Library Progress International
Vol.44 No. 3, Jul-Dec 2024: P. 14972-14981

Print version ISSN 0970 1052
Online version ISSN 2320 317X

Original Article
Available online at www.bpasjournals.com

An Experimental Exploration Of Strength And Durability Characteristics In Concrete Incorporating Partial Replacement Of Fine Aggregate With Waste Crushed Glass

M.Vishnu vardhan[1], M.Uday Bhaskar[2], G.Sneha[3]

[1]MTech Student, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India.
[2]Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana,India.
[3]Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana,India.

How to cite this article: M.Vishnu vardhan, M.Uday Bhaskar, G.Sneha (2024) An Experimental Exploration Of Strength And Durability Characteristics In Concrete Incorporating Partial Replacement Of Fine Aggregate With Waste Crushed Glass. *Library Progress International,* 44(3), 14972-14981.

Abstract

The increasing demand for concrete, driven by rising construction activities, has strained river sand, a key component, leading to environmental concerns and depletion of natural resources. This has prompted research into sustainable alternatives, including waste management solutions. This study explores using waste crushed glass as a partial replacement for fine aggregate in concrete (at 10%, 20%, 30%, and 40% of sand weight) for M30 and M60 concrete grades. The research evaluates the strength properties—compression, tensile, and flexural—at curing periods of 7, 14, 28, and 90 days, comparing them to conventional concrete. Durability tests, including acid attack, rapid chloride permeability, and abrasion, were also conducted. The findings aim to provide a sustainable alternative to traditional materials while addressing waste disposal challenges.

Keywords: Sustainable construction materials, Waste crushed glass, Fine aggregate replacement, Concrete strength properties, Durability testing.

1. Introduction

Due to the rising demand for traditional resources in concrete production, researchers are focusing on innovative technologies that are crucial for the construction industry to enhance material efficiency in infrastructure development. The excessive use of river sand in concrete mixes lowers the water table, causing erosion, construction challenges, and increased disposal costs. This has led to a growing need for alternatives to conventional sand, with crushed glass emerging as a promising substitute in various applications. Concrete made with crushed glass has been found to be both strong and environmentally sustainable. Using crushed glass in concrete represents a significant advancement in construction, as it reduces water consumption, minimizes shrinkage, and enhances resistance to abrasion. The unique properties of crushed glass make it an appealing option for concrete mixes. Moreover, reducing the crystal size of glass aggregates helps mitigate alkali-silica reaction (ASR), a common durability issue in concrete.

Incorporating crushed glass into concrete also addresses environmental concerns related to the disposal of municipal solid waste. Glass from LCD panels, used in devices such as TVs, computers, and smartphones, contributes to waste accumulation. Despite the benefits of these panels, such as slim design and energy efficiency, recycling the glass poses challenges due to the presence of composite materials and contaminants. However, research shows that waste crushed glass (WCG) in concrete improves resistance to chloride diffusion, offering significant protection to reinforced concrete structures exposed to seawater and salts, reducing the risk of corrosion. Crushed glass in construction not only repurposes discarded glass into a valuable resource but also lowers transportation costs, as it is locally available from solid waste. Its inclusion in concrete mixes reduces water absorption, shrinkage, and increases resistance to surface damage.

Studies indicate that replacing more than 25% of sand with finely crushed waste glass may lead to increased crack size, but moderate replacements (10-20%) enhance resistance to chloride ion penetration, making such concrete ideal for coastal areas. Researchers have demonstrated that crushed waste glass is a viable alternative to conventional aggregates in concrete mixes, reducing reliance on natural sand and overall mix preparation costs. Moreover, replacing 10-20% of cement with crushed glass further improves resistance to chloride intrusion, enhancing durability. In this study, finely processed crushed glass was selected to match the properties of fine aggregate, containing silica ($SiO2$), sodium ($Na2O$), and calcium (CaO) in oxide form.

The addition of crushed glass enhances the compactness of concrete, reducing porosity and improving performance. It increases the concrete's compressive, tensile, and flexural strengths, while durability improves with time, due to the pozzolanic effect of crushed glass powder. Concrete is the second most widely used material in the world after water, and its composition typically includes cement, fine and coarse aggregates, and water. Recently, there has been a growing trend to incorporate industrial waste into concrete to reduce dependency on natural resources. Crushed glass is a notable example of such waste being used as a replacement for aggregates. In some concrete formulations, finely crushed waste glass also serves as a substitute for cement. Although using recycled waste glass can raise production costs, this study explores the innovative use of finely crushed white waste glass to enhance concrete mixes while addressing cost concerns associated with waste glass concrete.

