iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** I **Month of publication:** January 2026

DOI: https://doi.org/10.22214/ijraset.2026.77049

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue I Jan 2026- Available at www.ijraset.com

Influence of Waste Glass Powder in Cement Mortar as Partial Replacement of Cement

Gamar Singh Dawar[1], Somaya Gangotiya[2], Kishor Patil[3]
[1]*M.Tech Scholar, Civil Engineering Department, Sushila Devi Bansal College of Engineering, Indore*
[2]*Assistant Professor, Civil Engineering Department, Sushila Devi Bansal College of Engineering, Indore*
[3]*Associate Professor, Civil Engineering Department, Sushila Devi Bansal College of Technology, Indore*

***Abstract**: The rapid increase in glass consumption in construction, packaging, and household applications has resulted in a significant rise in waste glass generation. Since waste glass is non-biodegradable, its disposal in landfills poses serious environmental and sustainability challenges. The effective utilization of waste glass in construction materials has therefore gained increasing attention as an eco-friendly alternative. This study investigates the feasibility of using waste glass powder (WGP) as a partial replacement of ordinary Portland cement (OPC) in cement mortar. Waste glass was collected, cleaned, crushed, and ground to obtain fine powder passing through a 75 µm sieve. Cement was replaced with WGP at proportions of 0%, 5%, 10%, 15%, and 20% by weight. Standard mortar specimens were cast and tested for compressive strength at 7 and 28 days. The results indicate that replacement levels up to 10–15% WGP show comparable or improved strength performance compared to conventional mortar, while higher replacement levels result in strength reduction. The study concludes that WGP can be effectively used as a sustainable supplementary cementitious material, contributing to waste reduction, conservation of natural resources, and reduction in carbon emissions.*

Keywords: Waste glass powder, cement replacement, mortar, compressive strength, sustainable construction.

I. INTRODUCTION

The construction industry is one of the largest consumers of natural resources and a major contributor to environmental pollution. Cement production alone is responsible for approximately 7–8% of global carbon dioxide emissions. At the same time, the disposal of industrial and municipal solid waste has become a major environmental concern worldwide. Among various types of waste, glass waste is particularly problematic due to its non-biodegradable nature and increasing generation rate.

Waste glass is produced from sources such as discarded bottles, windows, containers, and other glass products. Although a portion of this waste is recycled, a significant amount still ends up in landfills due to contamination, color-mixing issues, and high recycling costs. Finely ground waste glass exhibits pozzolanic properties due to its high silica content, making it a potential supplementary cementitious material.

The utilization of waste glass powder (WGP) as a partial replacement for cement can reduce landfill waste, lower cement consumption, and improve the sustainability of construction materials. This research focuses on evaluating the mechanical performance of cement mortar incorporating WGP as a partial replacement of OPC.

II. LITERATURE REVIEW

Extensive research has been carried out on the utilization of waste glass powder (WGP) in cementitious materials as a sustainable alternative to conventional construction practices. Previous studies indicate that finely ground waste glass exhibits pozzolanic behavior due to its high silica content and contributes to strength enhancement when used at optimum replacement levels.

Raghavendra K. and Virendra Kumara K. N. (2015) investigated the combined use of waste glass powder and foundry sand in concrete and observed that although early-age strength was relatively low, significant improvement was achieved at 28 days, with higher replacement levels yielding improved strength performance. Jitendra B. Jangid and A. C. Saoji (2015) studied waste glass powder as a partial replacement of cement and reported that a replacement level of about 20% resulted in higher compressive and tensile strength along with acceptable durability characteristics.

Sachin V. Bhosale and Shrivallabh S. Chavan (2014) highlighted that glass powder ground to particle sizes below 13 µm exhibits strong pozzolanic activity and acts as a micro-filler, enhancing density and long-term strength development. Priscilla M. and Pushparaj A. Naik (2014) demonstrated that waste glass powder can be effectively used as a supplementary cementitious material in recycled aggregate concrete, improving both strength and durability under sulphate exposure.

