

Innovative Brick Manufacturing Using Tungabhadra Dam Sediment Deposits with Partial Addition of GGBS and Recycled PET Plastic Strips

Akshata P^{1*}, Vasanth K. M.¹, Vinod Kumar K. S.¹, Vishwa Charan M.¹

¹Department of Civil Engineering, Ballari Institute of Technology & Management, Ballari – 583101, Karnataka, India

*Corresponding Author: ravibitm9@gmail.com

Abstract - Sediment accumulation in reservoirs reduces storage capacity and creates a persistent disposal problem, while plastic waste and cement production both carry significant environmental costs. This study investigates the feasibility of manufacturing bricks from sediment deposited at the Tungabhadra Dam (Munirabad backwater catchment, Hospet), with partial addition of ground granulated blast furnace slag (GGBS) and recycled polyethylene terephthalate (PET) plastic strips. The geotechnical properties of the sediment were characterised, and bricks were prepared with GGBS content varied from 5% to 25% and PET plastic strip content varied from 0.5% to 2.5% by dry weight. Compressive strength was evaluated for each combination. The results indicate an optimum GGBS content of 15% and an optimum plastic strip content of 2%, at which the bricks achieved their highest compressive strengths. The findings demonstrate that dam sediment, industrial by-products and recycled plastic waste can be combined to produce a viable, more sustainable alternative to conventional clay bricks.

Key Words: Dam sediment, GGBS, recycled PET plastic, brick manufacturing, compressive strength, sustainable construction.

1. INTRODUCTION

Siltation progressively reduces the water-storage capacity of reservoirs, making the beneficial use of dam sediment an increasingly important consideration for reservoir management. At the same time, the construction industry continues to face resource depletion, environmental degradation and the accumulation of industrial and municipal waste. This study examines sediment deposited at the Tungabhadra Dam, near Hospet, Karnataka, as a potential raw material for brick manufacturing, combined with ground granulated blast furnace slag (GGBS), an industrial by-product of steel manufacturing, and recycled PET plastic strips derived from post-consumer water bottles.

Combining sediment, GGBS and plastic strips offers a triple environmental benefit: it provides a productive use for dam sediment that would otherwise require disposal, recycles an industrial by-product, and diverts plastic waste from landfill. GGBS contributes pozzolanic reactivity that can improve the compressive strength and durability of the bricks while reducing reliance on cement, and PET plastic strips can improve toughness and reduce brick weight. This study characterises the sediment and constituent materials and evaluates the compressive strength of bricks produced across

a range of GGBS and plastic strip contents, with the aim of identifying proportions that offer the best mechanical performance.

1.1 Objectives

- To characterise the physical and geotechnical properties of sediment deposited at the Tungabhadra Dam.
- To identify the optimum proportions of GGBS and recycled PET plastic strips for brick manufacture.
- To evaluate the compressive strength of bricks produced with varying GGBS and plastic strip content.
- To assess the feasibility of using dam sediment, GGBS and plastic waste as a sustainable alternative to conventional clay bricks.

2. LITERATURE REVIEW

Several studies have examined the use of GGBS as a partial replacement for clay or cement in brick and soil-stabilisation applications. Xavier investigated bricks with clay partially replaced by GGBS (0-30%) with a constant 5% lime addition, reporting improved stability with increasing GGBS content. Oti studied unfired clay building materials stabilised with GGBS and found that strength increased with GGBS content up to 20% for 7- and 14-day curing, and up to 40% for 28-day curing, beyond which strength declined. Dave examined industrial by-product utilisation more broadly and concluded that recycling such wastes supports more efficient use of resources, while Kinuthia reported that GGBS-based stabilisation is an effective energy-saving technique that reduces CO₂ emissions.¹

Studies on concrete and mortar incorporating GGBS have similarly reported favourable results: Awasare found improved tensile strength at 20-40% GGBS replacement relative to plain concrete, Gadpalliwar reported maximum strength when natural sand was partially replaced with 60% quarry sand alongside GGBS and rice husk ash, and Mozaffari examined the hydration kinetics of GGBS blended with wastepaper sludge ash.¹ Ravikumar tested mortar specimens containing pozzolanic materials, including GGBS-clay brick combinations at 0-25% replacement, for compressive and flexural strength.¹

