

Performance Evaluation of Eco-Friendly Concrete Using Granite Powder And Waste Glass As Partial Replacements

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ABSTRACT:

The construction industry has developed at high rates and the resources consumed rapidly are natural river sand and cement, which cause a severe degradation of nature and also lead to high carbon dioxide emissions. At the same time, the amounts of industrial waste products including granite powder, waste glass, fly ash, and marble powder produced by stone-processing and manufacturing industry pose severe disposal and health problems. The research examines the potential of using granite powder as a partial substitute of natural fine aggregate and glass powder as an auxiliary cementitious material to come up with sustainable and strong concrete. Experimental studies were conducted by substituting cement with up to 25% of natural sand with glass powder and then substituting natural sand with granite powder up to 50% and a combination of the two. Moreover, fly ash (20 percent) was added to enhance optimum mixes and marble powder (10 percent) was incorporated as a filler material. Slump tests were used to evaluate fresh property and the hardened property that were assessed included compressive strength, flexural strength, splitting tensile strength, density, abrasion resistance and modulus of elasticity. The properties of durability such as water absorption, water penetration, acid attack, sulphate attack and quick penetration through chloride were also evaluated. EMU Microstructural characterization was done by SEM and XRD to learn the behavior of the internal matrix

and hydration. Findings show that the ideal ratios of granite powder and the glass powder are influential in improving the mechanical performance and durability as a result of better particle packing and pozzolanic reactions as well as reducing the reliance on traditional materials. The research shows that mixed use of these waste products is an effective, environmentally friendly and sustainable option towards concrete production.

Keywords: Granite powder, waste glass, fly ash, marble powder, concrete.

I INTRODUCTION

The most common construction material which is largely used is concrete because of its versatility, strength and durability, but the mass production of concrete causes severe environmental problems. The ever-growing need in cement and natural river sand has led to overuse of natural resources, which causes ecological disproportion, deterioration of riverbed, and depletion of ground water. River sand of billions of tons is being consumed by millions of people each year globally, and uncontrolled sand mining has led to some Indian states restricting or banning sand mining, which has in turn led to a shortage of material, as well as higher construction prices. Simultaneously, cement manufacturing is an exceptionally significant source of carbon dioxide emissions into the atmosphere because of the limestone calcination process and large amounts of energy usage in the manufacturing process. India on its side produces hundreds of millions of tons of cement every year and there is a lot of influence on carbon

footprints. These concerns have led to researches and policy makers emphasizing on sustainable construction procedures that cause less environmental losses and preservation of the structural functionality. A partial substitution of cement and natural aggregates with industrial by-products and waste materials is one of the potential solutions. Such materials do not only cut on the use of natural resources but also offer a proper source of waste management. Hence, the creation of an eco-friendly concrete with the help of industrial waste has become a significant research focus on the creation of sustainable infrastructure.

The construction and stone-processing sectors produce huge amounts of solid waste materials when performing quarrying, cutting, polishing, and finishing. The granite processing industries especially do generate large quantities of granite powder and slurry which in most cases are discarded at open lands or dumping yards. The mismanagement of granite waste causes extreme environmental and health risks such as pollution of air, soil infertility, obstruction of natural drainage systems, and respiratory complications among the communities surrounding the waste disposal sites. The state of Rajasthan, which produces a considerable amount of granite in the country, amounts to a large amount of granite waste every year, which is a serious issue of disposition. Meanwhile, the increasing lack of river sand has accelerated the research of the appropriate alternative fine aggregates. A potential substitute is granite powder which has the mineralogical composition and particle size properties of what natural sand has. It has been shown by previous research that granite powder can enhance the packing density and mechanical performance when they are used in proportions. Therefore, granite powder should be considered as a partial substitute of fine aggregate due to its environmental waste disposal

and natural sand scarcity which can be considered an alternative and sustainable construction material.

