International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com

Peer Reviewed, Referred & Indexed Journal

Research Paper

Use of Waste Glass Powder as Pozzolana in Concrete: An Experimental Investigation on Workability and Strength Characteristics

MA Liyakhat[1], M. Uday Bhaskar[2]

[a)] *M.Tech Student, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India.*

[b)] *Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India.*

Abstract

This paper offerings an investigational research on the effects of replacing cement with waste glass powder as a pozzolanic material in concrete. The study examines workability characteristics (slump, compaction factor, and Vee-bee degree) and power assets (compressive, tensile, flexural, and impact power) of material with varying percentages of glass powder replacement (0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40%). The waste glass was obtained from local sources, crushed in a cone crusher mill, and sieved through 600-micron sieve. M20 grade concrete with mix proportion 1:1.34:3.2 and water-cement ratio of 0.45 was used. Results indicate that replacing 20% of cement with waste glass powder yields optimal performance, showing approximately 24% rise in compressive power, 30% rise in tensile power, 25% rise in flexural power, and 100% rise in impact power equated to reference material. The study also reveals that workability improves up to 20% replacement before declining. Initial and final setting times increase with higher glass powder content. The findings demonstrate that waste glass powder can effectively serve as a sustainable pozzolanic material in concrete construction, offering both environmental and economic benefits.

Keywords: Waste glass powder, pozzolana, concrete, workability, compressive strength, sustainable construction, cement replacement

1. INTRODUCTION

1.1 Background

The building business faces dual challenges of environmental sustainability and resource conservation. Cement production contributes significantly to global CO_2 emissions, accounting for approximately 5-7% of total anthropogenic carbon dioxide releases. Simultaneously, waste management has emerged as a critical environmental concern, with millions of tonnes of waste glass generated annually worldwide. In the UK alone, approximately 3.6 million tonnes of glass are used yearly, with over 2.5 million tonnes disposed in landfills, constituting about 7% of average household waste.

Pozzolanic materials have been used in construction since ancient times. Romans utilized volcanic soils mixed with lime to produce hydraulic mortars, demonstrating remarkable durability that remains evident today. Modern pozzolanas include both natural materials (clay, shale, volcanic tuffs) and artificial materials (fly ash, blast furnace slag, silica fume, metakaolin, and rice husk ash). These materials, when finely divided, chemically respond with calcium hydroxide liberated during cement hydration to form compounds with cementitious assets.

1.3 Research Significance

The usage of waste glass as pozzolana addresses multiple sustainability objectives:

1. **Environmental benefits:** Reduces landfill burden, decreases cement consumption, drops greenhouse gas emissions, and conserves natural resources

2. **Economic benefits:** Utilizes waste material, potentially reduces concrete production costs, and adds value to waste streams

3. **Technical benefits:** Improves workability, enhances strength development, increases durability, and reduces heat of hydration

1.4 Research Objectives

The main objective of this investigation is to determine the optimal percentage of cement replacement with waste glass powder that yields superior workability and strength characteristics. Specific objectives include:

1. Evaluating the effect of varying percentages of glass powder replacement (0-40%) on workability parameters

2. Determining compressive, tensile, flexural, and impact strengths at different replacement levels

3. Assessing setting time characteristics with glass powder incorporation

4. Establishing optimal cement replacement percentage for enhanced concrete performance

2. REVIEW OF LITERATURE

2.1 Historical Context and Development

The use of pozzolanas in construction dates to ancient civilizations. Greeks (pre-400 B.C.) and Romans pioneered the use of pozzolanic materials in lime mortars. Romans discovered that volcanic soils near Pozzuoli produced excellent hydraulic mortars when mixed with lime. This led to revolutionary changes in Roman construction, enabling arches, vaults, and marine structures that demonstrated exceptional durability.

Modern applications have expanded significantly. Over 100,000 tonnes of pozzolana were used in the Los Angeles aqueduct construction (1910-1912). Subsequently, pozzolanas have been extensively employed in mass concrete structures, dams, and marine construction, particularly in Europe, North America, and Japan.

2.2 Glass Waste Generation and Characteristics

Suryawanshi C.S. (1999) highlighted that glass waste proportion in domestic refuse ranges from 3-4% in India, 6-8% in the US, and about 7% in the UK. Post-consumer glass containers have traditionally been disposed through domestic refuse ending in landfills, collected at designated spots for recycling, or through kerbside collection. The efficiency of glass recycling depends on color separation methods, as mixed-color glass becomes unsuitable for container manufacturing.

Weihua Jin et al. (2000) studied "Glascrete" and demonstrated that waste glass ground to U.S. standard sieve size No. 50 or lesser causes mortar bar developments less than 0.1% in ASTM C 1260 tests, which is fewer than reference bars without glass. Their research identified a pronounced particle size effect, with pessimum size being a function of glass type and color. Clear soda-lime glass showed peak reactivity, followed by amber glass, while green glass caused negligible expansion.

