shredded or pelletized plastic waste into concrete mixes, assisted by admixtures and controlled manufacturing processes to create sustainable, lightweight, and functional construction blocks.

ENCAPSULATION IN CONCRETE BY GROUT INJECTION

GROUT INJECTION IN CONCRETE is a specialized repair and strengthening technique involving injecting a fluid grout material into cracks, voids, or honeycombs within concrete structures. The goal is to fill these defects to seal cracks, restore structural integrity, reduce permeability, and improve durability. Encapsulation in concrete by grout injection is a technique where grout—usually a cementitious slurry or chemical sealant—is injected into cracks, voids, honeycombs, or porous zones within concrete structures. This process stabilizes, strengthens, and seals the concrete.[37–41] The CEMENTITIOUS GROUT INJECTION uses fine cement mixtures to fill larger voids and cracks. Cementitious grout is a fine cement slurry for void filling and non–structural repairs. Crushed plastic waste can be mixed with grout and injected into existing cavities or cracks in structures. This approach is primarily used for repair and strengthening applications, not as a primary construction material.[37–41] Overall, encapsulation in concrete by grout injection is a crucial rehabilitation and strengthening technology in civil engineering.

Grout injection entails injecting a low–viscosity grout under pressure into cracks or porous regions inside concrete. The grout flows into narrow cavities, filling them completely, then hardens into a solid or gel–like substance. This process helps seal cracks, bond fractured sections, and strengthen damaged or deteriorated concrete. [37–41] It is often called permeation or chemical grouting depending on the material used. In essence, grout injection is a key technique for concrete repair that uses various materials like cementitious mixes injected under pressure through drilled ports to reinforce and waterproof concrete structures.

GROUT INJECTION TECHNIQUES vary based on the application and the type of material to be filled or stabilized. The most usual form of grouting method is referred to as permeation grouting, which in simple terms, involves filling open voids. [37–41]

Figure 8. Cementitious grout injection

Although all varieties of grouting contain some measure of permeation grouting, there are four distinctive approaches: permeation, compaction, fractural and jet grouting. [37–41] Here is an overview of common grout injection techniques used in concrete and soil stabilization:

- PERMEATION GROUTING is used mainly to strengthen formations and create impermeable barriers against water. Also called PENETRATION GROUTING, it involves injecting low–viscosity grout into cracks, voids, or porous media without altering the overall volume or structure. The grout permeates through the material's pores or cracks, filling and sealing them.
- COMPACTION GROUTING is commonly used to mitigate settlement and stabilize foundations. It involves injecting a low–mobility grout (cement, sand, fly ash, water) at high pressure into the ground or concrete from the bottom up. The grout displaces and compacts loose soil or material, increasing density and load–bearing capacity
- FRACTURE GROUTING is often used for releveling structures and correcting settlement. Low–viscosity grout is injected at pressures high enough to hydraulically fracture the surrounding soil, creating new fractures filled with grout, densifying the area.
- JET GROUTING is a versatile method but may vary in efficiency with different soil types. High–pressure jets of grout, water, and/or air erode and mix the soil creating cemented soil columns ("soilcrete")

In summary, permeation grouting is common for filling cracks and fine voids with minimal disturbance; compaction grouting is best for densifying loose soils; fracture grouting creates controlled fractures; jet grouting is versatile but costly and disruptive. Choice depends on soil or material type, void size, structural needs, and project economics. Each technique has specific applications and benefits depending on site conditions, crack or void size, and required structural performance. Selecting the right injection method and grout material is key to effective concrete repair and stabilization. Grout injection is a method of injecting fluid grout into cracks, voids, or porous areas in concrete to seal, fill, and strengthen the structure. The grout fills these internal spaces and hardens, restoring integrity and reducing permeability.

Grout injection techniques using plastic particles in concrete or soil remediation are an emerging field that combines grout injection principles with the use of plastic materials to improve or modify grout and soil properties. Plastics could be involved as additives or fibres to modify grout properties or improve mechanical performance of the injected material. Plastic particles might be added to grout mixtures as lightweight fillers or to increase toughness and crack resistance, but their use requires careful optimization of particle size, shape, and dosage to maintain flowability and injectability through injection ports and soil or concrete voids. [37–41]

Grout injection techniques involving plastic particles aim to combine the environmental benefits of using recycled plastic within traditional or modified grout materials for concrete repair or soil stabilization. However, these techniques require tailored grout formulations and injection methods to ensure proper flow, filling, bonding, and mechanical performance.

PLASTIC WITH OTHER ADMIXTURES IN CONCRETE

Adding plastic with other admixtures in concrete is an innovative approach to enhance sustainability and modify concrete properties. Combined with chemical additives or admixtures, such as fly ash or silica fume, plastics can enhance the general performance (tensile strength and crack resistance), improving durability in some mixes. Admixtures like plasticizers improve workability and compensate for changes in mix behaviour caused by plastic inclusion, helping maintain or improve compressive strength. [37–41] This method requires less processing but calls for careful mix design to balance workability and strength.

The main methods of incorporating plastic with admixtures in concrete are:

- Direct addition of plastic particles or fibres: Shredded plastics or fibres are introduced during mixing as partial replacements of fine or coarse aggregates.
- Use of water–reducing agents (plasticizers): These admixtures reduce water demand and increase flowability, offsetting workability loss due to plastic particles' irregular shapes.
- Mix optimization: Water–cement ratio, aggregate grading, and admixture types are adjusted according to plastic content to balance strength, durability, and workability.

In fact, combining plastic wastes with suitable chemical admixtures in concrete can create more sustainable, workable, and durable materials. Optimal mix design and admixture selection are crucial to effectively balance the pros and cons of plastic inclusion in concrete.