Edson Jansen Pedrosa de Miranda Junior (2014) reported that concrete containing up to 20% flat glass powder achieved compressive strength suitable for structural applications when an appropriate water–cement ratio was maintained. Studies by T. Phani Madhavi et al. (2013) revealed that a combination of fly ash and glass aggregate resulted in improved compressive strength, with optimum performance observed at moderate replacement levels.

M. Iqbal Malik et al. (2013) concluded that waste glass can be used as a partial replacement of fine aggregate up to 30% without compromising strength and durability. Williams Kupolati et al. (2013) emphasized the environmental benefits of incorporating waste glass in concrete and identified that partial replacement of both cement and sand enhances strength and workability. Dhanaraj Mohan Patil and Keshav K. Sangle (2013) highlighted the importance of particle size and concluded that glass powder finer than 90 µm at 20% replacement yields higher compressive strength.

R. Vandhiyan et al. (2013) reported that the inclusion of glass powder reduces alkali–silica reaction and improves mechanical properties, while Sunny O. Nwaubani and Konstantinos I. Poutos (2013) confirmed that waste glass powder enhances compressive strength when used at appropriate replacement levels. Dr. G. Vijayakumar et al. (2013) demonstrated that glass powder finer than 90 µm can safely replace cement without adverse effects on strength.

Further studies by J. S. Dali and S. N. Tande (2012), Patel Dhirendra et al. (2012), and Mayur B. Vanjare and Shriram H. Mahure (2012) emphasized that optimum replacement levels are crucial, as excessive glass powder content may lead to reduced strength or workability. A. Khmiri et al. (2012) concluded that effective pozzolanic activity requires grinding waste glass powder to particle sizes below 40 µm.

Field investigations conducted by Ahmad Shayan and Aimin Xu (2006) confirmed that glass powder can replace cement up to 20–30% in high-strength concrete without detrimental effects, contributing to reduced greenhouse gas emissions and sustainable construction practices.

Overall, the literature clearly indicates that waste glass powder can be effectively utilized as a partial replacement of cement in mortar and concrete at optimized replacement levels, improving mechanical performance while addressing environmental and sustainability concerns.

III. AIM & OBJECTIVE

The main objective of this research is to study the effect of waste glass powder on the properties of mortar mixes as a partial replacement of cement. This goal can be achieved through the following objectives:

1) Identify the effects of adding waste glass powder of various grain sizes.
2) Study the influence of waste glass powder of various grain sizes on compressive strength.
3) The main aim of this study is to determine the optimum waste glass powder content to be added as a partial replacement of cement.

IV. MATERIALS AND METHODOLOGY

A. *Materials*

1) Cement: Ordinary Portland Cement (OPC) conforming to IS 12269 / ASTM C150.
2) Fine Aggregate: Standard graded sand conforming to IS 650.
3) Waste Glass Powder: Waste glass collected from local sources, washed, dried, crushed, and ground to pass through a 75 µm sieve.
4) Water: Potable water free from impurities.

B. *Physical and Chemical Properties of Materials*

Table 1 presents the typical physical and chemical properties of OPC and waste glass powder used in this study.

Property	OPC	Waste Glass Powder
Specific gravity	3.15	2.50–2.60
Mean particle size (µm)	15–20	<75
SiO_2 (%)	20–22	70–75
CaO (%)	60–65	<1
Al_2O_3 (%)	4–6	1–2
Loss on ignition (%)	<3	<1

Table 1. Physical and Chemical Properties of OPC and Waste Glass Powder

C. Mix Proportions

Cement was partially replaced with WGP at five different levels: 0%, 5%, 10%, 15%, and 20% by weight. The cement-to-sand ratio was maintained at 1:3 for all mixes, with a constant water–cement ratio.