Production of cement is an energy consuming activity that contributes a considerable proportion of the world CO₂ emissions. In order to alleviate this environmental impact, supplementary cementitious materials (SCMs), including fly ash, glass powder, and marble powder have attracted the interest as partial dispensing cement substitutes. Waste glass powder has exhibited promising pozzolanic properties when ground finely among them. There are huge masses of waste glass produced by the discarded bottles, windows, containers and household glass products a significant amount of which are not recycled and end up in landfills. The silica-rich fine glass powder reacts with the calcium hydroxide emitted during hydration of cement to create more calcium silicate hydrate gel (C-S-H) and therefore strengthens and increases the longevity. As the evidence of research shows, the regulated usage of glass powder increases working quality, concrete strength, and ability to withstand chloride infiltration and decreases the anxieties related to alkali-silica reactions when the particle size is small enough. Therefore, the addition of waste glass powder as a partial cement replacement will also add to the sustainability quest, through cement requirements reduction, carbon emissions lowered, and non-biodegradable waste recycling facilitation.

Other industrial by-products that have been extensively researched on the positive impact on the concrete performance include fly ash and marble powder. Fly ash, a by-product of coal-fired thermal power plant has pozzolanic properties, which make it to increase the long-term strength, decrease permeability, and deflect characteristics of durability, including sulphate and chloride attack resistance. Marble powder is a product of cutting and polishing of marble stones, which is mainly used as a filler material and enhances the packing of the particles and minimizing micro-voids in concrete. Marble

powder is known to make the workability, strength, and microstructure integrity of a mixture when used in optimum proportions, without negatively influencing the hydration. Fly ash and marble powder combined use in concrete does not only enhance the mechanical and durability features of the concrete but is the most viable solution to handling industrial waste. The volume of waste that goes to landfills is minimized by their integration and the environmental impact of construction materials has also been minimized. Thus, a holistic solution to green concrete development is in the combination of these SCM with other fine aggregates like granite powder and other binders like glass powder.

In that regard, the current research is supposed to create the concrete that can serve as a sustainable one by reducing the usage of traditional cement and natural river sand thanks to the joint usage of the granite powder and glass powder, as well as fly ash and marble powder. The study examines the interaction of these materials on fresh, mechanical, and durability properties of concrete by a comprehensive experimental study program. The partial cement replacement involves the use of glass powder and substitution of natural sand with granite powder in different ratios. In addition, the fly ash and marble powder are added in optimal amounts to increase pozzolanic activity and filler effects. Some of the properties that are tested include, workability, compressive strength, flexural strength, tensile strength, density, abrasion resistance, modulus of elasticity, water absorption, water penetration, sulphate resistance, acid resistance and chloride permeability. SEM and XRD microstructural are also used to get the insight on the internal matrix and hydration processes. The results of this research are meant to prove that the synergies of the industrial waste materials have the potential to generate durable, cost-effective and eco-friendly concrete that can be used in construction business in the modern times.

II SURVEY OF RESEARCH

Granite Powder as a Replacement of Fine aggregate [1].

Vijayalakshmi et al. (2013) analyzed the concept of granite powder used in place of a natural river sand in concrete. Their study showed that the granite powder possesses angular and rough-textured particle which consequently reduces the workability of that powder but increases the mechanical properties when in controlled proportions. The authors reported that compressive, flexural and splitting tensile strength was enhanced owing to the enhanced effects of interlocking of particles and fill-in of the void. Arivumangai and Felixkala (2014) also quoted that the compressive strength was improved by approximately 9 percent when fine aggregate was replaced by 25 percent granite powder over conventional concrete. Similarly, the validity of granite cutting waste was confirmed by Singh and Nagar (2016) when the analysis of SEM and XRD was applied, which is more dense microstructure. The overall conclusion of the studies is that granite powder could make an alternative to natural sand in order to make it stronger and more sustainable and solve the environmental issues that surround the disposal of granite wastes.

[2] Granite Powder Concrete performance in Durability.

The use of concrete in granite powder has been researched concerning its characteristics of durability by several researchers. Ghannam et al. (2016) observed that a higher percentage of the fine aggregate (15) was replaced by granite powder, which enhanced the splitting tensile strength by nearly a third and reduced porosity that enhanced durability. The research conducted by Singh et al. (2017) on the abrasion resistance revealed that the by-products of the granite industry were significant towards reducing the abrasion loss due to the increase in the surface hardness. It was noted that the higher resistance to sulphuric acid and chloride environment was observed in the case of the addition of

granite powder to the mixture, which was explained by the reduced permeability and a refined structure of the pore (Ghorbani et al., 2019). The Gupta and Vyas (2018) microstructural analysis confirmed that cementitious matrices were also denser and had few pores attached. They are the results which prove that granite powder may not only enhance strength, but also significantly enhance the resistance to the negative environmental conditions.

[3] Glass Powder: Substitution of Cement partially.

Aliabdo et al. (2016) explored the application of waste glass powder as a substitute of cement and estimated that it possessed a clear pozzolanic activity due to the content of silica in large quantity. They discovered 10-15% glass powder substitution to improve compressive and tensile strengths with generation of additional calcium silicate hydrate (C-S-H) gel. Flexural strength was found to be denser and stronger at 21% replaced by glass powder Bisht and Ramana (2018). Similarly, Islam et al. (2017) determined that the compressive strength was increased and the alkali-silica reaction concerns decreased with the replacement of 20 percent of cement with a transparent or coloured glass powder. Enhanced Particle arrangement and minimization of pores were determined through microscopic analyses. Such pieces of evidence indicate that grounded glass powder can be effectively utilized to reduce cement and enhance the performance of concrete in terms of mechanical and stability.

[4] Durability: Glass powder based concrete.

This has extensively been publicized on the longevity benefits of the glass powder in concrete. Du and Tan (2017) established that the absorption of water and increase of microstructural density decreased as the percentage of glass powder replacing cement increased to 30%. Harbec et al. (2017) investigated the use of glass fume as a pozzolanic substance and found it to have superior resistance to

chloride ingress and sulphate attack at later ages due to the prolonged pozzolanic activity. Liu et al. (2018) conducted a rapid chloride penetration test, and they passed lower charge in glass powder concrete, which implies that permeability was lower. The outcomes of SEM and XRD have confirmed the development of novel C-S-H gel and enhanced pore structures. The findings demonstrate that the glass powder is a viable alternative cementitious material to be used in addition to the concrete that is long-term and durable.

[5] Fly Ash as another Cementitious Material.

A study by Shirule et al. (2012) shows that compressive, tensile, and flexural strengths are improved in long-term pozzolanic reaction when a fly ash is used in the place of cement at a 25 percent ratio. Carette, et al. (1993) have known that high volume fly ash concrete was less permeable and water absorbing because the pore was refined. Similarly, Siddique et al. (2004) determined that the incorporation of 35 percent Class C fly ash was very considerable to pore size distribution, which enhanced durability. Naik et al. (2014) also confirmed that fly ash increases the resistance thematic of chloride permeation and sulphate assault. These studies are all indicated to point to fly ash as one of the environmentally friendly binders that enhance the cement durability, though reduces the CO₂ released.

[6] Marble Powder filler Material in concrete.

As a filler material, marble powder has been contributed by different scholars. In Binici et al., (2007) 10 percent of the fine aggregate was replaced with marble powder, the compressive strength was maximum due to increased packing of the particles. Belaidi et al. (2012) experienced a growth in workability and mechanical performance when substituting cement using marble powder (less than 10-percent). As Arel (2016) highlights, the marble powder reduced micro-cracks and porosity and led to the greater durability. The research on SEM determined that the powder of marble fills in between the matrices and enhances compactness. These studies confirm that marble powder can be used as an

excellent filler substance that will increase strength, durability and sustainability.

