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Building Construction Using Industrial Waste, Recycling and Reuse of Construction Material : A Sustainable Solution

Mrs. Shreya Tiwari
Assistant Professor, Department of Civil Engineering
Axis Institute of Technology and Management
Rooma, Kanpur India.

Shivam Gupta[1], Ayush Pandey[2], Pranav Pandey[3], Ashish Kumar[4].
[1-4]UGC Student, Department of Civil Engineering
Axis Institute of Technology and Management
Rooma, Kanpur India.

Abstract- *The construction sector is increasingly challenged to minimize environmental harm, preserve natural resources, and address the growing accumulation of industrial and construction waste. Sustainable Building Structure Using Industrial Waste, Recycling and Reuse of Construction Material examines the potential of incorporating materials like fly ash, slag, silica fume, and construction and demolition waste as eco-friendly replacements for traditional building materials. The study focuses on evaluating their physical characteristics, structural behavior, and long-term durability to determine their effectiveness in practical construction applications. Also, by encouraging recycling and reuse, this project seeks to reliance on natural aggregates, and advance circular economy principles within the industry. It also analyses the economic advantages, including lower material costs, reduced landfill disposal, and improved waste management practices. The results indicate that recycled waste materials can achieve reliable structural performance while offering notable environmental and financial benefits. Overall, the study shows that the use of industrial and construction waste in building systems is a viable strategy for promoting sustainable infrastructure and ensuring more responsible utilization of available resources. Experimental testing was carried out to evaluate compressive strength, durability, and material performance of waste-incorporated concrete mixes.*

Keywords- Sustainable Construction, Industrial Waste Utilization Recycling and Reuse, Eco-Friendly Building Materials, Circular Economy

I. INTRODUCTION

The increasing pace of construction worldwide has greatly intensified the consumption of raw materials, caused rapid depletion of natural resources and heightened environmental strain. Conventional construction continues to depend on cement, aggregates, and steel, all of which require significant energy and contribute to emissions and ecological stress. Meanwhile, industrial activities and urban growth generate large amounts of industrial waste and C&D debris, leading to major issues related to waste disposal, land scarcity, and environmental degradation. This scenario underscores the need for sustainable construction practices that ensure development without compromising ecological balance.

Over the past few years, sustainable construction has been recognized as an effective method to mitigate environmental impacts and promote efficient resource use. The use of industrial waste materials—such as fly ash, slag, silica fume, and recycled C&D waste—as replacements for conventional building materials offers a sustainable and practical option. These waste-derived materials lessen landfill accumulation while enhancing performance attributes like durability, workability, and long-term stability.[1]

Reusing and recycling industrial by-products aligns with circular economy principles by turning waste into valuable construction inputs, decreasing dependence on natural aggregates, and reducing the overall carbon footprint of the built environment. Additionally, the adoption of these materials can lead to economic benefits through material cost savings, reduced disposal requirements, and improved sustainability outcomes.

This research aims to evaluate the structural suitability, performance efficiency, and environmental impact of integrating industrial waste into building components. Through material testing, mix design evaluation, and performance assessment, the study seeks to establish waste-based construction as a scalable and sustainable method for future infrastructure. Ultimately, this research contributes to advancing environmentally friendly, resource-efficient, and economically feasible construction solutions.

II. LITERATURE REVIEW

2.1 General Overview

Literature review synthesis previous research to evaluate progress in a field, identify gaps, and position the current study within a broader academic context. This section reviews key contributions from previous scholars related to Building Structure Using Industrial Waste, Recycling and Reuse of Construction Material.