The durability tests for M30 and M60 grade concrete will involve several key evaluations. Acid attack tests will be conducted on 150 mm x 150 mm x 150 mm cubes to assess the concrete's resistance to acidic environments. Rapid chloride permeability tests (RCPT) will be performed on cylindrical specimens (50 mm in height, 100 mm in diameter) to measure the concrete's ability to resist chloride ion penetration. Abrasion tests will be carried out on specimens (100 mm in height, 300 mm in diameter) to evaluate wear resistance. The overall goal of the research is to systematically assess the viability and performance of using waste crushed glass as a partial replacement for fine aggregate in concrete production. This includes objectives such as designing concrete mixes, assessing workability, evaluating mechanical strength, and conducting durability tests for different concrete grades like M30 and M60.

2. Review of Literature

Bhupendra Singh Shekawat and Vanita Aggarwal (2015) found that partially replacing sand with glass in concrete not only enhances workability and strength but also improves durability. Durability was assessed through sorptivity and water absorption tests, showing that incorporating waste glass in concrete can address disposal challenges and lower construction costs.

Sadoon Abdallah and Mizi Fan (2014) observed improved workability with increased waste glass replacement, although there was a slight decline in performance. However, compressive strength at 28 days was 5.28% higher with 20% glass replacement, and water absorption decreased as glass content increased. Ultrasonic pulse velocity tests indicated a denser internal structure in concrete with glass.

Konstantinos I. Poutos and Sunny O. Nwaubani (2013) discovered that glass aggregates perform well in cold-weather concreting, where concrete with glass aggregates recovered strength after freezing, unlike control concretes, which experienced greater strength loss. Microscopic analysis confirmed that glass concrete is less affected by freezing conditions, highlighting its advantages in cold climates.

Roz-ud-Din Nasser and Parviz Soroshian (2011) demonstrated that using leftover cut-glass as a partial substitute for cement enhances the microstructure of recycled aggregate concrete, reducing permeability, increasing sorptivity, and improving freeze-thaw resistance.

The study emphasized the positive effect of waste glass on concrete durability. Nurhayat Degirmency, Arin Yilmaz, and Ozge Andik Kakirk (2011) investigated alkali-aggregate reaction (AAR) and volume change resistance in mortar containing waste crystal glass. They found that AAR development was minimal, and the results were within acceptable limits. Different colors of waste glass affected strength properties, but up to 30% replacement of sand with glass yielded similar or superior strength compared to conventional sand.

Danupon Tonnyopas and Chanamet Thanavisitsavas (2008) studied the impact of Alkali Activated Natural Pozzolan Fine Silica (ANFS) and Ground Waste Float Glass (GWFG) on mortar mixed with Oil Palm Fruit Fibre Ash (OPFFA). Partial replacement of OPC in GWFG mortar initially affected compressive strength, but it showed potential for mortar applications at specific replacement levels. The ASR expansion in GWFG-OPFFA mortar varied based on the content of GWFG powder and OPFFA.

3. Materials & Methods

This section focuses on the materials and methods used to develop an optimal mix for crushed glass concrete, as well as the procedures for evaluating its properties. Key materials include cement, fine aggregate (river sand), coarse aggregate, waste crushed glass, and an admixture (SP430 superplasticizer).

3.1 Cement

Grade OPC53 cement, conforming to IS 269 (2015), was used in this study. Cement acts as the adhesive in concrete, binding other materials together. Laboratory tests were conducted to determine its specific gravity, setting times, consistency, and compressive strength.

3.2 Fine Aggregate

Fine aggregate (river sand) is used to fill voids between coarse aggregates in the concrete mix. Sand of Zone-II was utilized as per IS 383-2016. The sand was washed and dried before use.

3.3 Coarse Aggregate

Coarse aggregate used was crushed granite with a particle size of 20 mm. The aggregate was sourced locally from Hyderabad.

3.4 Waste Crushed Glass

Waste glass was collected, cleaned, and crushed. It replaced fine aggregate in the mix in varying percentages.

3.5 Water

Water plays a crucial role in the hydration process. It was carefully measured to achieve the required water-to-cement ratio.

3.6 Admixture (Superplasticizer)

The superplasticizer (Conplast SP430) was used to enhance the workability of the mix. Its use also reduced the water-cement ratio without compromising strength.

3.7 Mix design

The mix design was developed using IS 10262-2009 and ACI 211 methods. Various mix proportions were tested for M30 and M60 concrete with waste crushed glass replacing fine aggregate in varying percentages.

The study focused on various tests to evaluate the workability, casting, curing, and strength characteristics of concrete, using a systematic approach based on established standards.