On the geotechnical side, Atkinson set out a systematic framework for soil description and classification [1], which underpins the index-property characterisation adopted in this study. Gougazeh and Al-Shabatat characterised the geological and geotechnical properties of soil materials at the Tannur Dam, Jordan [2], and Turgut et al. reported the physical and chemical properties of recently deposited sediment in the Borcka Dam reservoir, Turkey [3], both providing

comparative reference points for the classification of dam-related sediment. Akbarzadeh Kasani and Eslami reported the geotechnical properties of clay and silt deposits in northern Iran [4], and Tommasi et al. characterised the geotechnical properties of soft clayey sediment from the submerged Tiber River delta [5], both illustrating the range of index and strength properties reported for fine-grained fluvial and reservoir sediments internationally. Cui et al. examined the release and downstream transport of fine sediment following dam removal, providing a basis for evaluating the environmental impact of reservoir sediment management [6]. Bayewu et al. carried out geophysical and geotechnical investigation of a proposed dam site, characterising subsurface layers and soil engineering properties relevant to dam foundation design [7]. Jamshidi Chenari et al. investigated the dependency of geotechnical properties such as compaction characteristics, hydraulic conductivity and shear strength on index properties, developing prediction models validated against a database of laboratory results [8]. Naeini and Moayed examined the effect of plasticity index and geogrid reinforcement on the California Bearing Ratio of soft clay, finding that CBR could be considerably improved through multi-layer geogrid reinforcement, though less than with single-layer reinforcement in some configurations [9].

Taken together, the literature supports both the technical feasibility of GGBS as a clay or cement replacement in brick manufacture and the value of systematic geotechnical characterisation of reservoir sediment prior to its reuse. However, few studies have examined the combined use of dam sediment, GGBS and recycled plastic waste in a single brick-manufacturing process, which is the specific gap this study addresses.

¹ Full bibliographic details for these studies (Xavier; Oti; Dave; Kinuthia; Awasare; Gadpalliwar; Mozaffari; Ravikumar) were not available in the source document and could not be verified against the numbered reference list. Please supply complete citations before submission.

Editorial note: references [1]-[5] were listed in the source document's reference list but were not cited anywhere in the body text as written. Given that their subject matter (soil classification framework; dam-site and reservoir-sediment geotechnical characterisation) matches this paragraph closely, the citation markers [1]-[5] have been restored into the corresponding sentences here. Please verify this placement is correct against the original manuscript.

3. MATERIALS AND METHODOLOGY

3.1 Sediment

Sediment for this study was collected from the backwater catchment area along Kaasanakande Road at the Tungabhadra Dam site near Hospet, Ballari district, Karnataka, at a depth of 1 m below ground level, with care taken to exclude roots, waste and other extraneous material (Fig. 1). The sample was air-dried and tested in accordance with relevant IS codes. Index and engineering properties are summarised in Table 1; based on these properties the sediment is classified as silty clay of medium plasticity (CI).



Fig -1: Sediment collection at the backwater catchment area, Tungabhadra Dam site

Table -1: Index properties of the Tungabhadra Dam sediment

Property	Value	Test standard
Specific gravity, G	2.56	IS 2720 (Pt.III/Sec-1):1980
Liquid limit, wL (%)	38.0	IS 9256:1979
Plastic limit, wP (%)	9.38	IS 2720 (Pt.V):1985
Plasticity index, IP (%)	38.62	IS 2720 (Pt.V):1985
Max. dry density (g/cm ³)	2.00	IS 2720 (Pt.VII):1983
Optimum moisture content (%)	10.0	IS 2720 (Pt.VII):1983
Silt and clay content (%)	1.372	IS 2720 (Pt.IV):1985
Unconfined compressive strength (kg/cm ²)	1.20	IS 2720 (Pt.X):1991
Soil classification	CI (silty clay, medium plasticity)	IS soil classification

3.2 GGBS

GGBS, a by-product of the iron and steel industry produced by rapidly cooling molten blast-furnace slag, was used as a supplementary cementitious material (Fig. 2). It is composed primarily of calcium oxide, silica, alumina and magnesium oxide, giving it latent hydraulic reactivity, and its use in construction is regulated by standards such as ASTM C989 and EN 15167. Measured properties are given in Table 2.