2.1.1 Shamir Shakir et.al (2020) [1]:

The study finds that many industrial and agricultural by-products, when used as supplementary cementitious materials at optimum replacement levels, can maintain or improve the mechanical strength and durability of structural mortar. While workability may reduce in some cases, proper processing and mix design help overcome this issue. Overall, the use of these materials significantly reduces cement consumption, waste disposal problems, and CO_2 emissions, supporting sustainable construction without compromising performance.[2]

2.1.2 Hamid Shahrin et.al (2020) [2]:

The study indicates that recycling and reuse of construction waste are practiced in the Klang Valley, with timber being the most commonly recycled material, followed by metal and brick. The primary benefit identified is the reduction in landfill usage, along with cost savings and improved resource management. However, challenges such as risk of contamination, high processing and disposal costs, and transportation issues limit wider implementation of these sustainable practices.[3]

2.1.3 Rosaria E.C. Amaral et.al (2020) [3]:

The paper finds that effective waste management and energy strategies throughout a building's life cycle—especially during design, construction, and operation—can significantly reduce environmental, social, and economic impacts. It highlights that reducing, reusing, and recycling construction and demolition waste, optimizing resource use, and improving operational energy efficiency are key to achieving sustainable buildings. The review also identifies that decisions made early in design have a major influence on waste generation and energy performance, emphasizing the importance of integrated planning and sustainable practices to minimize embodied carbon, pollution, and resource depletion.[4]

2.1.4 Satyam Kumar et.al (2020) [4]:

The paper finds that a variety of sustainable "green" building materials—such as earthen structures, straw bale, insulated concrete forms, structural insulated panels, and wood—offer significant environmental and energy performance advantages over conventional materials by reducing greenhouse gas emissions, waste, and energy consumption. While some materials may have limitations in specific conditions (e.g., fire risk or structural weaknesses), overall, these materials contribute to improved insulation, resource efficiency, and long-term economic benefits. The study also highlights that green building certification systems like LEED support adoption of sustainable practices, though broader implementation is limited by lack of codes, awareness, and technology in many regions.[5]

2.1.5 Musa Mohammed et.al (2021) [5]:

The study finds that applying the 3R (Reduce, Reuse, Recycle) framework significantly enhances sustainable construction waste reduction in the Malaysian construction industry. Using Partial Least Squares Structural Equation Modeling (PLS-SEM) on survey data, it shows strong relationships between improving factors, policy-related factors, construction waste generation, and sustainable waste reduction, with the model explaining a high degree of variance. Key barriers to effective 3R implementation include lack of design planning and inadequate guidance for waste collection, while strategies such as on-site waste minimization and improved material handling were ranked as most effective in reducing waste.[6]

2.1.6 Schützenhofer S et.al (2022) [6]:

The study finds that improving construction waste management through dismantling, recovery, reuse, and recycling significantly enhances environmental sustainability and supports the circular economy in the built environment. It shows that construction and demolition waste, which constitutes a large portion of material flows, can be better managed by planning for material reuse early in project design and by integrating effective on-site waste handling, recovery processes, and policy mechanisms. The research highlights that while technical and cost-related challenges persist, linking waste management practices with eco-indicators and regional resource strategies can reduce raw material extraction, decrease landfill disposal, and promote a closed-loop resource system that benefits both environmental outcomes and circular economic goals.[7]

2.1.7 RK Shakthibhala et.al (2025) [7]:

The article finds that construction and demolition (C&D) waste is a major global environmental and resource challenge, and that recycling and reuse of these materials offer significant environmental and economic advantages. It identifies that applying refined waste management techniques—such as life cycle assessment, deconstruction methods, reuse of concrete, metals, and glass, digital tools, and circular economy principles—can reduce natural resource depletion and waste sent to landfills. However, the study also highlights gaps in current recycling practices and emphasizes the need for stronger policies, international collaboration, and innovative technologies to improve recovery rates and support sustainable construction.[8]

III. MATERIALS USED

In this study the following material will be used:

1. Fly Ash
2. GGBS (Ground Granulated Blast Furnace Slag)
3. Plastic waste
4. Demolition Debris (such as Steel bars, aggregates, etc.)