Initially, workability was assessed through the slump cone test, a method that gauges the ease with which concrete can be mixed, transported, placed, compacted, and finished. The slump cone, measuring 200 mm at the lower diameter, 100 mm at the upper diameter, and 300 mm in height, was filled in four layers, with each layer receiving 25 tamping rod blows. A total of 15 mixes were prepared, with slump values recorded for analysis.

For casting, two water-to-cement ratios of 0.45 and 0.35 were used for M30 and M60 grades, respectively. A total of 15 mixes were created, including a basic M30 mix with river sand and four additional mixes for both grades, incorporating crushed glass as fine aggregate replacement at 10%, 20%, 30%, and 40%. Specimens were cast in various dimensions, including blocks (150 mm), tubes (150 mm x 300 mm), optical prisms (100 mm x 100 mm x 500 mm), and cylinders for different tests.

After demoulding, the specimens were immersed in water for curing, and strength tests were conducted at 7, 14, 28, and 90 days to evaluate durability and performance. The compressive strength was determined using a 2000 kN testing machine, following the guidelines of IS 516:1959, with the load applied at a rate of 14 N/mm²/min until failure. Tensile strength was also assessed using the same machine on cylinders measuring 150 mm in diameter and 300 mm in length, following IS 5816:1999, and calculated using the formula \(f_t = \frac{2Q}{\pi D L} \), where \(Q \) represents the failure load.

Finally, the flexural strength test evaluated the modulus of rupture using 100 mm x 100 mm x 500 mm prisms, adhering to the Indian standards outlined in IS 516:1959. This structured approach ensured reliable data collection and analysis, providing insights into the performance of various concrete mixes under different curing durations and conditions.

4. Durability Studies on Waste Crushed Glass Concrete

It appears that the research study is absorbed on assessing the durability of real incorporating waste crushed cut-glass as a sustainable physical. The study includes various sturdiness exams such as cutting dose and chloride penetration resistance.

4.1 Acid Attack Test

4.1.1 Test Set Up

1. Objective: Evaluate the resistance of glass concrete specimens to external acid attack.
2. Concrete Specimens: Waste Crushed Glass real blocks of scope 150mm remained company and preserved for 90 days.
3. Cleaning and Weighing: Block exteriors remained gutted by means of a normal initial superficial housework procedure. Initial weights were noted after complete drying of specimens.
4. Acid Solution Immersion: Specimens were immersed in a 5% hydrochloric acid (HCl) solution. The experiment used Hydrochloric Acid and Sulphuric Acid at 5% concentration.
5. Weight Measurement: After 56 days of immersion, the weights of specimens were noted.

Results:

1. Weight Loss Calculation:

Weight loss due to acidic immersion was calculated as % = $[(W_{\text{initial}}-W_{\text{final}})/W_{\text{initial}})] \times 100$

2. Observations:

Percent weight loss was less for glass concrete mixes compared to reference concrete. Percent loss in weight for different mixes (M30, M60) was tabulated.

4.1.2 Chloride Attack:

i. Background: Concrete in marine structures is exposed to chloride attack. Presence of chlorides can lead to leaching of lime and corrosion of reinforcement.

ii. Test Setup: Assess the percentage weight loss of glass concrete mixes after 90 days of curing and HCl immersion for 56 days. Results tabulated and graphed for different replacement levels (0%, 10%, 20%, 30%, 40%)

iii. Observations: Glass concrete mixes showed lower percent weight loss compared to conventional concrete in different grades (M30, M60).

The findings suggest that the incorporation of waste crushed glass in concrete improves resistance to acid attack and chloride penetration, contributing to the overall toughness of the real constructions. The specific percentages of weight loss for different mixes provide quantitative data on the effectiveness of waste crushed glass in enhancing durability.

Table 1 Specimen in HCL Solution M30

S.NO.	MIX	Cubes weight kg	Cubes weight in HCL kg	% loss in weight
1	MCG0	8.36	8.26	1.20
2	MCG10	8.25	8.21	0.65
3	MCG20	8.23	8.18	0.25
4	MCG30	8.21	8.18	0.16
5	MCG40	8.11	8.09	0.12