Table -2: Properties of GGBS

Property	Value	Test standard
Specific gravity, G	2.80	IS 2720 (Pt.III/Sec-1):1980
Max. dry density (kN/m ³)	20.5	IS 2720 (Pt.VIII):1983
Optimum moisture content (%)	11.8	IS 2720 (Pt.VIII):1983



Fig -2: (a) Sediment sample and (b) GGBS used in the study

3.3 Recycled PET Plastic Strips

Plastic strips were obtained from post-consumer PET mineral-water bottles, processed through a plastic granulator after removal of the neck and base (Fig. 3). PET has a molecular formula of $(C_{10}H_8O_4)_n$, negligible water solubility (below 0.4%), and a melting point of 245–260°C. Strips were sieved into three size fractions: Type I (retained between 20 mm and 10 mm), Type II (retained between 10 mm and 4.75 mm), and Type III (retained between 4.75 mm and 1 mm). Measured properties are given in Table 3.

Table -3: Properties of the recycled PET plastic strips

Property	Value
Thickness (mm)	0.05
Specific gravity	1.33
Density at 20°C (g/cm ³)	1.38



Fig -3: Recycled PET plastic strips used in the study

3.4 Specimen Preparation

GGBS was added to the sediment in increments of 5%, up to a maximum of 25% by replacement, and mixed uniformly prior to compaction and unconfined compressive strength (UCS) testing. In a separate series, PET plastic strips were hand-mixed into sediment at 15% GGBS content, in strip contents of 0.5%, 1%, 1.5%, 2% and 2.5% by dry weight; oven-dried sediment passing a 4.75 mm sieve was used, with plastic strips distributed in three equal stages to ensure uniform mixing with the wetted sediment. Standard Proctor compaction was carried out in accordance with IS 2720 (Part VII), using a 2.6 kg rammer with a 310 mm free fall, applied in three equal layers of 25 blows each in a 100 mm diameter mould. Bricks were moulded, cured and tested for compressive strength in accordance with the relevant IS standards.

4. RESULTS AND DISCUSSION

4.1 Effect of GGBS Content on Compressive Strength

The compressive strength of bricks incorporating GGBS as a partial replacement of sediment, evaluated across 5–25% GGBS content, is summarised in Table 4 and Fig. 4. Strength increased from 3.60 N/mm² at 5% GGBS to a peak of 6.04 N/mm² at 15% GGBS, before declining at higher replacement levels (5.42 N/mm² at 20% and 4.85 N/mm² at 25%). The optimum GGBS content identified from this series is 15%, corresponding to a second-class brick classification.

Table -4: Compressive strength of bricks with varying GGBS content

Sediment (%)	GGBS (%)	Compressive strength (N/mm ²)
95	5	3.60
90	10	3.97
85	15	6.04
80	20	5.42
75	25	4.85

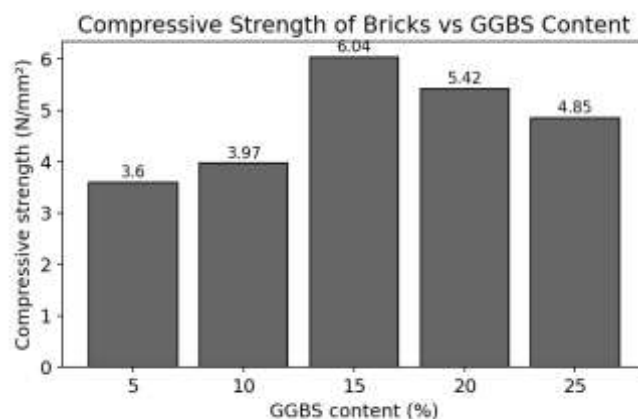


Fig -4: Compressive strength of bricks as a function of GGBS content

4.2 Effect of PET Plastic Strip Content on Compressive Strength

With GGBS held constant at the optimum 15%, PET plastic strip content was varied from 0.5% to 2.5% by dry weight (Table 5, Fig. 5). Compressive strength increased from 5.75 N/mm² at 0.5% plastic to a peak of 9.01 N/mm² at 2% plastic, before declining to 8.15 N/mm² at 2.5%. The optimum plastic strip content identified from this series is 2%, at which the brick meets first-class brick classification.