Fly Ash: Fly ash is a by-product of burning pulverized coal in an electrical generating station. Fly ash is a pozzolanic material. It is a finely-divided amorphous alumino-silicate with varying amounts of calcium, which when mixed with Portland cement and water, will react with the calcium hydroxide released by the hydration of Portland cement to produce various calcium-silicate hydrates (C-S-H) and calcium-aluminate hydrates. Some fly ashes with higher amounts of calcium will also display cementitious behavior by reacting with water to produce hydrates in the absence of a source of calcium hydroxide.[9]

For any given situation there will be an optimum amount of fly ash that can be used in a concrete mixture which will maximize the technical, environmental, and economic benefits of fly ash use without significantly impacting the rate of construction or impairing the long-term performance of the finished product. the use of fly ash in concrete across low to very high replacement levels and offers practical guidance for its application without adversely affecting construction practices or the quality of the final product.[10]

For this study, the replacement ranges listed in Table 1 are adopted to define low, moderate, high, and very high fly ash contents. As shown in table given below:

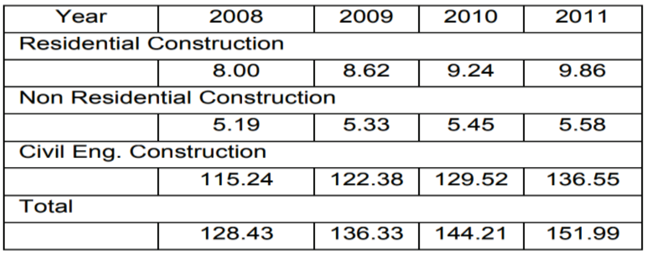
Table 1. Dosage level of Fly Ash

Level of Fly Ash % by mass of total cementitious material	Classification
<15	Low
15-30	Medium
30-50	High
>50	Very High

Ground Granulated Blast Furnace Slag: GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years. At equal cementitious content, concretes with up to 50% GGBS generally achieve 28-day strengths comparable to Portland cement concrete, while higher GGBS levels may require increased binder content. GGBS concrete gains strength more slowly, showing lower early-age strength but higher long-term strength, especially at high replacement levels and low temperatures. In comparison, Portland cement concrete typically reaches about 75% of its 28-day strength at 7 days, with only a small increase thereafter.[11], [12]

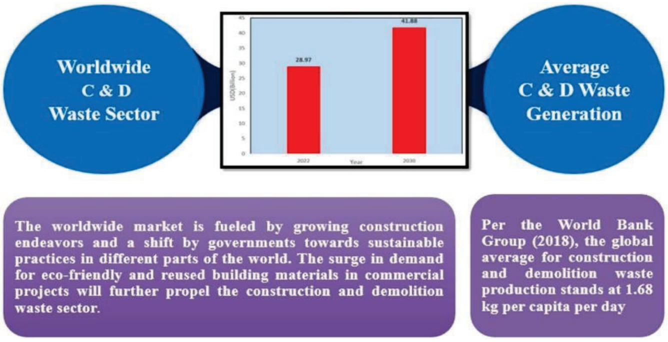
Plastic Waste in Concrete: Using Plastic Waste into concrete affects its performance, showing that adding plastic particles generally reduces key mechanical properties like compressive and tensile strength, with higher plastic content leading to greater strength loss due to increased porosity. However, at low substitution levels, the reduction is moderate. Despite this decrease in strength, plastic-modified concretes offer advantages such as lower density and improved properties (e.g., insulation or ductility in some cases), making them suitable for non-structural or lightweight applications. The study highlights that the size, type, and treatment of plastic waste significantly influence concrete behavior and that optimized mix design is needed to balance sustainability and performance.[13]

