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Effective Utilization of Quarry Residues and Mineral Admixtures in High Strength Concrete

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Abstract: The various requesting utilization of cement is not promptly met with Ordinary Portland cement (OPC) alone. To satisfy up the need and just as guaranteed the green concrete durability, it has ends up important to add mineral increments with the best blend of others by-product as substitution to improve the performance without risking the quality of the concrete. In the construction industry, OPC cement and stream sand are utilized as significant material making it rare and restricted. While, with respect to the cement is notable as the greatest guilty parties for discharging carbon dioxide (CO2). Consequently, incomplete substitution of cement turns into a need just as common sand in concrete by waste material or by-product without bargaining the nature of the finished result. Fractional supplanting with Ground Granulated Blast furnace Slag (GGBS), Silica Fume (SF) fuses with 100% of quarry dust (QD) as sand substitution has been utilized. The utilization of 100% QD with OPC+SF delivered increasingly durable concrete with low chloride ingress and preferred outfitting over with 100% stream sand. Notwithstanding the cost impact advantage, the decrease in exhaustion of stream sand, tending to condition and manageability issues, it is a significant commitment in making green concrete.

Key Words: Ordinary Portland cement, Ground Granulated Blast furnace Slag, Silica fume, quarry dust.

I. INTRODUCTION

Concrete is the significant building material that broadly utilized substance than other man-made material in this world. Cement being a noteworthy element of concrete, its creation contributes in harming the earth, is a major driver of environmental change, in charge of 5% of man-made carbon dioxide (CO2) revealed in [1]Berndt, (2015). OPC, Type I is the most widely recognized cement utilized as a rule for construction when there is no exposure to sulfates in soil and groundwater. From the statistic, about 60% of the cement utilized in the construction these days is OPC. Thus, with the use of by-product as halfway substitution cum substitution of constituents' materials in the green concrete mixes. The lessening in the wellsprings of typical sand and the need for diminishing in the cost of concrete age has presented low quality sand sources and thus expanded the need to recognize a substitute material to sand as fine aggregates in the formation of concrete ([2]Ankit and Jayesh, 2013). In this way, it is alluring to get cheap, amicable substitutes for cement and stream sand that are ideally by-products.

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To improve the green concrete creation, partial supplants of cement with Ground Granulated Blast Furnace Slag and Silica Fume, with 100 % quarry residues as fine aggregates was assessed. In the Peninsular of India there were likewise been numerous endeavors to utilize quarry dust as fractional substitution, yet just up to half on the lower levels concrete with various construction purposes. This might be required to draw out a decrease the utilization of stream sand, yet additionally will chop down the expense of construction with prudent concrete creation. The decision of using the waste item/by-product as a swap and substitution for cement and common stream sand has been bolstered in the past research, [3]Manassa (2010) and [4]Sukesh et al., (2013) showing up to 20% of sand has been viably supplanted by quarry dust in customary concrete. [5]Ilangovan et al., (2008), [6]Sivakumar and Prakash (2011) have declared that strength of quarry buildup concrete was identically 10-12% more than that of traditional concrete. [7]Divakar et al., (2012) have examined the conduct of the concrete with the usage of rock fines as fragmentary swap for sand up to half and procured the positive outcomes in quality and strength. Using quarry squander as a substitute of sand in construction materials would resolve the ecological issues brought about by the enormous scale consumption of the characteristic wellsprings of stream and mining sands ([5]Ilangovana et al., 2008, [8]Poonam et al., 2015). Quarry waste can be a productive option in contrast to the customary sands when the general construction cost increases as a result of the transportation of sands from their sources ([9]Safiuddin et al., 2007). For the most part quarry waste is utilized in enormous scale as a surface completing material in roads and highways. 10Rezende and Carvalho (2003) utilized this stone dust as the precept improvement material for the base layer of flexible pavement and watched its acceptable execution under field conditions. Safiuddin et al., (2007) and 11Lohani et al., (2012) uncovered that the workability of fresh concrete is upgraded, though the unit weight and air content keep on being unaffected within the sight of quarry squander. Quarry residue has likewise great potential for creating ordinary and lightweight concretes. Ilangovana et al., (2008) revealed that the penetrability is lesser; anyway water ingestion is more than that of the customary concrete. Along these lines, the nature of concrete could be influenced if quarry residue is utilized with an inexorably significant entirety. 12Hameed and Sekar (2009) considered the possibility of using quarry waste and marble sludge in concrete. They found that the compressive and split tensile characteristics and robustness of cement, including quarry waste were better as contrasted with the typical concrete as detailed by 13Vishal and Pranita, (2014).

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The resistance of concrete from sulfate attack was improved, the vulnerability was lessened, and anyway its water absorption ended up being barely higher than that of customary concrete. These outcomes endorse that the quarry residues can be utilized to make agreeably strong concrete. Quarry waste can in like way be used in unique concretes, for instance, high-performance and self-consolidating concretes. Safiuddin et al., (2000) made high- performance concrete utilizing quarry squander as a divided substitution of sand. Also, [14]Felekoglu (2007) demonstrated that a reasonable extent of limestone quarry residue can be used in self-consolidating concrete without influencing its compressive quality. Accordingly, the beneficial use of quarry waste in high-performance and self-consolidating concretes could change this waste material into a crucial resource referenced by ([15]Hmaid, 2015).The inspiration for the exploration is that there were never multiple times when stream sand is 100% supplanted by quarry dust together with the by-products. Accordingly, the research article is aimed for the assurance of the impact of 100% quarry dust substitution of sand and fractional supplanting of cement with mineral admixtures on properties of concrete. The impact of incomplete supplanting with GGBS, silica fume incorporating 100% of quarry dust as a sand substitution on concrete quality was assessed.

II. EXPERIMENT

A. Materials

Ultra-Tech Ordinary Portland Cement (OPC) of 53 grades was used in the present assessment. The properties of cement are attesting to IS 12269-1987 Specifications. Fine aggregate which is used in the examination is locally available from banks of Tungabhadra River and it fits in with IS Specifications. Coarse aggregate of ostensible size 20 mm and 12 mm, acquired from the neighborhood quarry asserting to IS details was utilized. GGBS and silica fume are acquired from AASTRA synthetic compounds, Pvt Ltd, Chennai. Quarry Dust is acquired from the neighborhood quarry close to Betamcharla town of Kurnool district in Andhra Pradesh state. The water utilized for casting and restoring of solid test samples was free of acids, natural issue, suspended solids and polluting influences which when present can unfavorably influence the quality of concrete.

Table- I: Test Outcomes Of Various Materials Employed In Investigation

Test on Cement	Normal Consistency	Specific gravity	Fineness	Initial setting time	Final setting time
Outcome	32%	3.13	6%	39 min	387 min

Test on fine aggregate	Specific gravity	Water absorption	Fineness Modulus	Silt content	Bulk density kg/m^3
Outcome	2.56	1.2%	3.32	1.98 %	1420

Test on coarse aggregate	Specific gravity	Water absorption	Fineness Modulus
Outcome	2.71	1.0%	2.22

Particulars of GGBS	Specific gravity	Fineness (Blaines)	Residue % (45 micron)
Outcome	2.78	380	7.2

Particulars of Quarry residue	Specific gravity	Fineness Modulus	Moisture content	Zone
Outcome	2.48	3.2	Nil	II

B. Mix Proportions

Eleven distinctive mix proportions were prepared. The first blend was prepared from 100% stream sand and cement content to deliver conventional concrete. The second mix was prepared using 100% quarry dust without any fractions of natural river sand. The rest of blends were prepared by partially supplanting cement with GGBS at various levels going from 10% to 50% with an increment of 10%, by weight. Maintaining half way substitutions of GGBS and cement, again cement was substituted by silica fume from 0% to 20% at an interim of 5%.The water cement ratio for all the blends was fixed at 0.27, by weight.

Table- II: Mix Proportions for M60 grade concrete

Cement	449 kg/m^3	1
SCM	112 kg/m^3	0.249
Fine Aggregate	664.52 kg/m^3	1.48
Coarse Aggregate	20 mm– 808.28 kg/m^3 12.5mm–202.1 kg/m^3	2.21
Water	153 kg/m^3	0.27
SP	62 kg/m^3	0.138

C. Methods

This exploration was led in the laboratory to decide the conduct of the concrete in terms of mechanical quality and durability properties. The extent of work covers the mechanical and physical properties with 100% quarry dust as fine aggregate, and fractional substitution of cement with mineral admixtures like GGBS and Silica fume. The mechanical properties of solidified concrete were attempted through the compressive strength test with cubes 150mm × 150mm × 150mm shape. The cube samples were tested at the ages of 7 days, 28 days, and 90 days and as long as 180 days after the wet curing process at the restoring tank in agreement to strategies of IS 9013: (1978). The split tensile strength was carried out on the standard test cylinder of concrete specimen of 150 mm diameter and 300 mm height. This test was done out as per IS: 5816-1970.The fresh properties of the green concrete are resolved through the slump test for the best workability, it is done as per IS 1199 -1959, for sampling at site and at the lab. The chemical admixture utilized in this examination was SP 430 Conplast super plasticizer. It is required because of the lower use of water to deliver high strength GGBS concrete that would influence the workability of new concrete.

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Modification was being made to guarantee the best usefulness acquired with best flow slump without endangering the concrete quality. It is utilized at a measurement rate, 2% of the cement by weight. The cementitious materials were mixed for 4 to 5 minutes in a mechanical blender at a speed of 80 rpm to ensure homogeneous blending. Water was then included and mixed with all the supplementary cementitious materials for 5 minutes, followed by 2 minutes resting period to scratch off any unmixed powders from the paddle sides of the blender and including them into the mixing bowl. The mixing was continued for an additional time of 5 minutes before placing the fresh concrete in 3D shaped molds. After complete mixing, the fresh paste was placed into 150 mm cube moulds and vibrated for 1 minute to expel air bubbles. Immediately after casting the moulds were covered with a polyethylene sheet to dodge any evaporating of water from the surface of the samples.

III. RESULTS & DISCUSSIONS

Mix design of concrete is significant so as to deliver a batch of concrete, which is having the properties wanted. Parameters like compressive quality and workability can be modified through the design procedure and will be observed every once in a while until acquired the best concrete blend. Table 3 demonstrates the compression test outcomes of concrete mix extents for the green concrete that joins with the mineral admixtures.

A. Compressive Strength

As referenced early, cube test was done in this examination to acquire the compressive quality of the concrete samples. Every three samples of cubes were casted for each individual distinctive concrete blends. The samples were tested with 4 diverse curing periods, to be specific 7 days, 28 days, 90 days and 180 days. The details of test results on various cement blends were showcased in Table 3 and Figure 1.

Fig.1 Samples in curing pond

Fig.2 Cube sample

Table- III: COMPRESSION TEST RESULTS OF VARIOUS MIXTURES EMPLOYED

Mix	Mixture	Compressive Strength (N/mm^2)			
	Days	7	28	90	180
M-1	100% natural river sand + 100% cement	39.12	57.13	58.11	60.39
M-2	100% quarry residue + 100% cement	36.35	53.51	55.24	57.44
M-3	100% quarry residue + 10% GGBS + 90% cement	35.58	52.59	54.7	55.49
M-4	100% quarry residue + 20% GGBS + 80% cement	34.71	54.16	58.29	59.42
M-5	100% quarry residue + 30% GGBS + 70% cement	35.35	56.33	59.8	60.69
M-6	100% quarry residue + 40% GGBS + 60% cement	37.52	58.42	59.93	63.31
M-7	100% quarry residue + 50% GGBS + 50% cement	38.81	61.49	64.97	67.44
M-8	100% quarry residue + 50% GGBS + 5% silica fume + 45% cement	36.61	57.47	59.16	60.23
M-9	100% quarry residue + 50% GGBS + 10% silica fume + 40% cement	35.34	56.39	59.72	61.6
M-10	100% quarry residue + 50% GGBS + 15% silica fume + 35% cement	35.24	60.19	61.49	63.17
M-11	100% quarry residue + 50% GGBS + 20% silica fume + 30% cement	34.55	62.17	63.82	65.56

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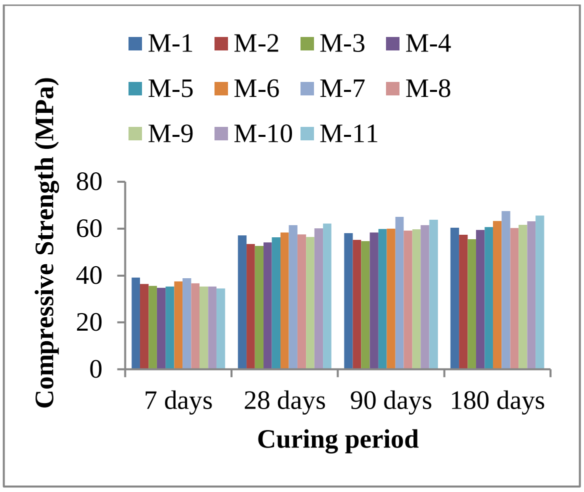

Fig. 3 Variation Of Compressive Quality Of 3D Concrete Squares At Different Ages

On perception of test outcomes delineated in Table-3 and Figure-3, it was seen that there was just a minimal decrease in compression of the samples made with quarry dust as 100% substitution for characteristic stream sand. At the point when concrete is supplanted with GGBS at an interim of 10%, a progressive increment in the compression was recorded. A most extreme estimation of compression quality was seen at midway supplanting of cement with GGBS. Be that as it may, with half GGBS, 20% silica fume and 30% cement, maximal compression quality was noted. GGBS works synergistically with Portland cement to build quality, diminish penetrability, improves resistance to chemical assault. GGBS improves huge numbers of the quality and toughness properties of solidified concrete. It is a hydraulic fastener that, similar to Portland cement, reacts with water to shape cementitious material (calcium-silicate hydrate or CSH). It likewise, like a pozzolan, devours result calcium hydroxide from the hydration of Portland cement to frame extra CSH. The ensuing cement paste is more grounded and denser, thus improving the quality of concrete. GGBS by and large improves functionality, finishability and pumpability of plastic concrete. It, in general increments the time of starting set, which is frequently an advantage in warm climate.

Pozzolanic response happens between silica fume and the calcium hydrate CH, creating extra CSH in huge number of the voids around hydrated cement particles. Due to the high surface territory of silica fume particles influencing the versatility of water inside concrete, segregation and bleeding of concrete are for all intents and purposes wiped out. Silica fume improves the properties of new and solidified concrete. Concrete made with silica fume is progressively firm. It decreases segregation and bleeding and permits progressively effective finishing process. It improves the durability of concrete.

B. Split tensile strength

Tensile strength is the noteworthy property of concrete since concrete structures are incredibly vulnerable against ductile breaking because of different sorts of effects and associated stacking itself. Anyway tensile strength of concrete is exceptionally low when contrasted with its compressive quality. It is the standard test to decide the tensile strength of concrete in an aberrant way. This test could be performed as per IS: 5816-1970. A standard test cylinder of concrete sample 300 mm x 150 mm is set on a level plane between the stacking surfaces of Compression testing machine. The compression load is applied diametrically and consistently along the length of the cylinder until the failure of the cylinder along the vertical diameter occurs. To permit the uniform dispersion of this connected load and to decrease the effect of the high compressive stresses close to the application of load, portions of pressed wood or steel plates are set between the sample and stacking platens of the testing machine. Concrete cylinder parts into two sections along this vertical plane because of indirect tensile stress generated by poisons effect.

Table- IV: Split Tensile Strength Test Results Of Various Mixtures

Mix	Mixture	Split Tensile Strength (N/mm^2)			
	Days	**7**	**28**	**90**	**180**
M-1	100% natural river sand + 100% cement	3.11	5.25	5.55	6.15
M-2	100% quarry residue + 100% cement	2.54	4.68	4.88	5.68
M-3	100% quarry residue + 10% GGBS + 90% cement	2.78	4.92	5.32	5.52
M-4	100% quarry residue + 20% GGBS + 80% cement	2.56	4.7	5.21	5.61
M-5	100% quarry residue + 30% GGBS + 70% cement	2.81	4.95	5.23	5.81
M-6	100% quarry residue + 40% GGBS + 60% cement	2.96	5.1	5.43	6.25
M-7	100% quarry residue + 50% GGBS + 50% cement	3.94	6.08	6.36	6.91
M-8	100% quarry residue + 50% GGBS + 5% silica fume + 45% cement	3.11	5.25	5.51	6.13
M-9	100% quarry residue + 50% GGBS + 10% silica fume + 40% cement	3.25	5.39	5.62	6.24
M-10	100% quarry residue + 50% GGBS + 15% silica fume + 35% cement	3.27	5.41	5.76	6.32

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M-11	100% quarry residue + 50% GGBS + 20% silica fume + 30% cement	3.45	5.59	5.82	6.41

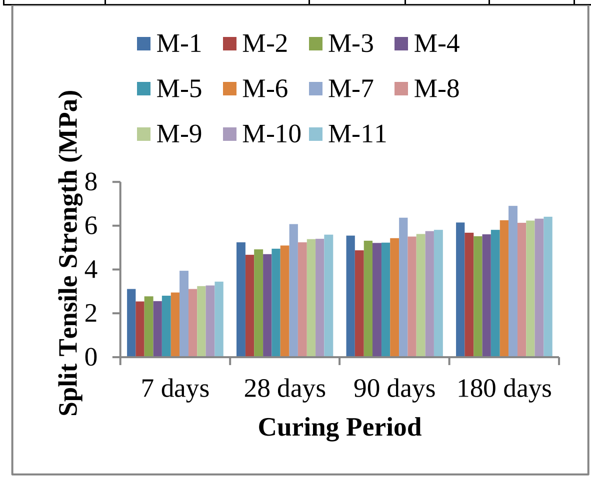

Fig. 4 Variation Of Split Tensile Strength Of Concrete Cylinders At Different Ages

Fig. 5 Cylindrical Sample

On watching the test consequences of split tensile tests displayed in Table-4 and Figure-4, it might deduced that there is a ceaseless augmentation in the split tensile strength of concrete samples prepared by fusing GGBS and silica fume. A minimal abatement in split pressure was recorded with 100% supplanting of characteristic waterway sand with quarry dust. With the expansion of mineral admixtures in cement, there is an increment in the extent of split tensile strength. At midway override of cement with GGBS, a split tensile strength of 6.91 MPa was noted at 180 days relieving period. It is seen that silica fume consolidation builds the split tensile strength of concrete. The underlying filling of the voids by GGBS and silica rage altogether improves split tensile strength. As the compressive quality develops, the tensile strength also augments, but at a gradually diminishing rate.

C. Carbonation Test

Concrete paste has a pH of around 13 which gives a protective layer to the steel reinforcement against erosion. Loss of passivity happens at about pH 11. Carbonation of the concrete, brought about via carbon dioxide in the environment, has the impact of decreasing the pH. It is associated with the corrosion of steel reinforcement and with the shrinkage of concrete. Carbonation is the delayed outcome of the breaking down of CO_2 in the concrete pore fluid and this reacts with calcium from calcium hydroxide and calcium silicate hydrate to outline calcite ($CaCO3$). Inside a couple of hours, or multi day or more, the surface of crisp concrete will have reacted with CO_2 from the air. Well ordered, the technique enters further into the concrete at a rate relating to the square root of time. Following a year or so it may normally have accomplished a significance of possibly 1 mm for dense concrete of low permeability made with a low water/cement proportion, or up to 5 mm or more for progressively permeable and penetrable concrete made utilizing a high water/cement proportion. The influenced profundity from the concrete surface can be expeditiously showed up by the use of phenolphthalein indicator solution. Phenolphthalein is a white or light yellow crystalline material. For use as an indicator it is broken down in an appropriate dissolvable, for example, isopropyl alcohol (isopropanol) in a 1% solution. The phenolphthalein indicator solution is applied to a fresh fracture surface of concrete. In the event that the solution turns purple, the pH is above 8.6. Where the solution remains insipid, the pH of the concrete is underneath 8.6, proposing carbonation. A completely carbonated paste has a pH value of about 8.4.

On watching the photos displayed in Figure-6, when phenolphthalein indicator solution is applied to the crisp fracture surface of concrete, it might be seen that the indicator has changed to purple shading, showing that the pH is above 8.6. Along these lines no indications of carbonation were seen in the concrete samples. Indicator was not applied to the concrete at the right of this picture and so the concrete here holds its unique shading.

Fig. 6 Samples Tested For Carbonation

D. Rapid Chloride-ion Permeability Test

Corrosion of reinforcing steel because of chloride entrance is one of the most widely recognized environmental assaults that lead to the decay of concrete structures.

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Concretes containing fly ash or silica fumes are less permeable to deleterious components and subsequently are more durable than ordinary concretes. Chlorides penetrate crack-free concrete by number of mechanisms: capillary absorption, hydrostatic pressure, diffusion, and evaporative transport. Principally dispersion happens when the concentration of chloride on the outside of the concrete member is more prominent than within. This results in chloride ions moving through the concrete to the level of the rebar. When this occurs in combination with wetting and drying cycles in the presence of oxygen, conditions are favorable for reinforcement corrosion. The rate of chloride ion ingress into concrete is fundamentally reliant on the internal pore structure. The pore structure in turn relies on other factors such as the mix design, degree of hydration, curing conditions, use of supplementary cementitious materials, and construction practices. Therefore, wherever there is a potential risk of chloride actuated corrosion, the concrete should be assessed for chloride permeability. The Rapid Chloride-ion Permeability Test (RCPT) is intended to assess the resistance of concrete to the entrance of chloride particles, an indicator of its permeability.

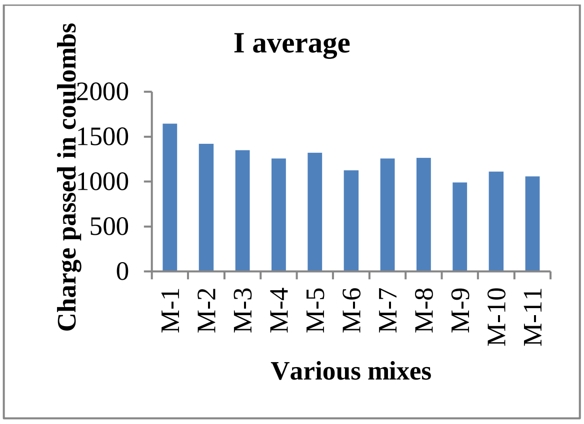

Fig. 7 Permeability of Chloride in Cement Concrete for every 30 min. interval up to 6 hrs using RCPT apparatus for different mixes

Table- IV: RCPT ratings (ASTM C1202)

Sl.no	Charge passed (Coulombs)	Chloride Ion Penetrability
1	Greater than 4000	High
2	2000 to 4000	Moderate
3	1000 to 2000	Low
4	100 to 1000	Very low
5	Less than 100	Negligible

On watching the test outcomes with respect to rapid chloride penetrability test, it can be concluded that the rate of chloride ion penetrability is low for all the concrete blends prepared with various combinations of mineral admixtures.

IV. CONCLUSIONS

All the research facility testing results obtained demonstrated that quarry dust and mineral admixtures particularly, GGBS and silica fume improve the physical and mechanical properties of the concrete blend. The outcomes are vital in light of the fact that concrete is the real structural material that broadly utilized than other man-made material in this world. Concrete requires a lot of cement and sand which are significant elements of concrete generation. Concrete production contributes in hurting the earth, is a major driver of environmental change, in charge of 5% of man-made carbon dioxide and consumption of the characteristic sand source. It is discovered that quarry residue can be utilized as an elective material to the normal sand without risking the concrete quality. Utilization of quarry dust as characteristic sand substitution in solid will annihilate the disposal issue and keep up the ecological well disposed therefore clearing route for greener concrete. The supplanting of the regular sand with quarry residue fuses with the mineral admixtures in cement demonstrates an improved compressive and tensile quality, by accomplishing the 8-10% level of strength gain.It is seen that with 100% supplanting of regular waterway sand with quarry residues, there is just a minimal decrease in compressive and split tensile strengths of concrete samples, giving an indication that quarry residue can supplant the natural stream sand, to be utilized as fine aggregate in concrete. It is observed that the GGBS based concrete have accomplished an expansion in compressive strength for 50% supplant level of cement, which can be ascribed to the filler effect of GGBS. The silica fume content also assists in increasing both the compression and split tensile quality of the concrete specimens. The compressive strength and split tensile strength have expanded in the blend of partial replacement of cement by GGBS and silica fume. It reduces greenhouse gas emissions by eliminating approximately one ton of carbon dioxide for each ton of Portland cement replaced. The energy consumption is diminished, since a ton of GGBS requires nearly 90% less energy to produce than a ton of Portland cement. The above conclusion gives clear picture that there is no damage in using quarry dust as a substitute for characteristic stream sand in concrete blends if unadulterated by soil and other unfortunate polluting influences.

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