Table -5: Compressive strength of bricks with varying PET plastic strip content (15% GGBS)

Sediment (%)	GGBS (%)	Plastic (%)	Compressive strength (N/mm ²)
84.5	15	0.5	5.75
84.0	15	1.0	6.43
83.5	15	1.5	7.29
83.0	15	2.0	9.01
82.5	15	2.5	8.15

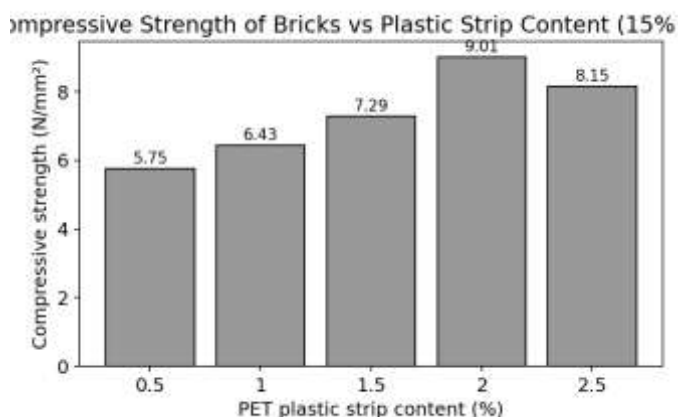


Fig -5: Compressive strength of bricks as a function of PET plastic strip content

4.3 Compressive Strength of Sediment-Only Brick

A control brick prepared using sediment alone (100%, without GGBS or plastic addition) achieved a compressive strength of 4.04 N/mm², corresponding to a third-class brick classification, confirming that both GGBS and PET plastic strip addition improve brick performance relative to the unmodified sediment.

5. CONCLUSIONS

- The Tungabhadra Dam sediment is classified as silty clay of medium plasticity (CI), with specific gravity 2.56, liquid limit 38%, plastic limit 9.38%, maximum dry density 2.00 g/cm³, optimum moisture content 10%, and silt and clay content 1.372%.
- Partial replacement of sediment with GGBS improves brick compressive strength up to an optimum of 15% GGBS, achieving 6.04 N/mm² (second-class brick); further addition reduces strength.
- Adding recycled PET plastic strips at 15% GGBS further improves compressive strength up to an optimum of 2% plastic content, achieving 9.01 N/mm² (first-class brick).
- Bricks manufactured from sediment alone achieve 4.04 N/mm² (third-class brick), confirming that GGBS and PET plastic strip addition each contribute measurable strength improvement.
- Combining dam sediment, GGBS and recycled PET plastic strips offers a technically viable and more sustainable alternative to conventional clay bricks, simultaneously addressing reservoir sediment disposal, industrial by-product recycling and plastic waste reduction.

REFERENCES

- [1] J. Atkinson, *Soil Description and Classification Based on Part of the Geotechnical Reference Package*. London, UK: University of the West of England, 2000.
- [2] M. Gougazeh and A. Al-Shabatat, "Geological and geotechnical properties of soil materials at Tannur Dam, Wadi Al Hasa, South Jordan," *J. Taibah Univ. Sci.*, vol. 7, pp. 216–224, 2013.
- [3] B. Turgut, M. Ozlap, and B. Kose, "Physical and chemical properties of recently deposited sediments in the reservoir of the Borcka Dam in Artvin, Turkey," *Turk. J. Agric. For.*, 2014, doi: 10.3906/tar-1404-60.
- [4] H. Akbarzadeh Kasani and A. Eslami, "Geotechnical properties of Rasht clay and silt in northern Iran," *Int. J. Geotech. Eng.*, 2017, doi: 10.1080/19386362.2017.1374496.
- [5] P. Tommasi, F. L. Chiocci, and F. Esu, "Geotechnical properties of soft clayey sediments from the submerged Tiber River delta, Italy," *Mar. Georesour. Geotechnol.*, vol. 16, no. 3, pp. 221–242, 1998.
- [6] Y. Cui, D. B. Booth, J. Monschke, S. Gentzler, J. Roadifer, B. Greimann, and B. Cluer, "Analyses of the erosion of fine sediment deposit for a large dam-removal project: an empirical approach," *Int. J. River Basin Manage.*, vol. 15, no. 1, pp. 103–114, 2017.
- [7] O. O. Bayewu, M. O. Oloruntola, G. O. Mosuro, and O. K. Abass, "Preliminary investigation of a proposed dam site along River Ome, Ago Iwoye, southwestern Nigeria," *J. Sci. Technol.*, vol. 1, no. 6, 2012.
- [8] R. Jamshidi Chenari, P. Tizpa, M. R. Ghorbani Rad, S. Machado, and M. Karampour Fard, "The use of index parameters to predict soil geotechnical properties," *Arab. J. Geosci.*, 2014, doi: 10.1007/s12517-014-1538-0.

- [9] S. A. Naeini and R. Ziaie Moayed, "Effect of plasticity index and reinforcement on the CBR value of soft clay," *Int. J. Civ. Eng.*, vol. 7, no. 2, 2009.