Construction & Demolition Waste Reuse: Construction and demolition (C&D) waste as waste materials consist of the debris generated during the construction, renovation, and demolition of buildings, roads, and bridges. C&D materials often contain materials that include: concrete, asphalt, wood, metals, gypsum, plastics and salvaged building components. It is a challenging task to handle C&D waste because it is bulky, heavy and inert and also mixture of various materials of different characteristics. It is also difficult to choose any suitable disposal method, for example, it cannot be incinerated due to its high density and inertness. With the advent of sustainable practices in the construction industry, C&D waste generation and handling issues have been in focus to achieve the sustainable goals for our common future. Reduce, Reuse, recycle (3Rs) philosophy is highly useful in handling of C&D waste.[14],[15]



Year	2008	2009	2010	2011
Residential Construction				
	8.00	8.62	9.24	9.86
Non Residential Construction				
	5.19	5.33	5.45	5.58
Civil Eng. Construction				
	115.24	122.38	129.52	136.55
Total				
	128.43	136.33	144.21	151.99

Fig 1: Estimated investment in Indian Construction Industry, amount



The worldwide market is fueled by growing construction endeavors and a shift by governments towards sustainable practices in different parts of the world. The surge in demand for eco-friendly and reused building materials in commercial projects will further propel the construction and demolition waste sector.

Per the World Bank Group (2018), the global average for construction and demolition waste production stands at 1.68 kg per capita per day

Fig 2: Average C & D waste generation

IV. METHODOLOGY

The study employs an experimental research methodology to evaluate the feasibility of sustainable building structures through the utilization of industrial waste materials and recycled construction resources. It includes the selection and characterization of industrial by-products and recycled materials, their incorporation as partial replacements for conventional construction materials, and the assessment of their effects on the mechanical, durability, and sustainability performance of building components. Standardized procedures were followed for material processing, mix design, specimen preparation, curing, and testing in accordance with relevant codes and guidelines. This systematic approach enables a comprehensive evaluation of recycling and reuse strategies as viable solutions for sustainable construction practices.

Mix Proportions and Sample Casting Procedure:

Materials:

1. Fly Ash
2. Cement
3. Sand
4. Recycled Aggregate

Mix Proportions:

1. M25 Grade

Table 2. Mix Proportion Value of Fly Ash Block

Ingredients	Quantity
Fly Ash	5.35 kg
Water	0.60 kg
Cement	270 ml (or more according to workability)

Table 3. Mix Proportion Value of Flexure Beam Cast

Ingredients	Quantity
Cement	346 kg/m3
Fly Ash	87 kg/m3
Water	195 kg/m3
Fine Aggregate	645 kg/m3
Recycled Coarse Aggregate	546 kg/m3
Natural Coarse Aggregate	546 kg/m3

Replacement Percentage:

Table 4. Replacement Percentage of Fly Ash

Ingredients	Fly Ash %	Cement %
Sample 1	90	10
Sample 2	95	5
Sample 3	-	-

Casting and Curing:

After completion of the mix proportioning process, the prepared mixes were cast into standard molds corresponding to the required test specimens. Proper compaction was ensured using appropriate techniques to eliminate entrapped air and achieve uniform density. Following casting, the specimens were kept undisturbed for 24 hours under controlled laboratory conditions before demolding. Subsequently, the specimens were subjected to curing for the specified duration in accordance with relevant standards to ensure proper hydration and development of desired material properties.

Size of Mould:

1. For Block 150 x 150 x 150 (mm)
2. For Beam 700 x 150 x 150 (mm)

Curing Period:

1. 7 days
2. 14 days
3. 28 days

Testing Procedure:

After the completion of the specified curing period, the cast specimens, including blocks and beam elements, were tested to evaluate their mechanical performance. All tests were conducted under controlled laboratory conditions using calibrated testing equipment in accordance with relevant standard specifications.

The block specimens were subjected to compressive strength testing to determine their load-bearing capacity, while the beam specimens, where applicable, were tested to assess flexural performance. In cases where beam specimens were not considered, the evaluation focused on block testing to analyze strength characteristics and structural suitability. Load application was carried out gradually until failure, and the corresponding load values and failure modes were recorded for analysis.