[7] Incineration in Concrete of Industrial Wastes.

Recent investigators are also interested in the combined use of various industrial waste products in the development of concrete on a sustainable basis. Lakshmi et al. (2013) established that the granite powder that was combined with fly ash reduced the porosity and increased the strength. The findings of a research conducted by Raghavendra et al. (2015) were that granite powder combined with other cementitious materials such as fly ash and silica fume had a 25 percent higher compressive strength compared to control mixes. The findings of Bacarji et al. (2013) were that a mixture of granite powder and marble powder increased the density and permeability. These tests demonstrate that synergistic effects are achieved when waste materials are compounded that lead to high mechanical properties and durability performance and putting into consideration issues of the environment and waste management.

III MATERIALS AND METHODS

The chapter outlines the characteristics of the different concrete constituents as they include cement, sand, admixtures, granite powder and glass powder. Additionally, guidelines are observed in various mechanical and durability test carried out in the course of the experiment study.

Blended Portland Cement (BPC)

The concrete in this study and what has been stipulated in the provisions of the IS 8112:2013 have been adhered to using the Ordinary Portland Cement (OPC) 43 grade as the primary binder in the concrete. Table 3.1 encompasses the index properties of OPC that are bulk density, modulus of fineness, initial setting time and final setting time and specific gravity. The fineness of the OPC was determined as per the procedure, as suggested in the IS 4031 (Part 1):1996. Table provides the chemical composition of OPC 43 grade.



Fig.1. OPC 43-Grade (Cement)

Property	Cement
Water absorption (%)	2.55
Specific gravity	3.15
Bulk unit weight (kg/m ³)	1440
Fineness modulus (FM)	2.25
Initial setting time (minute)	64
Final setting time (minute)	125

Coarse Aggregate (CA)

Course aggregates are required in a concrete because they form the main strength and rigidity. Angular shaped and rough-textured CA was obtained in this study in the region of Hathipura, Rajasthan, India. The sieves that were utilized in the study consisted of those with a size of between 4.75 mm up to 20 mm. They were graded according to the IS 386:2016. The distribution of the particle size of CA is presented in Fig. The density, water absorption and specific gravity of 10 mm and 20 mm aggregates are summed up in the index properties.



Fig.2. CA in 10 mm & 20 mm size

Fine Aggregate (FA)

River sand is traditionally employed in the concrete because it occupies the pores of CA and helps to develop the strength. In this study, natural sand was collected in the Banas River, Rajasthan, and India. It was graded in accordance with IS 383:2016, and the analysis was performed to prove that the sand was of Zone-II. Granite powder (GrP) was also chosen instead of natural sand. The source of GrP was the industrial regions of Kishangarh, Ajmer, and Rajasthan and was tested according to the IS 383:2016 and then it was used in the concrete. The physical nature of river sand and GrP is provided and the particle size distribution is illustrated in Fig. 3. The chemical structures of GrP and sand.



Fig.3. Fine aggregate (natural sand)

Granite Powder (GrP)

Granite sand, procured at the processing units around Kishangarh, Jaipur, Rajasthan was taken as a substitute to natural sand after a 4.75 mm sieve. Tables provide its physical properties. SEM analysis of grp and river sand as shown in Fig, suggests that the grains of granite are rough and irregular, whereas the grains of natural sand are smooth and rounded in nature. They were both studied using SEM under 500X magnification. The XRD analysis was also used to determine the mineral compositions of GrP and river sand with results being plotted in Fig. The chemical characteristics of sand and GrP.



Fig.4. Glass and granite powder.

IV METHODOLOGY

Materials Selection and Characterization

The present study starts its methodology with the selection and characterization of raw materials to guarantee constancy and reliability of the experiment outcome. The primary binder was Ordinary Portland Cement of 43 grade that met the requirements of IS 8112. The reference fine aggregate was natural river sand (Zone II), whereas granite powder obtained in granite processing industries was partially used as a substitute of sand. Preparation of waste glass powder was done by crushing and grinding of discarded glass bottles and sieving using 45-micron sieve to produce pozzolanic activity. The supplementary cementitious material (fly ash) was obtained in thermal power plants, whereas the filler material (marble powder) was obtained in marble cutting industries. The coarse aggregate of 10 mm and 20 mm were used according to IS 383. Standard tests were carried out to assess physical and chemical properties of all materials, and microstructural features were analyzed with the help of SEM and XRD to know more about the morphology of particles and the mineral composition.

Mix Design and Concrete Preparation

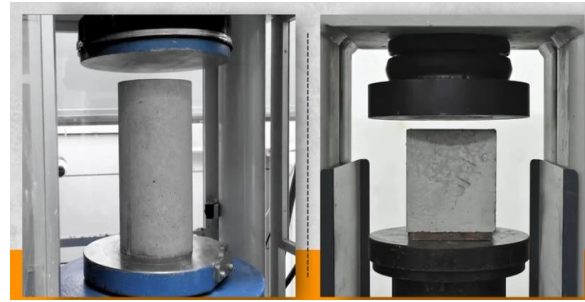
The mix design of concrete was done according to the rules of the IS 10262:2009. The experimental program was performed in two stages. The first phase involved the use of glass powder in place of cement with percentages of 0 to 25 and granite powder in place of natural sand with percentages of 0 to 50, at a time and in both combination. There was a fixed dosage of superplasticizer and constant water-binder ratio to have the same workability. The second step involved adding the

optimum levels of fly ash (20 percent) and marble powder (10 percent) to the blends of chosen glass-granite powders to add pozzolana and filler properties. A concrete mixer was used to mix all ingredients in order to get homogenous mixes. The fresh concrete was casted in regular molds and smoothed accordingly to ensure that no air was trapped. Demolding was done after 24 hours and curing was done in water until the specified testing ages.



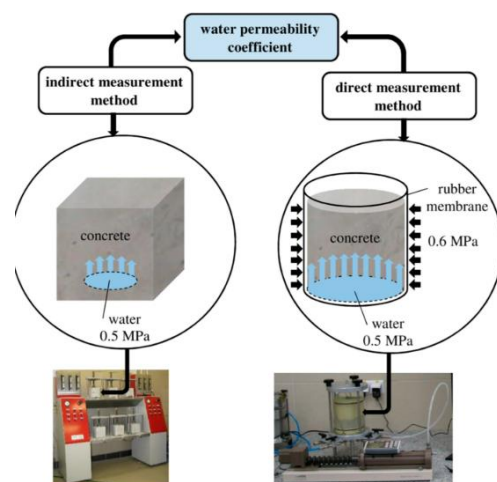
Testing of Fresh and Mechanical Properties

The slump test was used to measure fresh properties of concrete according to IS 1199 to determine the workability variation by varying replacement levels. The concrete properties were tested as hardened concrete based on compressive strength, flexural strength, and splitting tensile strength tests at different curing ages and as required by the IS 516 and IS 5816. Compactness was assessed by the density of hardened concrete, where oven-dried specimens were used in determining the density. Surface hardness and elastic behavior of concrete was also determined through a determination of abrasion resistance and modulus of elasticity. Each mix was tested on multiple specimens and average values were reported to be accurate. These tests allowed making a comparative evaluation of the strength formation and mechanical work of control and blended concrete mixes with industrial waste materials.



Durability and Microstructural Evaluation

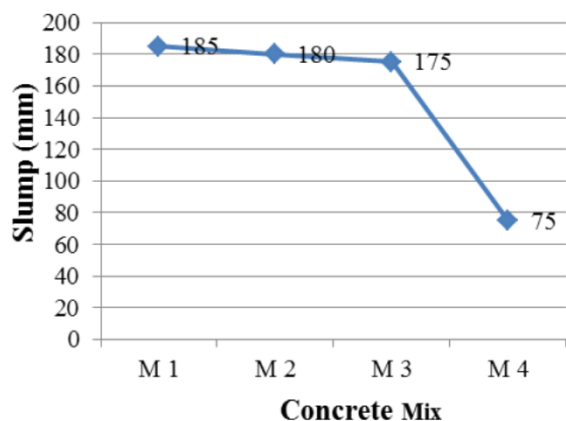
The concrete performance in regard to durability was assessed with respect to water absorption, water penetration, sulphate attack, acid attack and rapid chloride penetration test (RCPT) per the relevant standards of ASTM and DIN standards. These tests evaluated the resistance of the concrete to the adverse environmental conditions. To measure durability behavior, weight loss, strength loss, and depth of penetration were measured. Also, microstructural studies on the selected specimens were performed by scanning electron microscopy (SEM) and X-ray diffraction (XRD) in order to analyze pore structure, hydration products, and mineralogical phases. SEM pictures gave the idea of the packing, the distribution of the voids, and the bonding properties of particles, and XRD patterns proved the presence of more hydration compounds. This thorough methodology had ensured an in-depth study of the structural, durability, and sustainability performance of concrete with granite powder, glass powder, fly ash and marble powder.



V RESULTS ANALYSIS

Workability and Density Analysis

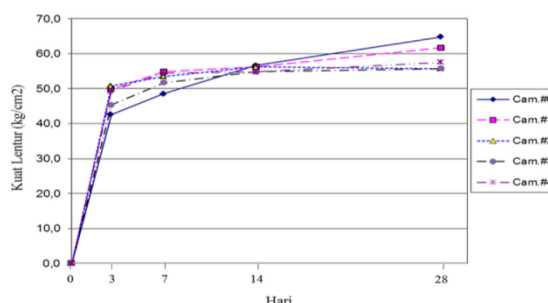
The slump test was used to assess the workability of concrete, and the findings showed opposite trends with the glass powder (GP) and granite powder (GrP) mixes. The concrete that contained glass powder showed slow growth in the values of slump as the content of replacements increased to the maximum workability of 25% GP replacement. This is because the amount of water that is absorbed and the surface texture of glass particles are reduced hence increasing flowability. Conversely, replacement with granite powder led to low slump since it is angular, rough and required more water. The GP-GrP mixes exhibited moderate workability when combined implying a compensating effect between the two materials. The density of hardened concrete showed a gain up to maximized replacement levels (20% GP and 30% GrP) which was due to better packing of the particles and minimized void. The levels further decreased at density beyond these levels since there were excess fines and less cementitious content. This means that optimal ratios of GP and GrP increase compactness without having negative impact on workability.



Mechanical Strength Performance

Strength tests including mechanical strength tests showed high improvement of compressive, flexural, and splitting tensile strength on concrete mixes of GP and GrP at optimum levels. The compressive strength also improved with the replacement of the glass powder up to 20 percent due to the reaction between the calcium hydroxide and the powdered calcium

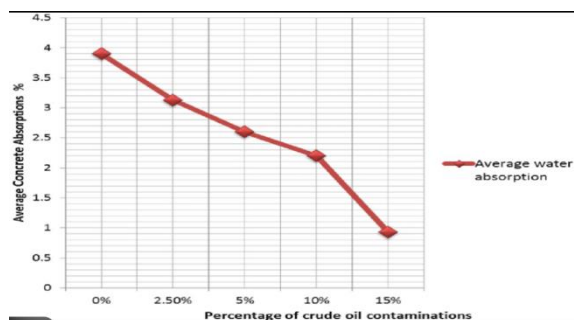
silicate as a pozzolan resulting in further C-S-H gel. Replacement by granite powder enhanced its strength to as much as 30 percent and this was attributed to the fact that the granite powder created better interlocking and filler properties that minimized the internal voids. The combined mixes of Gp-GrP mixes performed better than the individual replacements and the GP15-GrP30 mix recorded the highest strength values. Flexural and splitting tensile strength also showed similar trends, which ensured better bond between agencies and cement paste. Nevertheless, the replacement levels were too large leading to loss of strength through cement content dilution and water demand. On the whole, the strength results show that the controlled addition of GP and GrP has high effect on enhancing the structural performance.



Durability Performance Evaluation

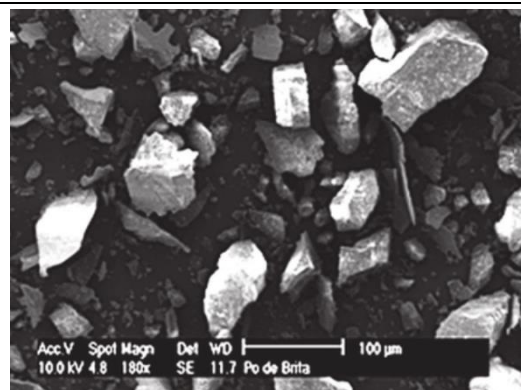
Test results of the durability showed significant results of the resistance of the blended concrete mixes to aggressive environmental conditions. Optimal GP and GrP replacement levels reduced water absorption and depth of water penetration which characterize a decrease in porosity and fineness of pore structure. An acid and sulphate attack test revealed that the GP-GrP concrete exhibited lower strength degradation than the control mix illustrating superior chemical resistance. The results of Rapid Chloride Penetration Test (RCPT) showed that the amount of charge passed on blended mixes was significantly reduced, which means that chloride ion permeability was also reduced. An addition of fly ash and marble powder also increased durability by increasing densification of the matrix and long term activity of the pozzolans. This proves that in addition to enhancing strength, the materials of industrial waste in question are

also very effective in making the concrete last longer and thus can be used in harsh environments.



Microstructural and Overall Performance Analysis

SEM and XRD methods of microstructural analysis were used to give good support to the mechanical and durability performance observed. SEM images of GP- and GrP-modified concrete demonstrated that there is a tighter microstructure and fewer microcracks and that the connectivity between the pore is less than that of control concrete. Granite powder and marble powder played the role of filler effect that filled the voids with the help of glass powder that helped in the secondary reactions of hydration. The XRD examination revealed that more hydration products were formed especially the calcium silicate hydrate which increased bonding and strength. The integration of the GP, GrP, fly ash and marble powder resulted in synergy effect which resulted in better performance. According to both experimental and microstructural findings, the paper concludes that optimal quantities of industrial waste material as replacement material can result in high performance, durable, and sustainable concrete, and that minimizes the environmental impact of concrete dramatically.



CONCLUSION

The current experiment has managed to show that it is possible to make sustainable and high-performance concrete using the collective use of industrial wastes like granite powder, glass powder, fly ash, and marble powder. When experimental findings have been conducted, it is clear that the partial replacement of natural river sand with granite powder and cement with glass powder enhance considerably the mechanical and durability properties of concrete when optimum proportions of each are used. Glass powder increased workability and helped develop strength via pozzolanic reactions and the granite powder enhanced the packing and interlocking of particles resulting in increased density and strength. The use of fly ash further enhanced the pore structure and enhanced long-term durability, and marble powder was used effectively as a filler to minimize the micro-voids and enhance compactness of the matrix. The test of durability proved enhanced water penetration resistance, chloride ingress resistance, acid attack resistance and sulphate attack resistance were better in blended mixes than in conventional concrete. SEM and XRD microstructural analysis confirmed the creation of compact and more homogenous cementitious matrix composition with the added hydration products. In general, the research makes a conclusion that the efficient utilization of such waste materials not only decreases the utilization of traditional cement or natural sand but also provides the solution to environmental and waste disposal problems, thus, the concrete developed could be considered as an ecologically friendly, cost-effective, and

sustainable alternative to the contemporary construction methods.

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