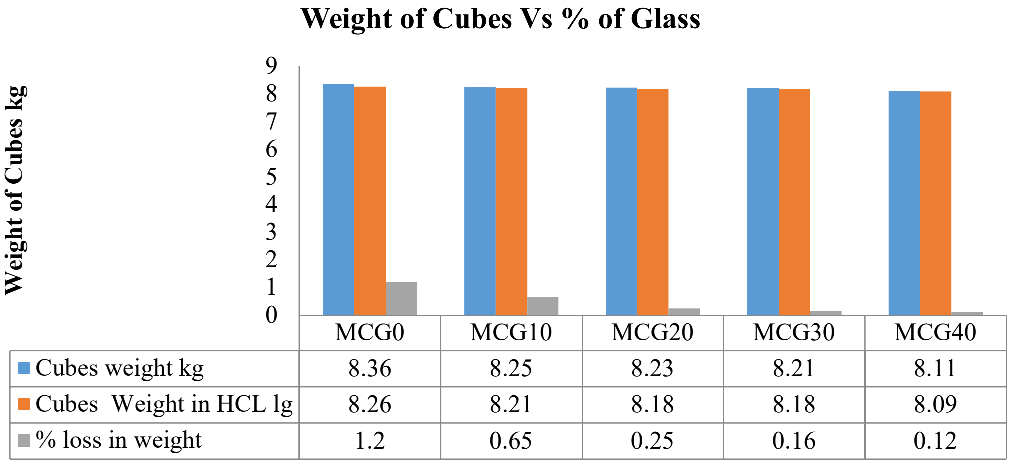


Fig. 1 Weight of Cubes Vs Mix M30

Table 2 Specimens in HCL Solution M60

S.NO.	MIX	Cubes weight kg	Cubes weight in HCL kg	% loss in weight
1	MCG0	8.47	8.38	1.06
2	MCG10	8.42	8.37	1.05
3	MCG20	8.39	8.29	1.06
4	MCG30	8.30	8.27	0.24
5	MCG40	8.25	8.22	0.38

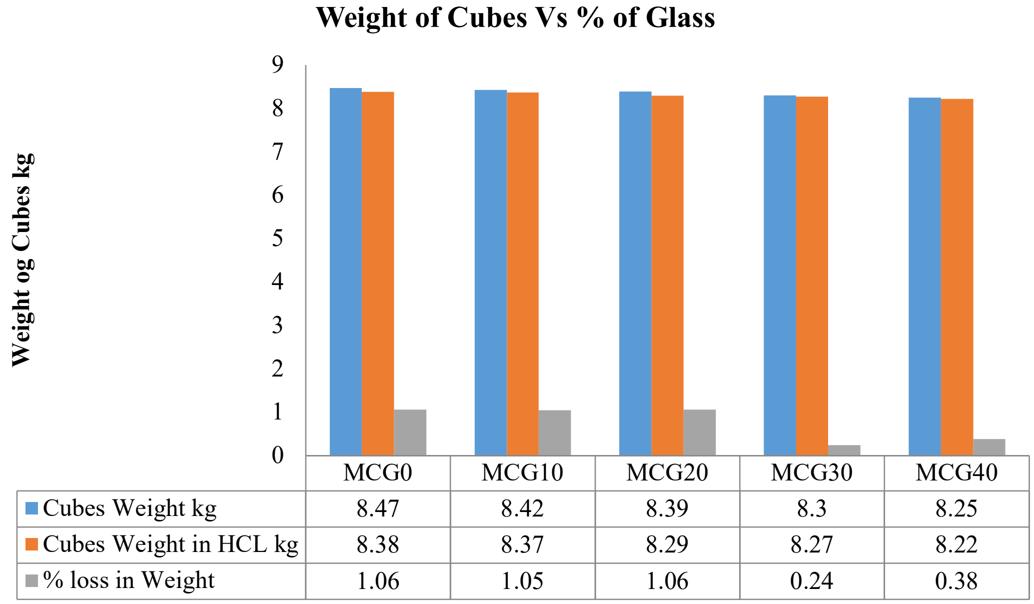


Fig. 2 Weight of Cubes Vs Mix M60

4.1.3 Sulphate Attack

Sulphate attack occurs when sulphates are present in the concrete surroundings, whether in soil or groundwater. When the presence of sulphates is identified physically, it is termed as physical sulphate attack. This attack is a result of the interaction between hydrogen ions in hydrated cement and sulphate ions. The chemical reaction between sulphates and cement leads to the deterioration of the cement, a crucial component of the built element. The study of concrete deprivation due to sulphates is an interesting topic for researchers focusing on sustainable mechanisms, and it is influenced by various other issues, as outlined below.