2.3 Alkali-Silica Reaction (ASR)

A significant concern with glass aggregate in concrete is the potential for alkali-silica reaction (ASR). Meyer C, Egosi N., and Andela C. (2001) extensively studied ASR in glass concrete, concluding that several mitigation strategies exist:

1. Grinding glass to pass mesh size #50 or finer

2. Using pozzolanic mineral admixtures (metakaolin, fly ash)

3. Employing low-alkali cements

4. Maintaining dry environments

5. Applying specialized ASR-resistant cements

The research demonstrated that controlling responsive silica, cement alkali level, and moisture can effectively reduce or eliminate ASR reactions.

3. MATERIALS AND METHODOLOGY

3.1 Materials

3.1.1 Cement

43-grade Ordinary Portland Cement (OPC) conforming to IS:8112-1989 was used. Physical properties: specific gravity 3.15, fineness 281 m²/kg, normal consistency 29.7%, initial setting time 100 minutes, final setting time 300 minutes. Compressive strength: 24.50 MPa (3 days), 35.00 MPa (7 days), and 48.00 MPa (28 days).

3.1.2 Fine Aggregate

Locally available sand from Belgaum with fineness modulus 2.54, conforming to grading zone-II as per IS:383-1970. Specific gravity: 2.62, silt content: 1.85%, bulking: 7.52%, free moisture content: 2.0%.

3.1.3 Coarse Aggregate

Crushed stone aggregate (12mm and down size) conforming to IS:383-1970. Specific gravity: 2.93, impact value: 15.50%, crushing value: 14.98%, water absorption: 0.5%.

3.1.4 Water

Ordinary potable water free from organic content, turbidity, and salts.

3.1.5 Waste Glass Powder

Waste glass collected locally was crushed in a cone crusher mill and sieved through 600-micron sieve. Chemical composition (Table 1):

TABLE 1: Oxide Content of Waste Glass Powder

Oxide	Content (%)
SiO_2	72
Na_2O	14
CaO	9
Al_2O_3	2
MgO	2.2
K_2O	0.5
Fe_2O_3	0.2
Others (Cr, S, Co)	0.1

3.1.6 Superplasticizer

Conplast SP 430 (sulphonated naphthalene polymer-based) complying with IS:9103-1979 and IS:2645-1975, used at 1% by weight of cement. Specific gravity: 1.220-1.225 at 30°C, chloride content: nil, brown liquid.

3.2 Mix Design

Concrete mix proportion 1:1.34:3.2 (M20 grade) with water-cement ratio 0.45 was designed as per IS:10262-1982. Target mean strength: 26.6 MPa. Quantities per bag of cement (50 kg):

- Sand: 68.34 kg (adjusted for moisture)
- Coarse aggregate: 159.20 kg (adjusted for absorption)
- Water: 21.96 liters (adjusted)

4. RESULTS AND DISCUSSION

4.1 Workability Characteristics

Table 2 present workability test results for varying glass powder replacement levels.

TABLE 2: Workability Test Results

Replacement %	Slump (mm)	Compaction Factor	Vee-bee Degree (sec)
0 (Reference)	90	0.81	150
5	100	0.84	50
10	115	0.85	50
15	130	0.87	52
20	140	0.89	48
25	110	0.86	58
30	95	0.83	65
35	90	0.82	75
40	90	0.80	83

Workability improved progressively up to 20% cement replacement, evidenced by increased slump (from 90mm to 140mm), higher compaction factor (from 0.81 to 0.89), and reduced Vee-bee time (from 150s to 48s). Beyond 20% replacement, workability declined, attributed to increased friction from excessive glass powder content. The zero water absorption property of glass particles combined with superplasticizer enhanced particle dispersion and mobility up to optimal levels.

4.2 Setting Time

Initial setting time increased from 40 minutes (reference) to 60 minutes (40% replacement), while final setting time increased from 420 minutes to 470 minutes. This gradual increase reflects the pozzolanic reaction characteristics, where glass powder reacts slower than Portland cement initially but contributes to long-term strength development.

4.3 Compressive Power

Table 3 present compressive power outcomes.