Mix ID	Cement (%)	WGP (%)	Sand	Water–Binder Ratio
M0	100	0	3	Constant
M5	95	5	3	Constant
M10	90	10	3	Constant
M15	85	15	3	Constant
M20	80	20	3	Constant

Table 2. Mix Proportions of Cement Mortar with WGP

D. Specimen Preparation and Curing

Mortar cubes of size 70.6 mm × 70.6 mm × 70.6 mm were cast for each mix. The specimens were demolded after 24 hours and cured in water at room temperature until the testing age.

E. Testing Procedure

Compressive strength tests were conducted at 7 and 28 days in accordance with IS 4031 / ASTM C109 using a compression testing machine.

Waste Glass Collection → Cleaning & Drying → Crushing & Grinding → Sieving (<75 μ m) → Mix Proportioning → Casting of Specimens → Curing → Mechanical & Durability Testing

Figure 1. Experimental Methodology Flowchart

V. RESULT & DISCUSSION

The compressive strength results indicate that the inclusion of waste glass powder improves the strength of cement mortar up to an optimum replacement level. Maximum strength was observed at around 15–20% replacement of cement by waste glass powder. This improvement is attributed to the pozzolanic reaction between finely ground glass powder and calcium hydroxide released during cement hydration, leading to the formation of additional calcium silicate hydrate (C–S–H) gel. Beyond the optimum level, a reduction in strength was observed due to dilution of cement content.

A. Compressive Strength

The compressive strength results of mortar mixes incorporating waste glass powder at various replacement levels are summarized in Table 3.

Mix ID	7-day Strength (MPa)	28-day Strength (MPa)
M0	32.5	45.0
M5	33.8	47.2
M10	34.5	48.0
M15	31.9	44.0
M20	28.4	39.5

Table 3. Compressive Strength Results of Mortar with WGP

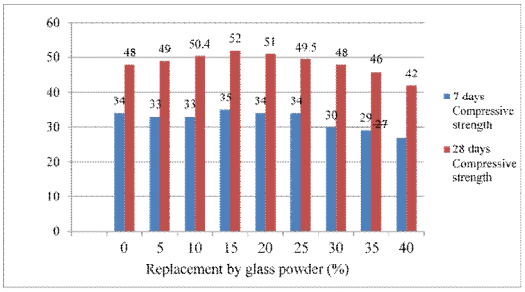


Figure 2. Compressive Strength Comparison at 7 and 28 Days

The results indicate that mortar mixes containing 5% and 10% WGP exhibit strength values comparable to or slightly higher than the control mix. The improvement is attributed to the pozzolanic reaction of finely ground glass powder, which contributes to additional C–S–H formation. At higher replacement levels, a reduction in strength is observed due to dilution of cement content.

B. Durability Properties

Durability performance is a critical parameter for evaluating the long-term behavior of cementitious materials. The incorporation of waste glass powder influences pore structure, permeability, and resistance to chemical attack.

1) *Water Absorption:* Mortar specimens containing WGP showed reduced water absorption up to 10–15% replacement levels. The fine glass particles act as micro-fillers, refining pore structure and reducing capillary porosity.
2) *Resistance to Sulfate Attack:* The high silica content of WGP contributes to the consumption of calcium hydroxide, thereby reducing the formation of expansive compounds such as ettringite in sulfate-rich environments. Mortars with up to 10% WGP demonstrated improved sulfate resistance compared to the control mix.
3) *Alkali–Silica Reaction (ASR):* When waste glass is used in coarse or fine aggregate form, it may contribute to ASR. However, when ground to powder size (<75 μm), the glass exhibits pozzolanic behavior, significantly mitigating ASR expansion. Thus, finely ground WGP is considered safe for use as a cement replacement material.

C. Microstructural Analysis (SEM and XRD)

1) *SEM Analysis:* Scanning Electron Microscopy (SEM) images reveal a denser and more homogeneous microstructure in WGP-modified mortars compared to the control mix. The presence of finely distributed C–S–H gel and reduced calcium hydroxide crystals is observed in mixes containing 5–10% WGP
2) *XRD Analysis:* X-ray Diffraction (XRD) patterns indicate a reduction in the intensity of portlandite ($Ca(OH)_2$) peaks in WGP-containing mixes, confirming the pozzolanic reaction between amorphous silica in glass powder and calcium hydroxide. Increased formation of C–S–H phases contributes to improved mechanical and durability performance.