Sulphate attacks typically occur in ground floor slabs. When the infill physical underneath the chunk comprises sulfates, and these sulphates are dissolved by ground dampness, they can travel hooked on the real forming the ground lump. The attacks can be caused by MgSO4 table salt, NaSO4 table salt, and additional salinities covering SO3- ions. The communication of Ca2+ ions with SO4 in the answer results in the production of CaSO4 or gypsum. The mechanism is explained as follows:

Mechanism of Acid Attack:

$$Ca(OH)_2 + \text{ACID} \rightarrow \text{Calcium salt + water}$$

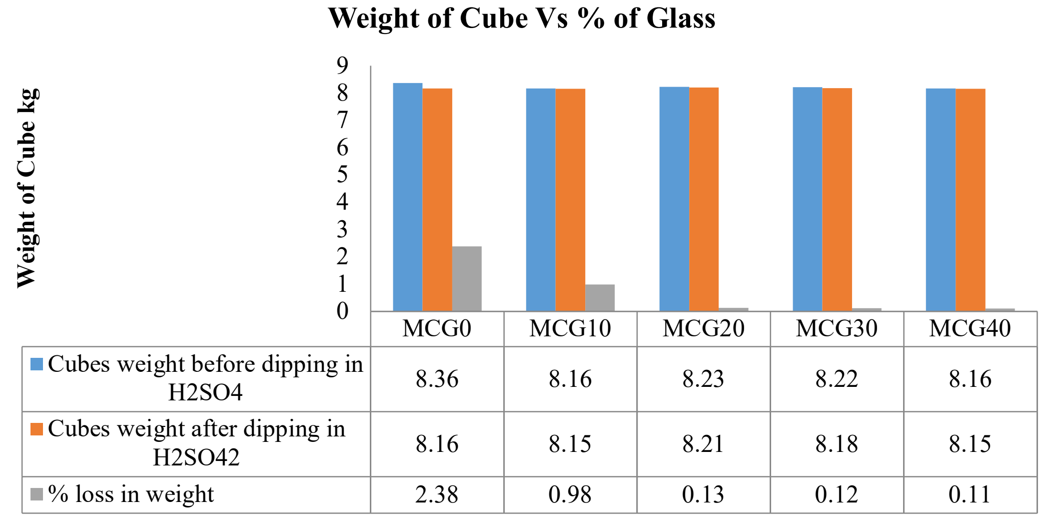
$$H_2SO_4 + Ca(OH) \rightarrow Ca(SO)_4 + 2H_2O$$

(calcium sulphate product contributes to sulphate attack)

Table 3 Specimens in H_2SO_4 Solution M30

S.NO	MIX	Cubes Weight Before Dipping in H2SO4-	Cubes Weight After Dipping in H2SO4- kg	% Loss in weight
1	MCG0	8.36	8.16	2.38

2	MCG10	8.16	8.15	0.98
3	MCG20	8.23	8.21	0.13
4	MCG30	8.22	8.18	0.12
5	MCG40	8.16	8.15	0.11

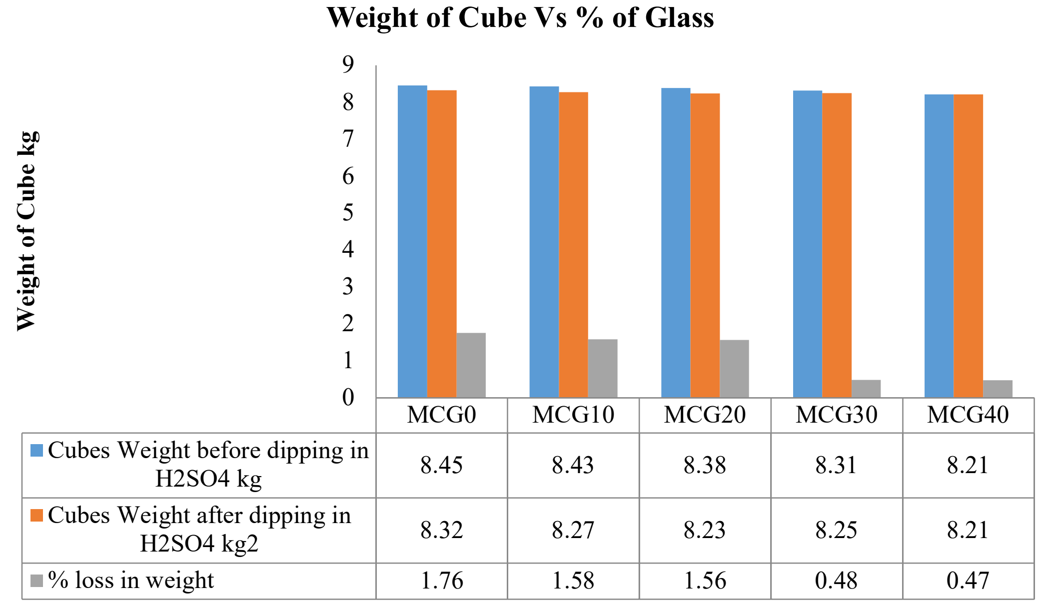


	MCG0	MCG10	MCG20	MCG30	MCG40
🟦 Cubes weight before dipping in H2SO4	8.36	8.16	8.23	8.22	8.16
🟧 Cubes weight after dipping in H2SO42	8.16	8.15	8.21	8.18	8.15
⬜ % loss in weight	2.38	0.98	0.13	0.12	0.11