TABLE 3: Compressive Power Outcomes (60-day curing)

Replacement %	Compressive Strength (MPa)	% Change vs Reference	Density (kN/m³)
0 (Reference)	26.81	-	27.42
5	28.29	+6	27.00
10	29.48	+10	27.17
15	31.25	+17	27.20
20	33.18	+24	26.92
25	30.22	+13	27.08
30	23.99	-11	25.96
35	22.22	-17	26.40
40	18.81	-30	25.81

Compressive strength increased progressively to a maximum at 20% replacement (33.18 MPa, 24% increase over reference), then declined significantly beyond this level. The optimal performance at 20% replacement is attributed to:

1. **Maximum pozzolanic reaction:** Sufficient glass powder to respond with liberated calcium hydroxide without excessive dilution of adhesive content

2. **Optimal packing density:** Glass powder particles fill voids between cement grains, creating denser microstructure
3. **Enhanced C-S-H formation:** Pozzolanic reaction produces additional calcium silicate hydrates with lower Ca/Si ratio, improving long-term strength

The strength reduction beyond 20% replacement results from:

- Insufficient cement to provide adequate calcium hydroxide for pozzolanic reactions
- Dilution effect exceeding pozzolanic contribution
- Reduced early-age strength development affecting overall performance

4.4 Splitting Stretchable Power

Tensile strength followed similar trends to compressive strength, achieving maximum at 20% replacement (5.09 MPa, 30% increase). The enhanced tensile performance is attributed to:

1. Improved interfacial transition zone (ITZ) among aggregate and paste
2. Refined pore structure from pozzolanic reactions and reduced microcracking
3. Better distribution of C-S-H gel throughout matrix

5. CONCLUSIONS

Based on a comprehensive experimental investigation on concrete incorporating waste glass powder as a fractional auxiliary for adhesive, it can be concluded that a 20% replacement level provides the most effective performance across all measured parameters. At this optimal level, the glass powder contributes significantly to pozzolanic activity while maintaining a proper balance with cement hydration. The results indicate notable strength enhancements, with compressive power increasing by 24% (from 26.81 MPa to 33.18 MPa), tensile power by 30% (from 3.91 MPa to 5.09 MPa), flexural power by 25% (from 4.78 MPa to 5.92 MPa), and impact power doubling by 100% (from 248.97 N-m to 497.95 N-m).

REFERENCES

1. Ahmad Shayan and Aimin Xu, "Value-added utilization of waste glass in concrete", Cement and Concrete Research, 34(2004), pp 81-89.
2. Bin Mu and Christian Meyer, "Flexural behavior of fibre mesh-reinforced glass aggregate concrete", ACI Material Journal, September-October 2002, pp 425-433.
3. Byars E.A., Zhu H.Y. and Morales B., "Conglasscrete-I", The Waste & Resources Action Programme, March 2004, www.wrap.org.uk.
4. Byars E.A., Morales B. and Zhu H.Y., "Conglasscrete-II", The Waste & Resources Action Programme, March 2004, www.wrap.org.uk.
5. Caijun Shi and Yanzhong Wu, "Mixture proportioning and properties of self-consolidating lightweight concrete containing glass powder", ACI Material Journal, September-October 2002, pp 355-363.
6. Chi Sing Lam, Chi Sun Poon and Dixon Chan, "Enhancing the performance of pre-cast concrete blocks by incorporating waste glass - ASR consideration", Cement and Concrete Composites, 29(2007), pp 616-625.
7. Christian Meyer, "Glass concrete", Concrete International, June 2003, pp 55-58.
8. ConGlassCrete website www.wrap.org.uk/conglascrete, September 2003.
9. Ducman V., Mladenovic A. and Suput J.S., "Lightweight aggregate based on waste glass and its alkali-silica reactivity", Cement and Concrete Research, 32(2002), pp 223-226.
10. Huiying Zhu and Ewan Byars, "Potential for use of waste glass in concrete", Concrete, February 2005, pp 41-45.

11. IS 516-1959, "Methods of tests for strength of concrete", Bureau of Indian Standards, New Delhi.
12. IS 5816-1999, "Splitting tensile strength of concrete method of test", Bureau of Indian Standards, New Delhi.
13. IS 10262-1982, "Recommended guide line for concrete mix design", Bureau of Indian Standards, New Delhi.
14. IS 8112:1989, "Specification for 43 grade OPC", Bureau of Indian Standards, New Delhi.
15. Meyer C, Egosi N. and Andela C., "Concrete with waste glass as aggregate", Proceedings of ICFRC International Symposium, March 2001.
16. Nathan Schwarz, Matthew DuBois and Narayanan Neithalath, "Electrical conductivity based characterization of plain and coarse glass powder modified cement pastes", Cement and Concrete Composites, 29(2007), pp 656-666.
17. Neville A.M., "Properties of concrete", Oxford Publication, January 2004.
18. Ravindra Dhir, Tomdyer, Albert tang and Yongjun cui, "Towards maximizing the value and sustainable use of glass", The Waste & Resources Action Programme, January 2004, www.wrap.org.uk.
19. Research Information Digest-2, "Recycled glass", Concrete, June 2005, pp 44-46.
20. Suryawanshi C.S., "Use of industrial and domestic waste in concrete", Civil Engineering and Construction Review, February 1999, pp 38-41.
21. Weihua Jin, Christian Meyer and Stephen Baxter, "Glascrete - Concrete with glass aggregate", ACI Material Journal, March-April 2000, pp 208-213.