Design mix made considering Indian Standard Code of Practice IS 456:2000.

V. RESULTS AND DISCUSSIONS

From a theoretical perspective, this study expands the existing body of knowledge on construction waste management strategies and provides a conceptual basis for future research in this area. The findings contribute to the literature by offering insights that can guide researchers interested in advancing effective construction waste management practices. Practically, the outcomes are expected to benefit construction firms, particularly in developing regions where construction waste generation is high and awareness remains limited. The results may also support small and medium-sized construction enterprises by facilitating the adoption of appropriate technologies and promoting efficient training aligned with sustainable development goals. Moreover, this study establishes a foundation for enhancing specifications and evaluation criteria essential for effective waste assessment and reduction. Emphasis is placed on construction waste prevention, highlighting the importance of minimizing design-related errors that contribute to waste generation, which is predominantly identified through conventional construction processes.

I. For Flexure Beam Test

a.) Test Results for Conventional Beam

Table 5. Flexure Test Result of Conventional Beam

Sample no.	Load	Flexure Strength
Sample 1	20.5	3.64
Sample 2	21.0	3.73
Sample 3	20.8	3.69

Hence Average Flexural Strength =3.686 Mpa

b.) Test Results for Sustainable Beam

Table 5. Flexure Test Result of Sustainable Beam

Sample no.	Load	Flexure Strength
Sample 1	17.2	3.06
Sample 2	17.8	3.16
Sample 3	17.5	3.11

Hence Average Flexural Strength =3.11 Mpa

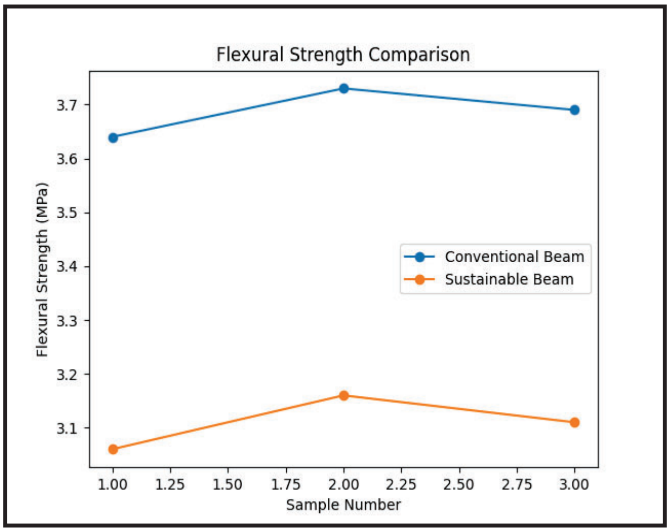


Fig 3. Comparison Graph of Flexural Strength of Conventional Beam with Sustainable Beam

II. For Compressive S ngth Test

a.) Conventional Fly Ash Block

Table 5. Flexure Test Result of Sustainable Beam

Sample no.	Load	Flexure Strength
Sample 1	600	26.67
Sample 2	580	25.78
Sample 3	610	27.11

b.) Sustainable Fly Ash Block

Table 5. Flexure Test Result of Sustainable Beam

Sample no.	Load	Flexure Strength
Sample 1	300	13.51
Sample 2	304	13.33
Sample 3	305	13.56

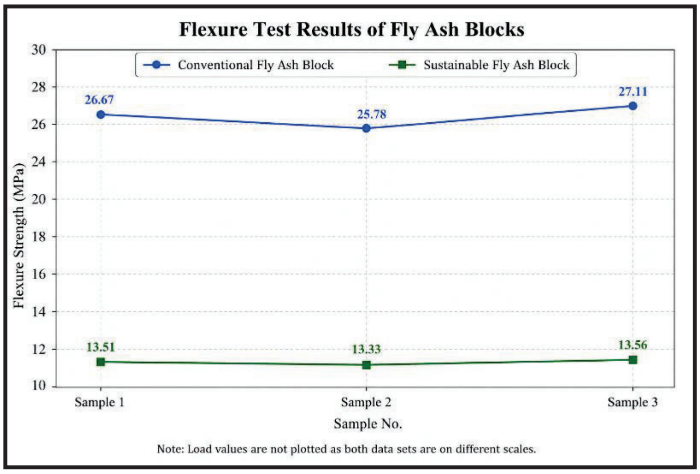


Fig 4. Comparison Graph of Compressive Strength of Conventional Block with Sustainable Bloc

III. Effect of Industrial By-Product in Strength of

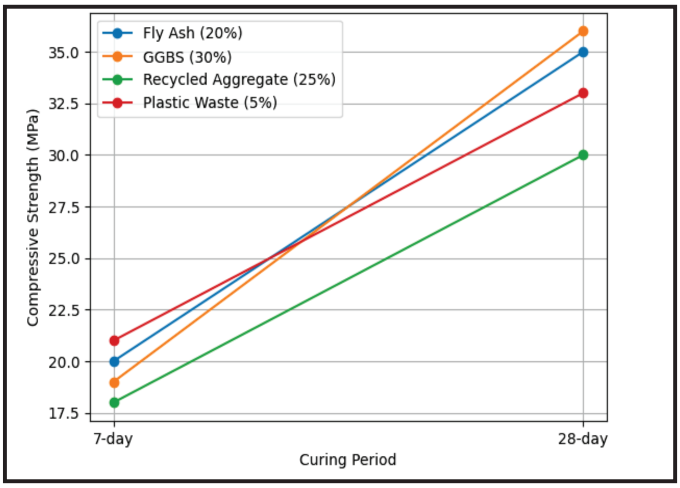


Fig 5. Strength Comparison of Different Industrial By product

VI. RESEARCH GAPS IDENTIFIED

- Limited study on Fly Ash, GGBS and Plastic waste as Cementitious Material.
- Lack of long-term durability studies (for utilization of waste generated by industries)
- Minimum data for curing period under different climatic condition.

VII. CONCLUSION

- The use of industrial waste and recycled construction materials in building structures leads to noticeable strength improvement due to enhanced pozzolanic activity and improved material bonding. When properly proportioned, these materials can achieve strength comparable to conventional construction materials, making them a reliable and sustainable alternative for structural applications.
- The use of industrial by-products and recycled construction materials lowers construction costs by reducing the demand for conventional materials and decreasing expenses related to waste management. Achieving similar structural performance, these materials offer an economically sustainable construction solution.[8]
- The use of industrial waste and recycled construction materials significantly enhances sustainability by conserving natural resources, reducing landfill disposal, and lowering carbon emissions associated with conventional construction materials. This approach supports environmentally responsible and sustainable building practices.
- An optimum level of industrial waste and recycled material replacement enhances structural performance without compromising strength or workability. Beyond this level, performance may decline, highlighting the importance of identifying optimal replacement ratios for sustainable and efficient construction.

VIII. FUTURE SCOPE

- Further studies can be carried out to optimize the mix proportions of industrial waste materials such as fly ash, slag, and recycled aggregates to achieve higher strength and durability.
- Long-term performance analysis of structures built with recycled and waste-based materials should be conducted to evaluate durability, creep, shrinkage, and resistance to environmental conditions.
- Research can be extended to investigate the use of other industrial by-products and construction demolition (C&D) waste in different types of structural elements like columns, slabs, and pavements.
- Advanced technologies and methods, such as nano-materials and chemical admixtures, can be explored to enhance the properties of sustainable construction materials.
- Economic analysis and life-cycle cost assessment should be performed to compare sustainable construction methods with conventional practices.
- Field implementation and real-time case studies can be undertaken to assess the practical feasibility and performance of such materials in large-scale construction projects.
- Environmental impact assessments, including carbon footprint and energy consumption, can be further studied to quantify sustainability benefits.

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