Fig. 3 Weight of Cubes Vs Mix M30 in H_2SO_4 Solution

Table 5.4 Specimens in H_2SO_4 Solution M60

S.NO	**MIX**	**Cubes Weight Before Dipping in H2SO4-**	**Cubes Weight After Dipping in H2SO4- kg**	**% Loss in weight**
1	MCG0	8.45	8.32	1.76
2	MCG10	8.43	8.27	1.58
3	MCG20	8.38	8.23	1.56
4	MCG30	8.31	8.25	0.48
5	MCG40	8.21	8.21	0.47



	MCG0	MCG10	MCG20	MCG30	MCG40
🟦 Cubes Weight before dipping in H2SO4 kg	8.45	8.43	8.38	8.31	8.21
🟧 Cubes Weight after dipping in H2SO4 kg2	8.32	8.27	8.23	8.25	8.21
⬜ % loss in weight	1.76	1.58	1.56	0.48	0.47

Fig. 4 Weight of Cubes Vs Mix M60 in H_2SO_4 Solution

4.2 Rapid Chloride Penetration Test

The measurement of chloride resistance is conducted using the Rapid Chloride Permeability Test (RCPT) device rendering to ASTM C 1202. This method, considered the fastest, assesses the erosion of sword in real due to chloride penetration, a common environmental factor that can damage constructions. It is crucial to determine the durability of concrete before its use in actual constructions.

Concrete permeability is higher than that of cement paste, as microcracks are typically present in the concrete, especially in the intermediate interfacial zone amid the collective and the adhesive. Strength and permeability are interrelated through capillary porosity, where factors affecting concrete strength also influence permeability. Reducing the volume of capillary pores can lower permeability, achieved by adopting a lower water-to-cement ratio, appropriate cement quantity, good compaction, and adequate moisture supply. Attention must also be paid to aggregate size, grading, and mineral composition. Higher permeability is observed in the interfacial transition zone.

In this research, waste crushed glass is incorporated into concrete preparation. The permeability of this concrete is evaluated using the Rapid Chloride Permeability Test conducted on tubular examples measurement 50 mm in tallness and 100 mm in width.

4.2.1 Rapid Chloride Permeability Test (ASTM C-1202) Experimentation

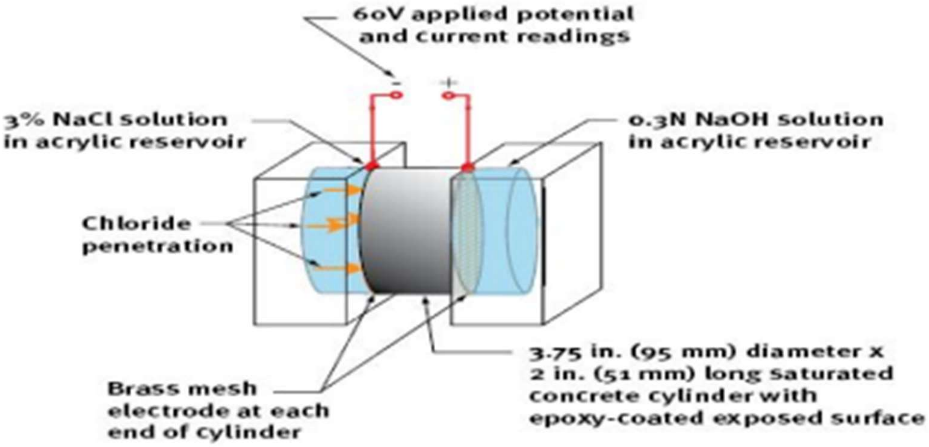


Fig: 5 RCPT - Procedure

The RCPT diffusion cell consists of two components: the power source component and the dispersion cell component. The power source delivers current to the dispersion cell, and the current is displayed on the LED display. Two separate chambers in the diffusion cell are filled with NaCl and NaOH answers of wanted concentrations. Silicon oxide cream is cast-off as an adhesive afterward enclosing the tangible sample amid the 2 dispersion cells to prevent solution leakage during the experiment. NaOH of 0.3N is placed in one chamber, and NaCl of 3% is filled in another chamber.