Overall, the combined mechanical, durability, and microstructural analyses confirm that waste glass powder acts as an effective supplementary cementitious material when used at optimal replacement levels. The compressive strength results indicate that mortar mixes containing 5% and 10% WGP exhibit strength values comparable to or slightly higher than the control mix. The improvement is attributed to the pozzolanic reaction of finely ground glass powder, which contributes to additional C–S–H formation.

At 15% replacement, the strength remains acceptable but shows marginal reduction compared to the control mix. A significant decrease in strength is observed at 20% replacement due to reduced cement content and slower pozzolanic activity at early ages.

Overall, the results suggest that the optimal replacement level of cement with WGP lies between 5% and 10% for achieving balanced strength and sustainability benefits.

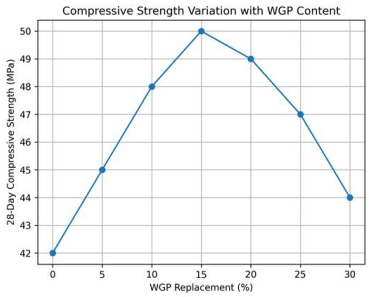


Fig. 3 Compressive Strength Variation with Waste Glass Powder Content

VI. CONCLUSION

Based on the experimental investigation, it can be concluded that waste glass powder can be effectively used as a partial replacement of cement in mortar. An optimum replacement level of about 15–20% enhances compressive strength and contributes to sustainable construction. The utilization of waste glass powder reduces environmental pollution, conserves natural resources, and lowers cement consumption. Further studies on durability and microstructural characteristics are recommended.

Based on the experimental investigation, the following conclusions can be drawn:

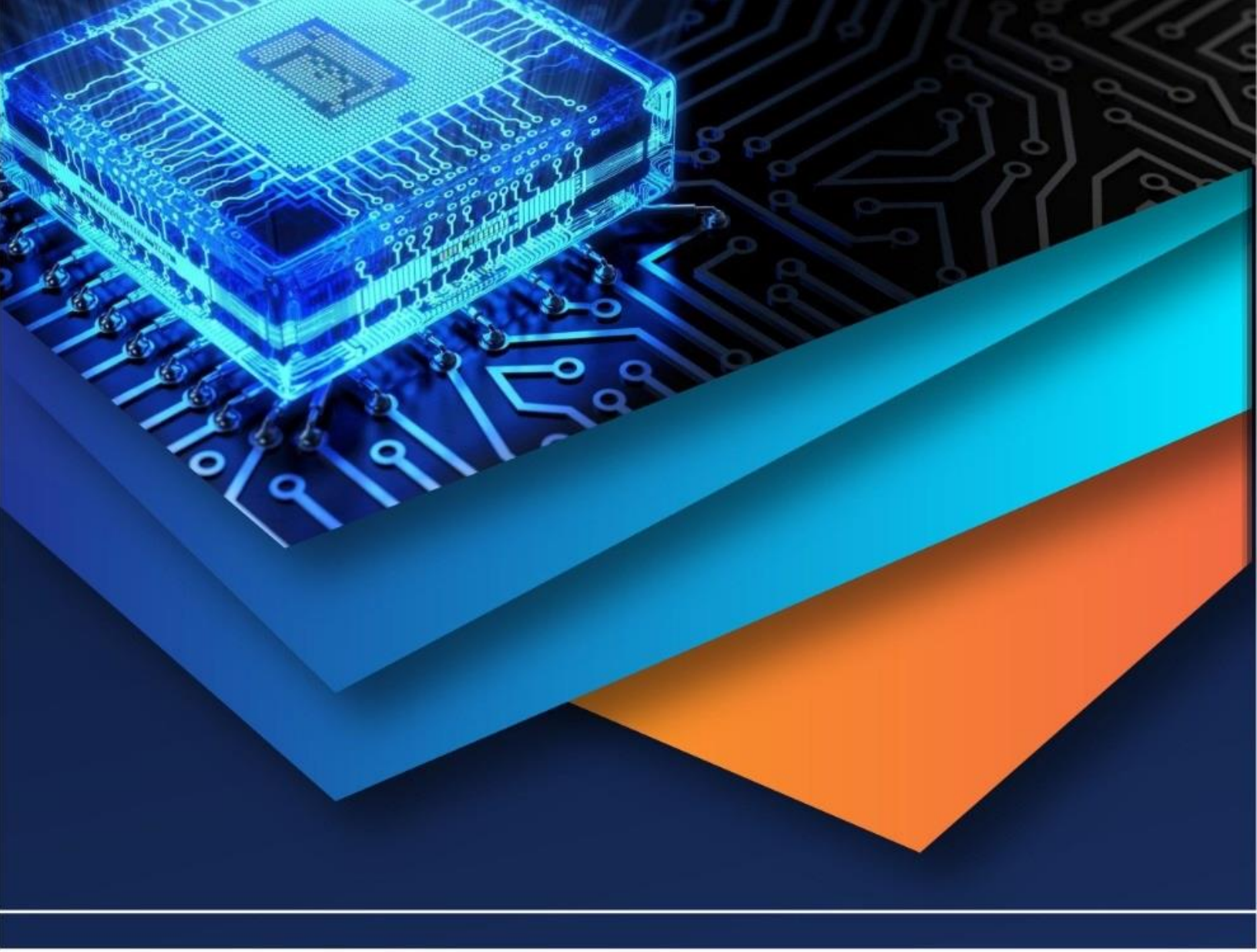
1) Waste glass powder can be effectively used as a partial replacement of cement in cement mortar.
2) Normal consistency and final setting time increase with increasing glass powder content, while initial setting time decreases slightly.
3) Compressive strength improves up to an optimum replacement level of about 30% of cement.
4) Finer waste glass powder (<75 μm) performs better than coarser glass powder due to higher pozzolanic reactivity.
5) The use of waste glass powder contributes to sustainable construction by reducing cement consumption and glass waste disposal.

VII. ACKNOWLEDGMENT

The author would like to express sincere gratitude to the faculty members of the Department of Structural Engineering for their guidance and support during the completion of this research work