KEY CONSIDERATIONS

The concept of using plastic wastes in the building material and concrete industry centres on transforming abundant plastic waste into valuable construction materials, thereby addressing environmental pollution, conserving natural resources, and creating sustainable economic opportunities. Plastics are strong, durable, lightweight, waterproof, and easy to mold — all ideal for construction materials. They can be processed by shredding, melting, or compounding with other waste materials to produce bricks, blocks, tiles, lumber, and aggregates for concrete.

Plastic wastes are shredded into flakes or granules, mixed with other waste streams or melted and molded in synthetic aggregates. Apart from environmental gains, plastic reuse provides affordable construction materials, and fosters innovation in the fast–growing construction sector. Plastic waste is used in building envelopes (walls, roofs), insulation, concrete additives and aggregates, brick and block manufacturing, facade panels, and other structural and non–structural elements. Plastic–enhanced concretes can improve mechanical properties and durability.

Utilizing plastics in construction is indeed a promising solution to the global plastic waste problem, but it is part of a broader, integrated approach necessary to manage plastic pollution sustainably. Key considerations include:

- Waste reduction and recycling: Incorporating plastic waste into construction materials like concrete, bricks, panels, and insulation helps divert huge volumes of plastic from landfills and oceans, reducing environmental pollution.

- Resource conservation: Using plastic waste as a substitute for natural aggregates or as reinforcement reduces demand for virgin materials and lowers carbon footprints associated with extraction and processing.
- Material performance and longevity: When engineered properly, plastic–incorporated construction materials offer enhanced durability, crack resistance, insulation, and lightweight properties, contributing to longer–lasting infrastructure and reduced maintenance.
- Circular Economy advancement: Recycling plastics in construction fosters circular economy models by converting waste into valuable resources, driving sustainable manufacturing and consumer practices.
- Limitations and challenges: Plastic use in construction must address issues such as consistent material quality, potential microplastic release, fire safety, bonding with cementitious matrices, and lifecycle environmental impacts.
- Complementary solutions needed: While construction uses absorb large volumes of plastic waste productively, further actions in plastic production reduction, improved collection, recycling technologies, behavioural change, and regulatory frameworks remain essential.

In fact, utilizing plastics in construction plays a critical role in mitigating plastic waste problems by creating sustainable, high–performance building materials. However, it is one vital component among many integrated strategies required for comprehensive plastic pollution solutions. Addressing variability in plastic types, mechanical property degradation during recycling, establishing standards, enhancing bonding with cementitious matrices, and integrating recycled plastic sustainably remain key focus areas. In essence, the concept revolves around leveraging the unique properties of plastics and advanced recycling technologies to create sustainable, cost–effective, and environmentally responsible building materials and concrete composites from plastic waste, turning a global environmental challenge into an opportunity for green construction and circular economy growth.

CONCLUDING REMARKS

These approaches contribute to sustainability by diverting plastic waste from landfills and reducing the use of finite natural aggregates. They provide lightweight concrete alternatives with adequate strength for many construction applications like pavements, blocks, and structural components. The integration of plastic waste also enhances certain physical properties. Overall, these methods effectively contain and stabilize plastic waste by converting it into a solid form safely integrated with cementitious matrices, making it suitable for disposal, reuse, or recycling in materials such as concrete.

While these approaches offer encouraging possibilities for incorporating plastic into concrete, it's essential to recognize that extensive research and development are required to understand the long–term impacts on performance, durability, and environmental impact. As these techniques advance and challenges are overcome, the use of plastic waste in concrete may improve the sustainability of the construction sector by minimizing waste while maintaining structural strength and the durability of built components. While initial material costs drop, reduced environmental impacts contribute to more sustainable construction, and lifecycle cost savings emerge through lower maintenance and resource depletion.

The escalating global plastic waste crisis has prompted a search for sustainable solutions, particularly in the construction industry. Recycling plastic waste to create sustainable construction materials, such as concrete, has emerged as a promising approach. Incorporating plastic waste into concrete supports initiatives aimed at advancing sustainable building practices. This method helps reduce waste and conserve resources by redirecting plastic waste from oceans and landfills. Additionally, adding plastic waste to concrete can improve the performance of lightweight concrete, providing benefits in cost and labour for construction projects. The effectiveness of these initiatives depends on the proper handling and processing of plastic waste to guarantee the quality and performance of the concrete products created. Continuous research is crucial to enhance the utilization of plastic waste in concrete and promote the advancement of eco–friendly building materials. Rethinking plastic waste as a building resource helps build circular economies, reduce environmental harm, and create sustainable construction solutions with significant social, economic, and ecological benefits.

The use of plastic waste as a replacement for natural aggregates in concrete is a direct response to two critical challenges: the abundance of plastic pollution and the depletion of natural sand and gravel reserves. This dual benefit—waste diversion and resource conservation—is the most compelling argument for the practice. By incorporating plastic into the concrete matrix, a significant volume of non–biodegradable material is permanently sequestered from landfills and ecosystems, offering a tangible environmental victory.

The integration of plastic waste in concrete fosters new research directions, advanced processing technologies, and innovative construction materials, aligning with global sustainability goals. Plastic–related concrete offers a multifaceted solution enhancing sustainability, lowering costs, improving construction material performance, and supporting waste recycling efforts, making it an important development in modern construction. These sustainable solutions demonstrate that incorporating plastic waste in the construction industry not only addresses plastic pollution but also boosts material performance and cost efficiency, contributing substantially to greener and more resilient built environments. These methods help transform plastic waste from environmental burdens to valuable, sustainable construction materials, contributing to greener, more durable, cost–effective, and resilient built environments.

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