When a DC current of 60V is applied across the dispersion compartments, chloride ions migrate through the centrally inserted example. The chloride ion penetrability of the mix is determined by measuring the voltage passing finished the sample every 30 notes for a period of 360 minutes. Advanced interpretations after 360 minutes indicate increased permeability, while lower readings suggest that the mix is less penetrable to the current. The present passage through the specimen is intended using the equation:

$$Q = 900(I0+2I30+2I60+2I90+2I120+\text{-----}+2I300+2I330+I360)$$

Q=charge through each cell.

I0=Current applied initially.

I_T=Current flowing at T minute.

4.2.2 Influence of Glass as well Aggregate on Permeability Resistance

The permeability values of glass concrete, using unused cut-glass instead of fine aggregate, are presented in Tables 6.8, 6.9, and 6.10, and graphically represented in graphs 6.6, 6.7, and 6.8. Observations show that the permeability values of glass concrete decrease compared to normal concrete with 90 days of curing for all three grades M30, M45, and M60.

For M30 grade concrete:

Permeability values at 90 days curing are 1148, 1128, 1023, 1008, and 994 for 0%, 10%, 20%, 30%, and 40%

glass substitution. Percentage decrease in permeability values is 13.14% for the mix with 40% glass for fine aggregate replacement.

For M45 grade concrete:

Permeability values are 1032.7, 1013.3, 927.6, and 939.2 coulombs for 0%, 10%, 20%, and 30% glass substitution. Percentage decrease in permeability is 9.05% for the mix with 40% crushed glass in fine aggregate.

For M60 grade concrete:

Permeability values are 1043.1, 921.6, 522.9, 345.6, and 391.5 coulombs for 0%, 10%, 20%, 30%, and 40% glass substitution. Percentage decrease in permeability is 62% for the mix with 40% crushed glass in fine aggregate.

4*.3 Abrasion Resistance of Concrete (Underwater Method)*

The scrape confrontation of real, indicating its resistance to rubbing and wear, is crucial for maintaining the appearance and integrity of structures. Poor abrasion resistance can result from factors such as over-vibration and placing concrete on hot summer days.

4.3.1 *Stage by Stage Process to Determine the Average Depth of Abrasion*

a) MASS OF SPECIMEN:

Note the mass of the specimen and record its dimensions before placing it in the abrasion machine.

b) POSITIONING THE SAMPLE:

Position the sample in a method that its superficial competitions with the chute.

c) SETUP AND RUNNING THE MACHINE:

Place the drill press over the specimen, raise the agitation blade. Weigh the abrasion charge to the nearest 10g. Run the machine for 72 hours, lifting the specimen out at predefined intervals.

d) CLEANING AND WEIGHING

Remove substantial material adhering to the sample. Record individual weights when the specimen is in air and water.

e) TESTING PROCEDURE:

Conduct the test for 3 days, noting readings at ½ day intervals according to the provided guidelines. Ensure the shaft drill is revolving, and the specimen is in water without any water leakage from the machine.

Formulas:

Volume of Specimen at Time (VT):

$$\text{Capacity of example at period } VT = (\text{Weight in air} - \text{Weight in water})/G_w$$

Where VT= Sample volume at time in m^3
W= Specimen weighed in air – kg
W_w = Specimen weighed in water - kg
G_w = Unit weight of Water kg/m3

The concrete volume scratched out is

$$Vs = V - VT$$

Where Vs.= Concrete scratched after the test in m^3
V= Initial Volume of sample - m^3
VT= Volume after the test - m^3
Depth of the Scratching =ADAL=VT/Na

5. Conclusion

The focus of this research is on utilizing Unused Crumpled Crystal in concrete to minimize reliance on natural river sand dredging and to tackle environmental issues. Waste Crushed Glass is incorporated as a replacement for river sand in varying proportions of 0%, 10%, 20%, 30%, and 40%. The study examines how Waste Crumpled Glass affects the strength and performance of the concrete mix. This section summarizes the conclusions derived from the research and suggests potential directions for further investigation into concrete made with unused crumpled glass.

- Acid Attack and Chloride Permeability: Specimens that had a 30% replacement of Waste Crumpled Glass (WCG) demonstrated improved resistance to acid exposure, showing lower weight loss compared to other mixtures. The Rapid Chloride Permeability Test revealed reduced measured currents for the 30% replacement, indicating enhanced performance in this regard.
- Abrasion Resistance: The abrasion resistance of the concrete improved with increasing WCG content, achieving its peak resistance at a 30% replacement level.