REFERENCES

[1] Raghavendra K.and Virendra Kumara. K. N., “Reusing of Glass Powder and Industrial Waste Materials in Concrete”, International Journal of Research in Engineering and Technology, EISSN: 2319-1163, PISSN: 2321-7308, Volume: 04, Issue: 07, July-2015
[2] Jitendra B. Jangid and A. C. Saoji, “Comparative Study of Waste Glass Powder as the Partial Replacement of Cement in Concrete Production-A Laboratory Investigation”, International Journal on Recent and Innovation Trends in Computing and Communication, ISSN: 2321-8169, Volume: 3, Issue: 2, 063– 066, February 2015
[3] Sachin V. Bhosale and Shrivallabh S. Chavan, “Green Concrete by Utilization of Waste Glass Powder & Industrial Waste Sand for Construction Industry”, International Journal of Advanced Technology in Engineering and Science, Volume No.02, Issue No. 08, ISSN (online): 2348 – 7550, August 2014
[4] Priscilla M and Asst Prof. Pushparaj A Naik, “Strength and Durability Study on Recycled Aggregate Concrete Using Glass Powder”, International Journal of Engineering Trends and Technology (IJETT), Volume-11, Number-5, May 2014
[5] Edson Jansen Pedrosa de Miranda Júnior, Helton de Jesus Costa Leite Bezerra, Flávio Salgado Politi and Antônio Ernandes Macêdo Paiva, “Increasing the Compressive Strength of Portland Cement Concrete Using Flat Glass Powder”, Materials Research. 2014; 17(Suppl.1): 45-50, April 13, 2014
[6] T. Phani Madhavi, V.Sampathkumar and P.Gunasekaran, “Partial Replacement of Cement and Fine Aggregate by Using Fly Ash and Glass Aggregate”, International Journal of Research in Engineering and Technology, eISSN: 2319-1163 | pISSN: 2321-7308, November 2013
[7] M. Iqbal Malik, Muzafar Bashir, Sajad Ahmad, Tabish Tariq and Umar Choudhary, “Study of Concrete Involving Use of Waste Glass as Partial Replacement of Fine Aggregates” IOSR Journal of Engineering (IOSRJEN), e-ISSN: 2250-3021, p-ISSN: 2278- 8719, Volume-03, Issue-07, July-2013
[8] Williams Kupolati, William Tchoundi Mbadie, Julius Ndambuki and Rotimi Sadiku, “Environmental Greening through Utilization of Glass Waste for Production of Concrete”, OIDA International Journal of Sustainable Development, June 2013
[9] Dhanaraj Mohan Patil and Dr. Keshav K. Sangle, “Experimental Investigation of Waste Glass Powder as Partial Replacement of Cement in Concrete”, International Journal of Advanced Technology in Civil Engineering, ISSN: 2231 –5721, Volume-2, Issue-1, 2013
[10] R.Vandhiyan, K. Ramkumar and R. Ramya, “Experimental Study on Replacement of Cement by Glass Powder”, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Volume-2, Issue-5, May – 2013
[11] Sunny O. Nwaubani and Konstantinos I. Poutos, “The Influence of Waste Glass Powder Fineness on the Properties of Cement Mortars”, International Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume-02, Issue-02, ISSN 2319 - 4847, February 2013
[12] Dr. G. Vijaya kumar, Ms H. Vishaliny and Dr. D. Govindarajulu, “Studies on Glass Powder as Partial Replacement of Cement in Concrete Production”, International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 2, February 2013
[13] Gunalaan Vasudevan and Seri Ganis Kanapathy pillay, “Performance of Using Waste Glass Powder in Concrete as Replacement of Cement”, American Journal of Engineering Research (AJER), e-ISSN : 2320-0847, p-ISSN : 2320-0936 Volume-02, Issue-12, pp-175- 181, 2013
[14] J.S. Dali and S.N. Tande, “Performance of Concrete Containing Mineral Admixtures Subjected to High Temperature, 37th Conference on Our World in Concrete & Structures, Singapore, 29-31, August 2012
[15] Patel Dhirendra, Yadav R.K. and Chandak R., “Strength Characteristics of Pre-Cast Concrete Blocks Incorporating Waste Glass Powder”, ISCA Journal of Engineering Sciences, Volume-1, 68-70, July (2012)
[16] Mayur B. Vanjare and Shriram H. Mahure, “Experimental Investigation on Self Compacting Concrete Using Glass Powder”, International Journal of Engineering Research and Applications, ISSN: 2248-9622, Volume-2, Issue-3, pp.1488-1492, May-Jun 2012
[17] Dhirendra Patel, R.K.Yadav and R.Chandak, “Strength Characteristics of Cement Mortar Paste Containing Coarse and Fine Waste Glass Powder”, International Journal of Engineering Sciences Research-IJESR, ISSN: 2230-8504; e-ISSN-2230-8512, Volume-03, Issue-02; May-June 2012
[18] A. Khmiri, B. Samet and M. Chaabouni, “Assessmen[
[19] t of the Waste Glass Powder Pozzolanic Activity by Different Methods”, International Journal of Research and Reviews in Applied Sciences, Volume 10, Issue 2, February 2012
[20] J.M. Khatib, E.M. Negim, H.S. Sohl and N. Chileshe, “Glass Powder Utilisation in Concrete Production”, European Journal of Applied Sciences 4 (4): 173-176, ISSN 2079- 2077, 2012



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY