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Original Article

Green Concrete Using Industrial Waste Materials

Dr. Mohammed Asif Khan[1], Dr. Shalini Gupta[2]

[1]*Professorof, Jamia Millia Islamia, India.*

[2] *Associate Professor, Panjab University, India.*

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ABSTRACT

The construction industry has been ranked among the biggest consumers of natural resources and added to greenhouse gas emissions, which has been mainly precipitated by the high use of Portland cement and natural aggregates in the traditional concrete. Over 8% of all carbon dioxide emissions in the world are contributed by cement production, which drives the necessity to find sustainable alternatives to the same. Green concrete has become a viable option through the use of industrial waste resources including fly ash, ground granulated blast furnace slag (GGBS), silica fume, rice husk ash and recycle aggregates to minimize the environmental impact without affecting or improving the mechanical and durability characteristics. This paper involves a thorough research on the producing of green concrete using industrial waste materials of choice as part-replacement of cement and natural aggregates. Their studies are directed at the characterization of the materials, mix design procedure, fresh and hardened concrete features, and the durability. Most of the replacement levels are studied to come up with the best proportions that would be sustainable and performance-focused. The results of the experiments have shown that the recycling of industrial waste materials leads to a significant decrease in carbon emissions, better long-term strengthening, and resistance to aggressive environmental factors. The results show that green concrete will be able to support structural performance demands and at the same time add to the sustainable construction practice. The paper has presented useful knowledge to researchers, engineers, as well as policymakers who need to advance the use of environmentally friendly construction materials in accordance with the sustainability objectives of the world.

KEYWORDS

Green Concrete, Industrial Waste Materials, Fly Ash, GGBS, Sustainable Construction, Eco-Friendly Concrete.

1. INTRODUCTION

1.1. Background

Modern infrastructure development could not be achieved without concrete as the most used construction material with great versatility, durability, and cost-effectiveness in the whole world. The field of its application in buildings, bridges, pavements, and dams, and other objects of civil engineering is very vast because of the possibility to shape it in the required form and due to its possibility to endure the high severity of the environment. Nonetheless, urbanization and industrialization have substantially escalated the rate of concrete demand, which has impacted on the amount of consumption of major materials used in making concrete cement, aggregates and water that have been overused. This increasing demand has brought about serious environmental concerns relating to the production and use of the conventional concrete. Ordinary Portland Cement (OPC), a major constituent of concrete is especially a material that consumes too much energy to produce. The process of production is the calcification of limestone by using high temperatures of flaming, which does not only use much energy in the form of the fossil fuel, but also emits a high amount of carbon dioxide into the atmosphere. Cement production in itself contributes more or less percentage of the overall CO 2 in the world contributing to the climatic change and global warming. Besides greenhouse gases, cement production is known to be associated with consuming large quantities of energy and exhaustion of non-renewable natural resources. Moreover, analysis of natural aggregates like sand and crushed stone has an adverse effect on the environment. The major impacts associated with the practice of the behemothic quarrying and river sand mining include land degradation, deforestation, biodiversity loss and changes in natural ecosystems. Over sand mining also impacts on riverbeds and underground water levels leading to erosion and unbalance of the ecology. Such environmental impressions confirm the fact that sustainable alternatives and new innovative ways of building are needed very much. As a result, there has been a need to develop and implement materials that are environmentally friendly like green concrete in which the ecological footprint of the construction sector is lowered with the population of infrastructure demands increasing.

1.2. Role Of Industrial Waste Materials

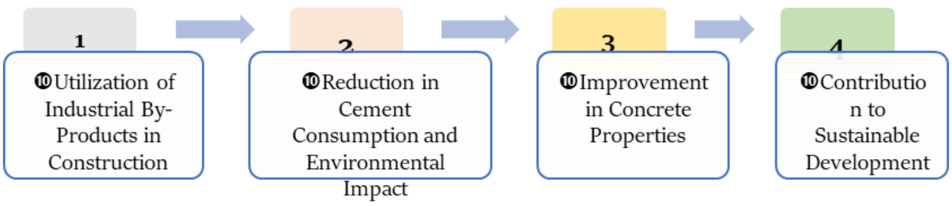

Fig 1 - Role of Industrial Waste Materials

1.2.1. Utilization of Industrial By-Products in Construction

The fly ash and the Ground Granulated Blast Furnace Slag (GGBS), silica fume among other by-products produced by thermal power plants, steel industries and manufacturing centers in large amounts. Conventionally, such materials were regarded as waste and they were either placed in landfills or ash ponds causing severe environmental and land-use issues. Another practical answer to

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the waste management problem is their use in the construction sector especially in manufacturing of concrete thus cutting down the usage of the traditional raw materials.

1.2.2. Reduction in Cement Consumption and Environmental Impact

The fact that industrial waste materials partially substitute Ordinary Portland Cement in a concrete is one of the most important functions of the waste materials. As a significant polluter of carbon dioxide, the use of cement as a production solution may be substituted by industrial by-products, which would immediately help reduce the amount of greenhouse gases and energy use. Compounds like fly ash and GGBS contain pozzolanic or latent hydraulic qualities and therefore are able to take part in hydration reactions and initiate the formation of strengths hence cutting down on the total cement requirement without affecting performance.

1.2.3. Improvement in Concrete Properties

The industrial waste products are also significant in improving the mechanical and the durability characteristics of the concrete. Fly ash enhances the workability and long-term strength whereas the GGBS enhances the durability, permeability, and chemical resistance. Such materials contribute to a increased microstructure, a refined pore structure as well as enhancement of resistance to environmental degradation thus culminating into an increased service life of the concrete structures.

1.2.4. Contribution to Sustainable Development

There is a balance between the concept of sustainable development and the circular economy, and the inclusion of industrial waste products in concrete. It will ensure that there is effective use of resources, less disposal of landfills, less use of natural resources and less environmental degradation due to the extractions activities of the raw materials. Therefore, the waste products of industry are highly important in the creation of green concrete that facilitates the green construction practice and would support the establishment of sustainable infrastructure.

1.3. Green Concrete Using Industrial Waste Materials

Green concrete is a concrete that is environmentally friendly that uses industrial waste materials as partial substitutes to traditional constituents including cement and natural bases. The main aim of green concrete is to minimize the environmental effects of the conventional concrete production process without diminishing or degrading its mechanical and structural durability qualities. The ex-products of industries like fly ash (thermal power plants), Ground Granulated Blast Furnace Slag (GGBS) (steel industries), silica fume (silicon manufacturing) are the commonly used agents of green concrete because they have cementitious or pozzolanic properties. The efficient usage of these materials can be employed to solve the twofold problem of disposing of waste materials and conservation of resources. By adding waste materials of industries in green concrete, the amount of Ordinary Portland Cement is greatly minimized since this is among the most energy-consuming and carbon-releasing material to be used in construction. Green concrete will have a significant impact in carbon dioxide emissions reduction and reduced energy usage by partially replacing cement by the

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use of fly ash and GGBS. Moreover, these substances enhance the microstructure of concrete by increasing the supplementary calcium silicate hydrate with the help of pozzolanic and latent hydrolysis reactions, which provide the increased strength and life cycles. There is also the advantage of green concrete with regard to better durability conditions as compared to conventional concrete. It is the industrial waste substances that increase the refined pore structure and lower the permeability which, in turn, raises the resistance to chemical attacks, sulfate exposure and ingress. Such enhancements have the effect of prolonging service life and also a decrease in the maintenance of the concrete structures. Moreover, industrial waste materials are used to facilitate sustainable construction activities through conservation of natural resources, minimization of landfill wastes, and lessening environmental degradation due to extraction of the raw materials.On the whole, the use of industrial waste materials as green concrete is a potential opportunity and a green solution with regards to the existing concrete. Its implementation in the contemporary construction can be used to sustain the development of infrastructure in a friendly environmental way, adhering to the global sustainability and lowering the environmental impact of the construction sector on the environment without affecting the structural performance.

2. *LITERATURE SURVEY*

2.1. Fly Ash in Green Concrete

Fly ash Gray-brutal by-product More Fly ash is a fine dust that is produced by combustion of ground coal in thermal power plants and has been applied a lot as an additional cementitious material in green concrete. Because of its pozzolanic property it is able to reconnect with calcium hydroxide emitted throughout the cement hydration process to construct further calcium silicate hydrate gel to enhance better long-term strength and durability. Most of the researchers have found that the incorporation of fly ash improves the workability because it is in form of a ball bearing bearing in the midst of the concrete mass, because it has a spherical particle form. Substitution levels of between 20-40 percent by weight of cement have actually shown positive results in terms of lower heat of hydration, cracking resistance and sustainability in terms of lower carbon dioxide emission that are related to cement production.

2.2. Ground Granulated Blast Furnace Slag (Ggbs)

Ground Granulated Blast Furnace Slag is a latent hydraulic material, which is produced as an elucidate in the production of iron. GGBS when utilized in a partial replacement of cement plays a key role towards enhancing the concrete durability. Scientists have noted that the concrete using GGBS has lower permeability and porosity thus with greater ability to withstand external hostile environment factors like sulphate corrosion and chloride intrusion. It has been reported to offer optimum performance when replacement to a level of 50% cement is done especially in mass concrete and marine structures. Further on, GGBS decreases the heat of hydration and enhances the development of strength over the long-term, which makes it a viable material to build the construction in a sustainable and long-standing manner.

2.3. Silica Fume

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Silica fume is a by-product of production of silicon and ferrosilicon alloys of ultra-fine size mainly composed of amorphous silicon dioxide. Silica fume is a pozzolanic material and a micro-filler because of its very fine particle size and mass, and high surface area, it contributes greatly to the density of the concrete matrix. The addition of it leads to a significant enhancement of compressive strength, tensile strength and permeability resistance due to the optimization of the pore structure. But utilization of silica fume is also likely to decrease the workability, raise the demand of water so the utilization of superplasticizers and effective dosage control is essential. Generally, the silica fume is added in low percentages of between 5 to 10 percent of cement content to give optimum outcomes without affecting fresh concrete properties.

2.4. Recycled Aggregates

Recycled aggregates are made out of construction and demolition wastes and form a sustainable substitute of natural aggregates as landfill disposal and consumption of natural resources! Recycled aggregates have been utilized widely in green concrete where the results showed that the level of mechanical strength had reduced marginally than in concrete which utilized recycled aggregates. This is mainly because there are adhered old mortar and greater absorption of water to the recycled aggregates. Nonetheless, research conducted has indicated that the loss of strength can be effectively eliminated through proper mix design modifications, like application of additional cementitious materials, better management of aggregate processing, and the water to cement ratios. Recycled aggregate concrete has been discovered to suit structural and non-structural applications in case it is designed correctly.

2.5. Research Gaps

Although there is a large body of literature on the topic of green concrete with the use of additional cementitious materials and recycle aggregates, there are still gaps in the research. The main weakness is that there are no standardized mix design processes that can consider the variability of industrial by-products and recycled materials. Moreover, the majority of the existing studies are laboratory-scaled investigations, there is not much long-term field performance data to be found to determine durability at actual environmental conditions. The synergistic interactions of various green materials concurrently taken are to be explored as well. To resolve these gaps, it is necessary that systematic experimental research and long-term observations are made to enable more people to adopt green concrete in the mainstream construction industry.

3.METHODOLOGY

3.1. Materials Used

The materials employed in the current research were selected well to give consistency, reliability and adherence to the relevant standards in the manufacture of the green concrete. Ordinary Portland Cement (OPC) of grade 53 was the bind material that was primarily employed. OPC 53 grade is very popular in the field of structural concrete because of early strength development and stable quality. The cement was of specific gravity of 3.15 which is normal in Portland cement and shows a good fineness and health and this leads to the efficient hydration of the

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concrete and the formation of strength. It was a supplemental cementitious material, fly ash which was obtained at a thermal power plant. It currently possessed a specific gravity of 2.2 which is low compared to that of cement since it contained smaller and lighter particles. Fly ash does not only increase the concrete sustainability by decreasing cement usage but also improves workability and long-term strengths as it reacts as a pozzolanic substance with the calcium hydroxide that is emitted during cement hydration. The sphericity of its particle shape adds value in packing the particles and to water demand. Particular replacement of cement was also done with Ground Granulated Blast Furnace Slag (GGBS) which was obtained as a by-product in the steel industry. Having specific gravity of 2.9, GGBS is a latent hydraulic substance that increases the life expectancy, decreases permeable area, and boosts chemical defense. Its inclusion factors in reduction of heat of hydration and enhancement of long-term mechanical characteristics thus it can be used in the construction of durable and sustainable concrete structures. Fine aggregate was made of natural river sand that had a certain gravity of 2.65. The sand was also clean, of good grade and not contaminated with deleterious impurities like clay, silt and organic contaminants. To attain good workability as well as reduce the amount of voids in the concrete matrix, proper grading of fine aggregate is necessary. The coarse aggregate that was utilized in this experiment was that of crushed stone and its specific gravity was 2.70. It gave the concrete the required strength and stability guaranteeing satisfactory transfer of loads and structural overall performance. All the materials were checked and tested in accordance to standard requirement.

3.2. Mix Proportioning

In the current study, mix proportioning was done with the aim of developing a balanced mix of strength, durability, workability, and sustainability in green concrete. Supplementary cementitious materials which are fly ash and Ground Granulated Blast Furnace Slag (GGBS) were used to partially replace ordinary Portland Cement as the replacement contents of 10 percent, 20 percent, and 30 percent of wt. cement. The percentages of these replacements have been determined after the result of past studies which show that moderate cement substitution percentages could have major positive effects on the concrete performance given a reduction in the environmental impact found in the manufacture of cement. The use of GGBS and fly ash was to use their latent hydraulic and pozzolanic properties, respectively. Fly ash helps in increased workability and growth of strength in the long-term, whereas GGBS helps in increasing the durability and the chemical resistance. Through varying the replacement of the levels, the study will determine how the various binder composition can affect the fresh and hardened properties of concrete as well as to determine which level of mixture has the best proportion to use in order to adopt sustainable construction practices. All concrete mixes were kept at a constant water rate to binder (w/b) ratio of 0.45 so that results could be compared and be uniform. The chosen w /b ratio: it is a balance between sufficient workability and adequate strength development. A consistent ratio of w/b also enables the effect of different degrees of cement replacement to be determined directly without necessarily affect ones water content. In this way, it can be observed that the identified changes in the strengths and durability characteristics can be predominantly explained by the use of fly ash and GGBS. The fine aggregate and coarse aggregate quantities were held constant in all mixes to further remove an effect of binder composition. It was

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mixed properly, using relevant mixing procedures to ensure that all the contents were mixed evenly. Still, the mix proportioning methodology adopted presents a systemized system of assessing the performance of the green concrete partially replacing the cement with industrial by-products.

3.3. Methodology Flow

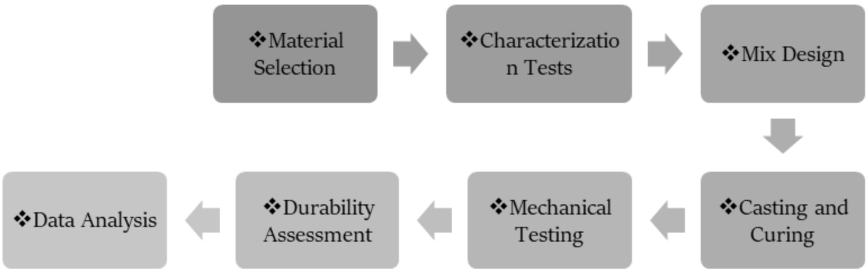

Fig 2 - Methodology Flow

3.3.1. Material Selection

The initial process of the methodology was the selection of raw materials that were to be used in the manufacturing of the green concrete diligently. Ordinary Portland Cement, fly ash and Ground Granulated Blast Furnace Slag, fine aggregate and coarse aggregate were selected depending on their availability, quality and conformity to the relevant standards. Use of industrial by-products which included fly ash and GGBS were highlighted in the selection to improve on sustainability and guarantee that all materials were having the right physical and chemical qualities to produce concrete.

3.3.2. Characterization Tests

There was selection followed by characterization tests on all the materials in order to establish their physical properties. Specific gravity, fineness, and water absorption tests were done to determine the quality and suitability of materials. These tests were critical as their input data was important to mix design and could also guarantee consistency in behavior of materials when mixing, casting and hardening of concrete.

3.3.3. Mix Design

Characterization tests were conducted and based on the outcome of the tests, the concrete mix design was done. A set percentage amount of cement was substituted with fly ash and GGBS whilst keeping the ratio of water to binder constant. The mix design focus was to ensure that the workability, strength, and durability were met as well as the reduction of the supplementary cementitious materials as a factor in the production of concrete that is sustainable.

3.3.4. Casting and Curing

The concrete specimens were made by mixing all the constituents appropriately in all cocktailed proportions and pouring it in standard molds. Compression was done correctly to remove air pore and get an even-density. The specimens were demolded in 24 hours to allow the material to

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dry after casting and to cure under controlled conditions, usually in water, which contributes to the development of strength and hydration.

3.3.5. Mechanical Testing

Mechanical tests were done to determine the strength features of the concrete mixes. Other tests like compressive strength were done at given curing age to determine the effect of the replacement levels of fly ash and GGBS on the load bearing capacity of concrete.

3.3.6. Durability Assessment

Durability tests to analyse the concrete resistance to the environment were conducted. Such parameters as permeability, water absorption, vulnerability to chemical assault were considered to find out the long term functioning and usability of green concrete.

3.3.7. Data Analysis

The results of the experiment in mechanical and durability tests were analyzed and compared in a systematic manner. The analysis of data was aimed at identifying trends to determine effectiveness of cement replacement levels and finding the best mix proportion that can provide better performance and sustainability.

3.4. Testing Procedures

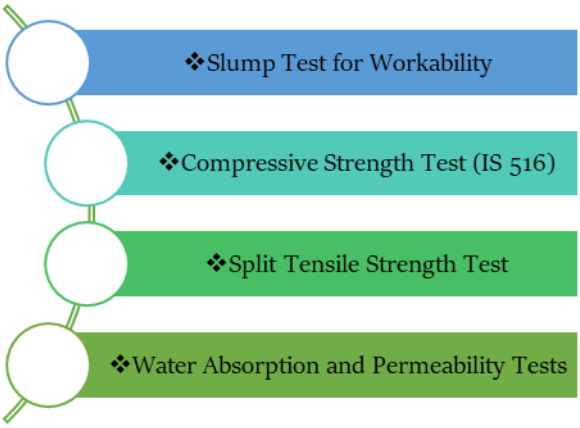

Fig 3 - Testing Procedures

3.4.1. Slump Test for Workability

Slump test was done to examine the workability and uniformity of fresh concrete mixes. This test is a fast and effective determination of the ease of concrete mix, placing, and compacting. A standard slump cone was used to conduct the test in line with the available codes of practice. The concrete was then poured into the cone in layers that were duly compacted with every layer being raised up. The slump value was taken as the decrease in height of the concrete which expressed the workability of the mix.

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3.4.2. Compressive Strength Test (IS 516)

Compressive strength test was conducted as per IS 516 to find out the weight bearing capacity of hardened concrete. Cube specimens of standard size were casted, left to harden of certain lengths, and then experimented with with a compression testing machine. The load was applied at the same rate until it failed and recorded the maximum load. Dividing the force that was applied by the cross-sectional area of the specimen gave the compressive strength, an important measure of the strength of concrete.

3.4.3. Split Tensile Strength Test

Split tensile strength test was carried out to judge the tensile behavior of concrete that is significant to learn the resistance to cracking. Cylindrically shaped specimens were removed in a compression testing apparatus in the horizontal position and compressive weight was exerted along the diameter. Tensile stress was induced which led to the specimen dividing vertically and standard calculation formulas were used to determine the tensile strength.

3.4.4. Water Absorption and Permeability Tests

The water absorption and water permeability tests were conducted to determine the durability properties of concrete. These are testing the capabilities of the concrete to prevent water intrusion that have a direct impact on the overall performance and the strength of the concrete against the deterioration in the long run. The reduced values of water absorption, and permeability imply a higher density of concrete matrix and enhanced durability of concrete in aggressive environments it is especially prone to.

3.5. Governing Equations

Compressive strength of concrete is among the most significant mechanical properties that are used to assess structural performances of concrete. It is the capacity of concrete to enable structural stability against compressive pressure to failure and is typically obtained by subjecting standard specimens to laboratory examinations. The compressive strength of this study was obtained by the use of a basic governing relationship divides the force that was applied upon failure by the cross-sectional area of the test specimen. Compressive strength is simply said to be the weight that is supported and the weight supported per unit area at the point of failure. The compressive strength test involves placing a concrete specimen, another concrete, normally in the form of cube or cylinder, which has undergone due time under proper conditions up to the time of compression testing. The load is gradually increased steadily across the specimen up to its failure. The applied load indicates the maximum load which the specimen will hold at the failure point. This load represents the internal resistance of the concrete to compression and depends on such factors like the composition of materials, conditions of curing, and the concrete age. The governing equation is compressive strength= applied load/ cross-sectional area of specimen where this compressive strength is applied. The force exerted is described by newtons and the size of the cross section is described by millimeters. When the load that is applied is divided by the area, the value obtained constitutes stress

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that is expressed in megapascals. This point is recorded to be the compressive strength of the concrete. This equation can be used to obtain a similar and standard examination of concrete strength between various mixes and testing conditions. Due to the consistency of the dimension of specimen and testing, changes in compressive strength can be directly linked to changes in material composition, including partial replacement of cement by fly ash and GGBS. The governing equation is therefore a basic instrument used in the appraisal and comparison of the performance of various concrete mixtures in a scientific and consistent way.

4. RESULT AND DISCUSSION

4.1. Workability Results

Table 1: Workability Results

Mix ID	Replacement (%)	Slump Increase (%)
CC	0	0
GC20	20	13.33
GC30	30	20

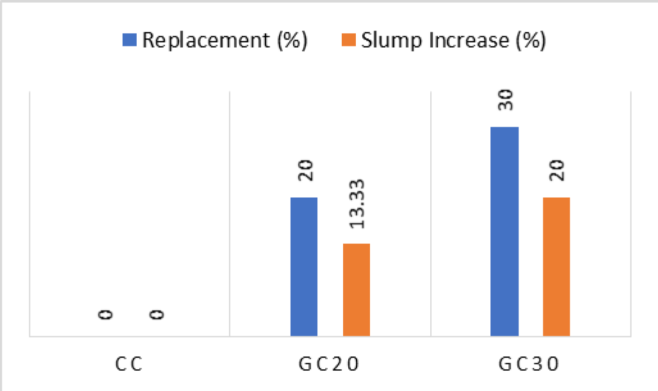

Fig 4 - Workability Results

4.1.1. Control Concrete (CC)

The concrete mix control with 0% cement replacement had 0% slump increase, which was used as a control mix against other mixes. The slump figure that is recorded reflects the natural slump of typical imports and home-made concrete that is ready with Ordinary Portland Cement without the addition of any cementitious aids. This level of workability is the typical behavior of normal concrete and can be used as a standard by which the impact of fly ash and GGBS inclusion can be assessed.

4.1.2. GC20 Mix (20% Replacement)

The mix with a substitution of 20 per cent of the cement with fly ash and GGBS namely GC20 had an increase of 13.33 per cent slump relative to the control mix. This increase in workability is possible due to the smaller sizes and fine, smooth, round shape of fly ash which increases the flow properties of a concrete composition, as the transgression of internal friction or particle-to-particle

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contact is minimized. Having GGBS makes the packing of particles better as well leading to more workable and cohesive mix.

4.1.3. GC30 Mix (30% Replacement)

The greatest increase in slump was 20.00 in the GC30 mix whose percentage cement replacement was 30. The drastic increase in workability means that greater contents of supplementary cementitious products further increase the lubrication effect in the concrete skeleton. Subsequently, this workability allows concrete to be mixed, placed and compacted easily. It is however, positive in view of the fact that even though improved workability is desirable, it needs to be balanced well with strength and durability needs to guarantee overall performance of green concrete.

4.2. Compressive Strength Results

The obtained compressive strength results on various curing ages will give good information on how replacement of partly cement with fly ash and GGBS affects the development of strength of the green concrete. When the control concrete (CC) was at the tendering age of 7 days, the compressive strength of the concrete was at 28.5 Mpa which was better than that of the green concrete mixes. GC20 mix had a strength of 26.2 Mpa with GC 30 mix having a very similar value of 24.8 Mpa. The fact that early-age strength is lower can be explained by the fact that both the pozzolanic and latent hydration of fly ash and GGBS proceed at slower rates than the rapid hydration of Ordinary Portland Cement. These supplementary materials added at the early stages add less to the strength building and thus they lead to a comparatively low compressive strength. Yet another trend was witnessed at an age of 28 days. The compressive strength of the GC20 mix was best with the highest compressive strength at 40.2 Mpa exceeding the compressive strength of the concrete control at 38.6 Mpa. This enhancement denotes the successful addition of fly ash and GGBS to the long-term strength building due to the continuation of pozzolanic and hydraulic reactions. These reactions give rise to the development of more calcium silicate hydrate gel, which satisfies the concrete mass and produces strength. Competitive compressive strength of GC30 mix also showed a strength of 39.1 Mpa in 28 days and it was slightly superior to control mix, and slightly inferior to GC20 . The findings are evident that higher replacement levels will decrease early-age strength, but on the other hand, enhance or do not affect compressive strength long-term. The percentage of replacement which is found to be ideal among the mixes examined is 20 per cent which gives the balance in between early strength and increase in long term performance. The results provide credence to the fact that fly ash and GGBS could be used as a sustainable replacement of cement in green concrete without affecting the structural integrity.

4.3. Durability Performance

The performance of durability is an important parameter in analysis of the long term behavior and the service life of concrete especially in case of alternative material applications and sustainable material. In the current experiment study, the use of green concrete mix with fly ash and Ground Granulated Blast Furnace Slag (GGBS) portrayed better characteristics of durability in comparison to

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the conventional control concrete. The important observations included the decrease in water absorption in green concrete mixes which showed denser and more advanced pore structures. Reduction in water absorption implies that fewer linked pores will occur where ingress of moisture can take place and this lowers resistance to environmental deterioration in concrete. This can further be explained by the fact that the pozzolanic and latent hydraulic reaction of fly ash and GGBS enhance the superior quality of green concrete. These additional cementitious components react with the calcium hydroxide generated during cement hydration in providing more calcium silicate hydrate gel. This secondary gel occupies the capillary pores and voids in the concrete matrix that causes decreased permeability and compactness. Not only does the refinement of the pore structure reduce the movement of water, but also reduces the infiltration of a detrimentary ion, including sulfates and chlorides that may induce chemical degradation and reinforcement corrosion. Green concrete mixes performed better in terms of sulfate resistance, since the accessibility of calcium hydroxide, tricalcium aluminate phases, which are the leading factors in sulfate attack, were low. In specific GGBS, it is known to enhance sulfate-rich environment resistance by formulating a more stable and less reactive cementitious structure. That is why green concrete is particularly applicable to the applications that have hostile environments like marine structures, sewage systems, and foundations in sulfate-bearing soils. In sum, it is possible to note that the decrease in the water absorption and increased ability of green concrete to withstand sulfate attack reveals the promise of this construction material to be a long-term sustainable solution in construction. These findings prove that incorporation of fly ash and GGBS do not only offer environmental benefits but also make concrete structures to be more efficient in terms of performance and durability in the long run.

4.4. Environmental Impact Assessment

A clear advantage of the concrete mixes in terms of sustainability is indicated in the environmental impact analysis of the mixes whereby partial replacement of cement with fly ash and Ground Granulated Blast Furnace Slag (GGBS) has been made. The process of production of cement can be recognized as one of the greatest sources of carbon dioxide consumption in the world because of the energy-consumptive production of clinker and the process of calclination of lime. With this, one can create a considerable decrease in embodied carbon by cutting down the cement content in the concrete mixes. Green concrete has been proved to be environmentally effective as seen in the current research where using secondary cementitious materials in place of cement led to a CO 2 mitigation rate deemed to be about 25-40 percent. Fly ash and GGBS are industrial wastes which do not need any further processing as compared to cement. Not only do they lower the cement demand since they are used in a concrete but they also assist in the proper management of the industrial waste which would have been disposed of in landfills. This two-fold advantage has the purpose of conserving the natural resources and minimizing the environmental impact of dumping of the waste. Besides, the reduced energy consumption involved in processing them leads to a significant reduction in the greenhouse emissions during the life cycle of concrete production. The decline in CO 2 emission is exaggerated whereby in mixes of 20 percent and 30 percent replacement of cement, there is amplification in CO 2 emission. These blends showed that it is possible to apply the same mixes without interfering with the mechanical and durability of concrete to attain meaningful gains on the

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environment. The use of supplementary cementitious materials in addition to the reduction of carbon emissions also enhances a decreased use of energy, limestone reserves preservation and enhancement general sustainability of the construction practice. All in all, the results prove that green concrete is an eco-friendly substitute of regular concrete. The high decrease in the number of carbon dioxide emissions, along with its acceptable strength and increased durability, justifies the need to introduce green concrete as one of the main materials in building green infrastructure and creating the building resistant to climate change.

5. CONCLUSION

This paper has clearly indicated that green concrete that uses industrial wastes likes fly ash and Ground Granulated Blast Furnace Slag (GGBS) is technically viable and an environmentally friendly substitute of ordinary concrete. This experimental research proves that, once the cement is partially substituted by these additive cementitious products, fresh and hardened qualities of concrete will be enhanced and the burden caused to the environment by cement productions will be largely lessened. Improved workability of green concrete mixes can be explained with the enhanced packing and lubricating property of fly ash and GGBS that can easily be mixed, placed, and compacted without the services of extra amount of water. Findings of the mechanical tests show that despite the fact that green concrete mixes have a slightly lower early age strength, they attain similar, or better compressive strength later at advanced ages, especially at the best replacement levels. It is still the pozzolanic and latent hydraulic reaction of fly ash and GGBS which assists in development of long-term strength by creation of more calcium silicate hydrate gel and hence denser and finer microstructure. This can be attributed to the fact that the microstructural integrity is improved and leads to enhanced concrete durability as witnessed in the reduced water absorption and damage or resistance to sulfate attack in the green concrete mixes. Environmentally, the research points out the immense positive points in minimizing cement concentration in concrete. The carbon dioxide emission would reduce by about 2540 per cent, which will offset green concrete as a way of reducing the environmental effect of the building process. In addition, the use of industrial by-products like fly ash and GGBS leads to effective waste management, less landfill and conserves natural resources and this is in accordance with the values of sustainable development and the circular economy. All in all, it can be stated that the results of green concrete proved to meet the paramount structural and durability standards, thus allowing this material to be used in the broadest scope of construction possible. Its utilization in mass infrastructure projects can be instrumental in the effort to cut carbon footprint of the construction industry as well as facilitating the concept of responsible building practices that are environmentally friendly. Nevertheless, to make it wider, and more acceptable to the practitioners, the next step is to conduct research on the field performance over the long-term, the lifecycle analysis, and how green concrete should behave in various environmental factors. These types of studies will also justify the use of green concrete as a major material in developing a sustainable and resilient infrastructure.

REFERENCES

ISSN: 3071-6357
PP: 01-14.

[1] Mehta, P. K. (2001). Reducing the environmental impact of concrete. ACI Concrete International, 23(10), 61–66.
[2] Malhotra, V. M., & Mehta, P. K. (2005). High-performance, high-volume fly ash concrete. Supplementary Cementing Materials for Sustainable Development Inc., Ottawa.
[3] Thomas, M. D. A. (2007). Optimizing the use of fly ash in concrete. Portland Cement Association, Skokie, Illinois.
[4] Siddique, R. (2004). Performance characteristics of high-volume Class F fly ash concrete. Cement and Concrete Research, 34(3), 487–493.
[5] Shi, C., Krivenko, P. V., & Roy, D. (2006). Alkali-activated cements and concretes. Taylor & Francis, London.
[6] Higgins, D. D. (2006). Ground granulated blast-furnace slag. Cementitious materials. Lea's Chemistry of Cement and Concrete, 4th ed.
[7] Neville, A. M. (2011). Properties of concrete (5th ed.). Pearson Education Limited.
[8] Bijen, J. (1996). Benefits of slag and fly ash. Construction and Building Materials, 10(5), 309–314.
[9] Aïtcin, P. C. (1998). High-performance concrete. E & FN Spon, London.
[10] Papadakis, V. G. (1999). Effect of fly ash on Portland cement systems. Cement and Concrete Research, 29(11), 1727–1736.
[11] Scrivener, K. L., Kirkpatrick, R. J. (2008). Innovation in use and research on cementitious material. Cement and Concrete Research, 38(2), 128–136.
[12] Poon, C. S., Shui, Z. H., & Lam, L. (2004). Effect of microstructure of ITZ on compressive strength of concrete prepared with recycled aggregates. Construction and Building Materials, 18(6), 461–468.
[13] Limbachiya, M. C., Leelawat, T., & Dhir, R. K. (2000). Use of recycled concrete aggregate in high-strength concrete. Materials and Structures, 33(9), 574–580.
[14] Xiao, J., Li, J., & Zhang, C. (2005). Mechanical properties of recycled aggregate concrete under uniaxial loading. Cement and Concrete Research, 35(6), 1187–1194.
[15] IS 456:2000. Plain and reinforced concrete – Code of practice. Bureau of Indian Standards, New Delhi.