REFERENCES

[1]. Aman Roy Patil Assess the Appearance of Concrete by using Waste Glass as Aggregate Volume 6 Issue6 June 2019

[2]. T O Ogundairo et al. "Sustainable use of recycled waste glass as an alternative Material for building construction "Conference Series Materials Science and Engineering -NOV 2019

[3]. Mohammed Seddik –"Properties of glass concrete" Conference Series: Materials Science and Engineering

[4]. H. Dabiri et.el "The Influence of Replacing Sand with Waste Glass Particle on the Physical and Mechanical Parameters of Concrete" civil engineering journal AUG-2018

[5]. Bhupendra Singh Shekhawat et al "Utilisation of Waste Glass Powder in Concrete A Literature Review " International Journal of Innovative Research in Science, Engineering and Technology An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 7, July 2014.

[6]. M. Adaway& Y. Wang " Recycled glass as a partial replacement for fine aggregate in structural concrete – Effects on compressive strength" Ejse/International Special Issue: Electronic Journal of Structural Engineering 14(1) 2015.

[7]. SadoonAbdalla,Mizi Fan "Charecterstics of concrete with Waste Glass as Fine Aggregate replacement " . ISSN : 2321 - 0869 Volume - 2 Issue - 6, June 2014. www.researchgate.net/publication/263652300.

[8]. IqbalMalik et al. "Study of Concrete Involving Usage of Waste Glass as Partial Replacement of Fine Aggregate" e-ISSN:2250-3021, p-ISSN:2278- 8719 Volume-3 Issue-7, July 2013. www.researchgate.net/publication/263652300

[10] Tung-Chai Ling et al. "Management and recycling of waste glass in concrete products: Current situations in HonKong"(2012)-ELSEVIER.

[11] Tomas. ''Use of Recycled Glass Bottles as Fine Aggregates in Concrete Mixture" Volume-61 (2013) pp.-17-28 http://dx.doi.org/10.14257/ijast.2013.61.03

[12] Ahmad SHAYAN. "Value-added Utilization of Waste Glass in Concrete" IABSE symposium Melbourne 2002.

[13] Jadhav G Set al. "Partially Replacement Of Waste Toughen Glass As Fine Aggregate In Concrete" ISSN: 2347-1697 Volume 3 Issue 9 May 2016.

[14] Weihua et al." Glass Crete as construction material" ACI Materials journal March/April 2000.79

[15] Bhupendra Singh Shekhawat et al."Utilization of Waste Glass Powder in Concrete" ISSN: 2319-8753 Vol. 3, Issue 7, July 2014.

[16] Vivian W.Y. Tam et al. "A review on the viable technology for construction waste recycling" Resources, Conservation and Recycling 47 (2006) 209–221 www.elsevier.com/locate/resconrec

[17] B.Naga Niranjan Kumar et al." Influence Of Glass Powder On The Properties Of Concrete" Vol. 2 Issue 4 April 2016-IJRD

[18] T. Phani Madhavi et al. "Partial Replacement of Cement And Fine Aggregate By using Fly Ash And Glass Aggregate" eISSN: 2319-1163 | pISSN: 2321- 7308

[19] Yasser Sharifi et al. "Recycled glass replacement as fine aggregate in self compacting concrete" Frontiers of structural and civil engineering Volume 7, Issue 4, pp 419–428 December 2013

[20] Dr. M.Vijaya Sekhar Reddyet al. "Incorporation of Waste Glass Powder as Partial Replacement of Fine Aggregate in

Cement Concrete" International Journal of Scientific & Engineering Research ISSN 2229-5518 Volume 6, Issue 12, December-2015

[21] I. B. Topcu et al ."Properties of concrete containing waste glass,". Res., vol. 34, pp. 267-274 July 02, 2009.

[22] Geetha Bhargava et al. "State of art of usage of alternative materials in concrete" IJESM -ISSN: 2349-6193 Dec-2015.

[23] C.Meyer et al . "Concrete With Waste Glass As Aggregate" in "Recycling and Re-use of Glass cullet"-International Symposium Concrete Technology Unit of ASCE and University of Dundee. March -19-20 2001.

[24] Perkins "Development of concrete containing waste glass" University of Glamorgan

[25] Dr.Zubaidah Abdullateef "Mechanical Properties And Behaviour of Sustainable concrete"-Journal of Engineering and Development- ISSN: 1813- 7822 volume:17 2013

[26] MohamadIqbal Malik et al . "Positive Potential Of Partial Replacement of Fine Aggregates By Wastage Glass