Effects of Steel Fibers (SF) and Ground Granulated Blast Furnace Slag (GBBS) on Recycle Aggregate Concrete

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Abstract

Recycle aggregate is one of the good options to use in concrete as coarse aggregate which results environmental benefits as well as sustainable development. However, recycle aggregate cause reduction in concrete performance. On the other hand, the removal of industrial waste would be considerably decreased if it could be incorporated in cement concrete production. One of these possibilities is the substitution of the cement by slag, which enhance concrete poor properties of recycle aggregate concrete as well as provides to the decrease of cement consumption, reducing carbon dioxide productions, while resolving a waste management challenge. Furthermore, steel fiber was also added to enhance the tensile capacity of recycle aggregate concrete. The main goal of this study is to investigate the characteristics of concrete using Ground granulated blast-furnace slag (GGBS) as binding material on recycle aggregate fibers reinforce concrete (RAFRC). Mechanical performance was assessed through compressive strength and split tensile strength, while durability aspects was study through water absorption, acid resistance and dry shrinkage. The results detected from the different experiments depict that replacement of Ground granulated blast-furnace slag (GGBS) enhance mechanical performance as well as durability aspects of the recycle aggregate fibers reinforce concrete (RAFRC).

1 Introduction

Recycled concrete aggregate (RCA) is made by crushing, sieving, and cleaning this waste material from demolished concrete. Using recycled aggregates (RA) likewise decreases the raw materials demand by extracting them from the ground, which too reduces the negative environmental effects. By volume, RA comprises 60–70% of natural aggregates, and also 30–40% mortar from old cement. Compressive strength and other characteristics of RCA are affected by parent concrete properties, workability, mix proportion, etc [1]. The mechanical and durability performance of RCA is very low as compared to concrete with natural aggregates. This lower performance of RCA could be reduced by utilizing fractional substitution of pozzolanic materials and mineral admixtures. These materials and admixtures enhance the durability by filling the RCA porous microstructure and thus reduces the RCA permeability [2]. It has been concluded that RCA reduced performance of concrete considerably. Therefore, it is recommended that it is necessary to used Cementitious materials in recycle aggregate concrete to improves its permeance [3]. It has been also recommended that, it is necessary to add secondary cementitious materials such fly ash, silica fume and GGBS into the recycle aggregate concrete to improve their performance [4].

Different Cementitious materials such as fly ash [5], silica fume [6], waste glass [7], wheat straw ash [3], marble waste [8], bentonite clay [9] as well as GGBS [10] used in concrete production. Ground granulated blast-furnace slag (GGBS) is basically industrial waste as a by-product material which is rich in amorphous calcium, silica, and alumina, which becomes it appropriate to be utilized as a binder in the cement concrete production [11]. GGBS is widely used in several civil engineering projects to replace the cement in concrete production [12]. GGBS is basically industrial by-product achieved in steel production and is generally utilized as binding material in cement concrete production since it enhances mechanical performance of concrete and decrease permeability by improving the interface with the

aggregate. Economic and ecological advantages in the shape of power savings and source saving can also be accomplished by using GBBS as a binding material in concrete production [13]. Furthermore, the substitution of ordinary Portland cement (OPC) decrease the release of greenhouse gases and utilization of unnecessary power [14]. Mechanical performance and long term material properties similar to those of OPC, beside with its charge-effectiveness and environmental friendliness, Ground granulated blast-furnace slag -based geopolymer concrete has develop an gorgeous goal to scholars as an alternate binding material instead of cement in concrete production [15].

Zhao et al [16] show that, the strength improves and the matrix develops further homogeneous as the proportion of Ground granulated blast-furnace slag (GGBS) to fly ash enhance due to the increase in the calcium content, resulting to the development of calcium silicate hydrates (C-S-H) and calcium aluminate silicate hydrates (C-A-S-H) bonding. Increasing very fine GGBS can made self-compacting concrete (SSC) achieve a greater concentration of mechanical strength [17]. The chemical composition, particle morphology, water demand, and hydration characteristics of various Ground granulated blast-furnace slag (GBBS) were studied. The outcomes demonstrated that there was no considerable variation in the chemical composition and particle morphology of GGBS with variations to the GGBS particle size, but also proved that the variation rate of water need and the intensity shifted rapidly with the variation of Ground granulated blast-furnace slag (GGBS) particles [18]. A researcher analyzed the influence of ground nano slag (GNS) on the compressive strength, porosity, sorption, and resistance to chloride ion penetration of high strength concrete. They realized that the strength and durability of high strength concrete were good quality when the GNS substitution rate was 10% by weight of cement. Furthermore, a lesser proportion (5%) of the ground nano slag (NGS) is not well distributed and is not sufficient to achieve more strength. A large ratio (15%) of ground nano slags (NGS) result to an enhance in the aggregated ultrafine particle size of concrete and the improper filling of pore resulting more strength [19]. Experimental studies were performed on the compressive strength, split tensile strength, modulus of elasticity, chloride ion migration, and resistivity of concrete combined with ultra-fine slag powder. It was noticed that concrete mixed with ultrafine slag powder has greater early compressive strength, lessor permeability and better durability after three days curing [20]. Some studies show that, GBBS improved mechanical performance of concrete in terms of compressive strength more effectively than tensile strength [10]. According to past literature, concrete with addition of cementitious materials still need tensile reinforcement to enhance their tensile capacity [21] Fibers are one of the most prevalent methods to enhance the tensile capacity of concrete [22].

A general observation is that tinny fibers are additional imposing in decreasing the width of plastic shrinkage cracks than thick fibers according to past literature as given in ACI 544.5R-10 [23]. The positive response of steel fibers added in concrete depends on various aspects such as diameter, length, aspect ratio, types, cross sectional area, concrete mix design, water cement ratio, method of mixing etc [24]. For engineering purpose particular where high strength is required, steel fiber reinforced is most widely used due easy fabrication, low cost as well as high performance [25, 26]. However, the some studies reported that uneven addition of steel fiber results negative effects on workability of fresh concrete leading to poor bond of fibers with surrounding concrete resulting porous concrete and mechanical performance of fibers

reinforced concrete decreased [27–29].” The important feature in material energy absorption is the way of bonding between binder matrix and fibers [30]. Their ability to slow the propagation of cracks is known as the highly useful feature of fibers. According to [31], the utilization of polypropylene fibers leads to a major decrease in the compressive strength of concrete. Revealed that 0.15% polypropylene fibers and 0.90% steels are the best combination to obtain good performance in high-strength concrete [32]. A study determined the effect of basalt fiber on microstructure, mechanical, and shrinkage behavior of fly ash-based geopolymer concrete [33]. They observed that basalt fiber enhances the production rate of C-S-H, N-A-S-H, and C-A-S-H, which can have a positive influence on the mechanical and durability aspects of the binder. A study revealed that polypropylene fibers have a positive effect on geopolymer composites flexural strength [34]. Some studies reported that, fiber improve tensile strength more effectively than compressive strength [22, 35].

1.1 Research Significance

A primary objective of this research is to focus to utilize recycle coarse aggregate (RCA) in concrete production. A brief literature review show that RCA decrease performance of concrete due porous nature which absorb more water resulting pore in harden concrete. The second objective of this study is to add GBBS into recycle coarse aggregate concrete to offsets it porous nature by filling voids and by pozzolanic reaction which enhance mechanical performance of recycle coarse aggregate concrete. Zaid et al show that, although pozzolanic materials improve compressive strength of concrete but still concrete has less tensile capacity resulting brittle failure which is obviously unacceptable [4]. Further research was recommended [4] that fiber must be added to GBBS recycle aggregate concrete to achieved high strength, durable and ductile concrete. Therefore, final objective of this study is to add steel fiber to GBBS recycle coarse aggregate concrete to obtain high strength durable concrete. A successful utilization of these materials in concrete gives multiple benefits including energy saving, economical, solving environmental pollution as well as much better performance as compared to conventional concrete.

2 Experimental Program

2.1 Materials

2.1.1 Cement

Ordinary Portland cement (OPC) type-1 as per ASTM C150 [36], was used throughout in this study. Its chemical composition and physical properties were shown in Table 1.

Table 1 Physical and Chemical Property of OPC			
Chemical Property	Percentage (%)	Physical Property	Results
CaO	62.7	Size	$\leq 75\mu$
SiO ₂	22.9	Fineness	94%
Al ₂ O ₃	6.4	Normal Consistency	28%
Fe ₂ O ₃	2.7	Initial Stetting Time	36min
MgO	2.5	Final Stetting Time	418min
SO ₃	1.4	Specific surface	322 m ² /kg
K ₂ O	1.2	Soundness	1.60%
Na ₂ O	0.2	28-days compressive Strength	42Mpa

2.1.2 Aggregate

Locally accessible river sand in SSD (saturated surface dry) condition was used as a FA (fine aggregate) was kept constant throughout study for mixes. Normal weight crush stone in SSD (saturated surface dry) condition was used as coarse aggregate for all mix. condition (SSD) which was obtained from Margallah Wah cantt Punjab Pakistan. Furthermore, physical properties were shown in Table 2 while particle size distribution (gradation curve) of aggregate were shown in Fig. 1 .

Table 2
Properties of Aggregate

Physical Property	Fine aggregate	Coarse Aggregate	RCA
Particle Size (mm)	4.7 to 0.075	25 to 4.75	25 to 4.75
Fineness Modulus	2.55	4.23	4.12
Absorption Capacity (%)	3.9	2.9	4.4
Moisture Content (%)	1.6	1.4	1.8
Bulk density (kg/m ³)	1556	1580	1485

2.1.3 Ground granulated blast-furnace slag (GGBS)

Ground granulated blast-furnace slag (GGBS) is cheaply accessible in significant amounts and appropriate for production of larger amounts of cement concrete production. The granulated slag is dry and ground to a fine powder which is called Ground granulated blast-furnace slag (GGBS). GGBS is usually off-white in color and has a bulk density of approximately 1200 kg/m³. Physical and chemical properties of GGBS used in this study is give in Table 3. The mineralogy of the tested samples was studied by using the results achieved through the XRD analysis. Figure 2 show XRD pattern of GGBS. It can be noticed that a wide range of amorphous peak of quartz (Q) were observed at 29° and 38 ° which show that the dominant amorphous nature of GGBS. Furthermore, some minor peak of mullite (M), hematite (H), and magnetite (G) can also be observed at different angle.

Table 3
Physical and Chemical Property of GGBS

Chemical Property	Percentage (%)	Physical Property	Results
CaO	53.55	Color	White
SiO ₂	9.13	Specific Gravity	2.20
Al ₂ O ₃	20.2	Type	F
Fe ₂ O ₃	7.23	Clay (%)	0.9
MgO	4.32	Bulk density (kg/m ³)	1180
SO ₃	2.07		
K ₂ O	1.9		
Na ₂ O	1.6		

2.3 Tests Setup and Sample Preparation Method

Workability of fresh concrete was measured through slump cone test as per ASTM standard [37]. Compressive strength was evaluated on standard size cylinder 150 x 300 mm through compressive testing machine as per ASTM standard [38]. For split tensile strength, similar cylindrical samples were prepared of size 150 x 300 mm as per ASTM [39]. For the water absorption test, 100 mm cubes sample were used per ASTM [40]. According to ASTM standard [41] was used for drying shrinkage tests. A 100mm cubical sample were casted to evaluate acid resistance of concrete which was cured 4% sulfuric acid for specified period. To maintain 4% concentration acid, change every week. Acid attacks was calculated in terms of mass loss in percentage due to attack of sulfuric acid. All tests were conducted after 14 days, 28 days and 56 days of curing. At least three sample were casted for each batch and their average value was considered as actual result of that test.

According to the standard casted of sample was done in three different layer and each was compacted through tamper rod with twenty five no of blows Casting of test sample and compaction was done with tamper rod in three different layer manually having 25 blows per layer [42]. To study the effect of marble waste and coconut fibers on the behaviors of hardened and fresh concrete, six mixes were prepared. Before start of mixing process, the necessary amount of concrete ingredients was weighted by the method of weighing. Speed of mixer was kept constant 35 rev/min for mixing of concrete ingredients. Coarse aggregate was put into the mixture first and then fine aggregate, both materials were dry mixed then required amount of cement, steel fibers, GBBS were added and superplasticers were mix in water which were added with time and mixing was done about 10 minutes for all mixes. Details of the mixes with different dosages were provided in Table 4.

Table 4 Quantification of Materials per m³							
Mix ID	Cement (kg)	F.A (kg)	C.A (kg)	RCA (kg)	HRWR (kg)	GBBS (kg)	SF (kg)
R-0, G-0, S-0	425	625	1275	-	-	-	-
R-20, G-0, S-0	425	625	1020	255	4.25	-	-
R-40, G-0, S-0	425	625	765	510	4.25	-	-
R-60, G-0, S-0	425	625	510	765	4.25	-	-
R-20, G-10, S-0	382.5	625	1020	255	4.25	42.5	-
R-40, G-20, S-0	340	625	765	510	4.25	85	-
R-60, G-30, S-0	297.5	625	510	765	4.25	127.5	-
R-20, G-10, S-1	382.5	625	1020	255	4.25	42.5	4.25
R-40, G-20, S-2	340	625	765	510	4.25	85	8.85
R-60, G-30, S-3	297.5	625	510	765	4.25	127.5	12.75
<ul style="list-style-type: none"> • R = RCA, G = GBBS, S = SF • F.A = Fine aggregate, C.A = Coarse Aggregate, RCA, Recycle Coarse Aggregate, • HRWR = High Range Water Reducing Admixture. • GBBS = Ground granulated blast-furnace slag, SF = Steel Fibers 							

3 Results Analysis

3.1 Fresh Property

3.1.1 Slump and Fresh Density

Workability fresh concrete is a mix property which includes the different requirements of stability, mobility, compatibility, finish ability and placeability [43]. Workability of Concrete decreased as the proportion of RCA enhanced as compared to blank mix. Maximum slump was achieved at 0% substitution of RCA while maximum slump was obtained 60% Substitution of RCA as shown in Figure 3. It is due to physical features RCA i.e porous nature that absorb more water from concrete mix and hence less free water is available for lubrication to reduce the internal friction between concrete ingredients. It has been reported aggregate that the surface texture of RCA is more rough as compare to coarse which adverse effect on workability of concrete [44]. Furthermore, when GBBS was added to recycle aggregate concrete mix, workability of concrete increased as compared to without GBBS recycle aggregate concrete mix. This increased in workability is due to smooth and fine particle of GGBS [45]. The fine particle of GBBS fills the gap between coarse aggregate, RCA, sand and cement leading to more dense concrete having less voids and hence more paste is available which facilitate better flow of cement concrete. It has been also reported that, more voids is present in concrete, lesser will be workability because paste fills the void and no paste is available for lubrication [3]. It well known that any kinds of fibers reduce workability of concrete due larger surface area of fibers that increased the internal friction between aggregate resulting less workable concrete [35, 46]. It has been also reported that, for higher dosages of steel fiber required higher dosage of super plasticizer [35]. Therefore, 1.0 % of superplasticizer was kept constant throughout studies. However, addition of GBBS and steel fiber required higher dosage of superplasticizer. It can be observed that workability of recycle aggregate concrete is still improved with incorporation of steel fiber and superplasticizer. Although it has been also reported that steel fibers decreased workability [35] while superplasticizer increased workability [47], however combined substitution ratio steel fibers and superplasticizer shows workability comparable to control [22].

Figure 4 shows fresh density of concrete with varying dosages. Fresh density is index that determine performance concrete i.e higher density results more dense concrete with less voids in harden concrete resulting more strength. Fresh density decreased with addition of RCA. Maximum fresh density was obtained at 0% substitution of RCA while minimum fresh density was obtained at 60% substitution of RCA. Negative effect of RCA could be attributed due to porous nature of RCA having large volume with less mass which results lower fresh density as compare to control mix (concrete made with natural coarse aggregate [44]. When GGBS was added to recycle aggregate concrete, fresh density improves as the percentage of GGBS increased. Maximum fresh density was obtained at 20% substitution of GGBS to recycle aggregate concrete as in comparison to reference mix. The positive influence of GBBS on fresh density is ascribed to the pozzolanic reaction of SiO_2 in GGBS with Ch of cement creating secondary cementitious compounds resulting to more density of concrete [45]. Also, GGBS fill the voids in RCA, which was in porous nature, giving more compact mass, leading to more fresh density. When Steel fiber was added to GGBS recycle aggregate concrete, fresh density of mix still improved. Although it has been reported the fresh density concrete decreased with incorporation of steel fiber, particular at higher dosage (beyond 2.0% by weight of cement) due to lack of workability [35]. Therefore, super plasticizer was added for each dosage of steel fiber which results more dense concrete. When superplasticizer is added to

concrete, create similar charge resulting repelling to each other, lead to more workable and dense concrete [47].

3.2.1 Compressive Strength

Compressive strength of concrete is one the most important property of concrete which can be define as the ability of cylindrical sample to resist stresses when it is subjected to compressive forced in compressive testing machine. A standard size cylinder of 300mm length and 150mm diameter were casted and tested to find compressive strength of concrete as per ASTM standard [48].

Figure 5 shows compressive strength of different dosages of RCA, GGBS and SF. It can be noticed that compressive strength decreases with incorporation of RCA having minimum strength at 60% of RCA as compared to the reference concrete. It is due physical nature of RCA which absorb more water, leading to porous concrete resulting less compressive strength.

It has been also reported that compressive strength of recycle aggregate concrete due unreactive cement [4]. RCA absorb water from concrete and no water is available for hydration process. When GGBS was added to recycle aggregate concrete, considerable improvement in compressive strength was observed. At 28 days curing, compressive strength of aggregate 60% recycle aggerate concrete is approximately comparable to control mix at 20% substitution of GGBS. The positive impact of GGBS on compressive strength is due to the pozzolanic reaction of SiO_2 in GGBS with Ch of cement, producing additional cementitious compounds [3, 21]. The additional binder produced by the GGBS reaction with available lime allows concrete to continue to gain strength over time. However, at higher dosage of GGBS (beyond 20 % by weight of cement) strength reduce due dilution effect which leads to alkali silica reaction due higher quantity of unreactive silica available due high quantity of GGBS [4]. Also, GGBS fill the voids in recycle aggregate, giving more dense concrete which results improvement in compressive strength of concrete. when steel fiber was to GGBS recycle aggregate concrete, compressive strength increased as the dosage of steel fiber increase up to 2.0% and then reduced. All the fiber reinforced shows higher compressive strength as compared to control concrete having maximum compressive strength after 28 days curing as compared to control mix ta 2.0% substitution of steel fibers. The positive impact of steel fibers on compressive strength is due to confinement of steel fibers around the cylindrical specimens. Laterally expansion produce under the application of compressive load which resisted by fibers due to confinement and as result to increase compressive strength [35].

A relative is also carried out in which 28 days of control mix is considered reference mix, from which other mix is compared as shown in Figure 6. After 7 days curing, compressive strength is about 19% less than from reference mix at 60% substitution of RCA. When GGBS is added to recycle coarse aggregate concrete, at 20% substitution of GGBS and 40% RCA show 7.0% more than compressive strength from reference mix after 7 days of curing. When steel fiber is added, concrete of mix 40% RCA, 20%GGBS and 2.0% steel fibers shows compressive strength more than 14% from reference mix at 7 days of curing. After 28 days curing, compressive strength is about 13% less than from reference mix at 60% substitution

of RCA. When GBBS is added to recycle coarse aggregate concrete, at 20% substitution of GBBS and 40% RCA show 12% more than compressive strength from reference mix after 28 days of curing. When steel fiber is added, concrete of mix 40% RCA, 20%GBBS and 2.0% steel fibers shows compressive strength more than 17% from reference mix at 28 days of curing. After 56 days curing, compressive strength is about 7.0% less than from reference mix at 60% substitution of RCA. When GBBS is added to recycle coarse aggregate concrete, at 20% substitution of GBBS and 40% RCA show 26% more than compressive strength from reference mix after 56 days of curing. It due to fact that pozzolanic reaction procced slowly. Some studies also reported that, early age strength reduced with addition of pozzolanic materials to concrete [21]. When steel fiber is added, concrete of mix 40% RCA, 20%GBBS and 2.0% steel fibers shows compressive strength more than 36% from reference mix at 56 days of curing.

3.2.2 Split Tensile Strength

The ability of cylindrical sample to resist the stresses when it is subject to tensile (Stretching or pulling) force are terms as tensile strength of that material. Direct tensile strength of concrete is not possible because of eccentricity and griping of sample. Therefore, indirect split tensile strength can be determined by placing cylindrical sample in compressive machine to split in vertical diameter. As per standard procedure define by ASTM as ASTM C39/C39M [48] was apply for split tensile strength test of cylindrical sample size 300mm length and 150mm diameter.

Figure 7 shows compressive strength of different dosages. Similar to compressive strength, split tensile strength decreases with incorporation of RCA having minimum strength at 60% of RCA as compared to reference concrete. It is because of physical nature of RCA which absorb more water, leading to porous concrete resulting lower compressive strength. it is worth to mention that split tensile more effectively decreased with incorporation of RCA than compressive strength. When GGBS was added to improve split tensile strength of recycle aggregate concrete. At 28 days curing, split tensile strength of aggregate 60% recycle aggragate concrete is about 10% more than to control mix at 20% substitution of GGBS.

The positive impact of GGBS on compressive strength is because of pozzolanic reaction of silica (SiO_2) in GGBS with calcium hydrate (CH) of cement, giving supplementary cementitious gel i-e calcium silicate hydrate (C-S-H) [21]. According to past literature, split tensile strength mainly depend upon the binder strength. Aggregate trying move away from each other during tensile force. The additional binder produced by the GGBS result more resistance [3]. But, at higher proportion ratio of GGBS (beyond 20 %) split tensile strength decrease because of dilution effect which results to alkali silica reaction because of higher amount of unreactive silica (SiO_2) accessible because of high quantity of GGBS [21]. Also, GGBS fill the voids in recycle aggregate, providing more compact concrete which results improvement in split tensile strength of concrete. when steel fiber was to GGBS recycle aggregate concrete, split tensile strength increase as the proportion of steel fiber (SF) enhance up to 2.0% and then decreased gradually. All the fiber reinforced shows higher strength as comparison to reference concrete having maximum split tensile strength after 28 days curing at 2.0% addition of steel fibers. It is wort to mention here that split tensile of concrete increased more effectively than compressive. According to the past researchers show

that fiber improved split tensile strength more effectively than compressive strength [46]. Laterally expansion produce under the application of compressive load which resisted by fibers because of confinement and as result to increased split tensile strength [35].

3.3.0 Durability of concrete

3.3.1 Water absorption

Water absorption is one of the simple tests to detect durability concrete. Higher water absorption results lower durability of concrete. More water absorption also led to freezing and thawing action which results degradation of concrete. According to past literature, higher water absorption of concrete cause freezing and thawing of concrete particularly when concrete is to place in abruptly changing of temperature [22].

Figure 8 shows Water absorption of different dosages. Water absorption increased with incorporation of RCA having minimum Water absorption at 0% of RCA as compared to control mix. RCA are pore which absorb more water, leading to less Water absorption. When GGBS was added to recycle aggregate concrete, Water absorption decreased.

At 28 days curing, Water absorption at aggregate 60% recycle aggerate concrete is almost equal to control mix at 20% substitution of GGBS. The positive impact of GGBS on Water absorption is due to the pozzolanic reaction which produce more viscus binder surrounding to the aggregate which decreased water absorption [21]. Also, GGBS fill the void in recycle aggregate which result less water absorption. However, at higher substitution ratio of GGBS (beyond 20 %) Water absorption enhanced because of less workability of concrete which enhance compaction affords resulting more porous concrete [4]. When steel fiber (SF) was added to GGBS recycle aggregate concrete, Water absorption decreased as the substitution ratio of SF enhanced up to 2.0% and then decreased gradually. All the fiber reinforced shows lower Water absorption as compared to control having minimum water absorption after 28 days curing at 2.0% substitution ratio of steel fibers. According to past literature, fiber protect formation of shrinkage cracks due to which water cannot be easily penetrate [22].

3.3.2 Acid Resistance

Different aggressive acids available, like as HCL (hydrochloric acids), NHO_3 (nitric acids) and H_2SO_4 (sulfuric acids) etc. In this study, H_2SO_4 (sulfuric acids) is considered as an acid attack, on the concrete specimens with different proportions of RCA, GBBS and SF.

Figure 9 shows Acid resistance of different dosages of RCA, GBBS and SF. Acid resistance decreased with incorporation of RCA having minimum acid resistance at 0% of RCA as compared to control mix. RCA are pore through which acid can easily penetrate through concrete, leading to less acid resistance. When GGBS was added to recycle aggregate concrete, acid resistance increased due filling voids and pozzolanic reaction leading to more dense concrete through which acid cannot easily penetrate. At 28 days curing, acid resistance at aggregate 60% recycle aggerate concrete is 5.0% more than control mix at

20% substitution of GGBS. However, at higher dosage of GGBS (beyond 20 % by weight of cement) acid resistance decreased due less workability of concrete which enhance compaction affords resulting more porous concrete [49]. When steel fiber was to GGBS recycle aggregate concrete, acid resistance increased as the dosage of steel fiber increase up to 2.0% and then reduced. All the fiber reinforced recycle aggregate concrete shows more acid resistance as compared to control having maximum acid resistance after 28 days curing at 2.0% substitution of steel fibers. According to past literature, fiber protect formation of shrinkage cracks due to which acid resistance cannot be easily penetrate [49].

3.3.3 Drying Shrinkage

Concrete durability can be detected through dry shrinkage. Water and chemical can easily inter onto the concrete body through small cracks on the surface of concrete causing deterioration of concrete due dry shrinkage of concrete which results less durable concrete. Drying shrinkage with respect to time for varying dosage of RCA, GGBS and SF is given in Figure 10. RCA increased dry shrinkage of concrete. Although it has been reported that dry shrinkage is basically movement of cement paste while aggregate restrict these movement [50]. According to past literature drying shrinkage is affected by the concrete porosity and stiffness [50]. RCA is basally porous nature which results pores in harden concrete. It has been also reported that dry shrinkage of concrete increased with addition of RCA. When GGBS is added to recycle aggregate concrete, dry shrinkage is considerably reduced. The formation C-S-H (calcium silicate hydrate gel) due to pozzolanic reaction cause more dense concrete which might be caused to decrease shrinkage. It has been also reported that fly ash considerably reduced drying shrinkage to filling micro pore in concrete which enhance internal compactness of concrete [21]. when SF is added to GGBS recycle aggregate concrete, dry is father reduced. SF restrict the formation of microcracks on the surface of concrete which restraint the movement of harmful elements in samples, which leads to minimalized cracks density and dimension and eliminates the detrimental effects of drying shrinkage. Addition of SF to GGBS recycle aggregate concrete, reduced the drying shrinkage due crack prevention by SF as well as pozzolanic reaction of GGBS.

3.4.0 Scan Electron Microscope (SEM) and X-Ray Diffraction (XRD)

SEM is used to evaluate the microstructure analysis of steel fiber, GGBS and recycle aggregate in concrete as per ASTM C1293 267 test [51], Scanning Electron Microscope (SEM) images of concrete samples and to X-ray diffraction analysis with presence and absence of steel fiber (SF), GGBS and recycle Coarse aggregate on concrete after curing of 28 days as show in Figure 11 and Figure 12 respectively. Figure 11 (a), (b), (c) and (d) shows that, Various pore and interfacial transition zone (ITZ) are appear as percentage of RCA increased particularly at 60% substitution which results lower strength. To analyze the measure of quartz and C-S-H (calcium silicate hydrate) gel in control and GGBS substituted batches. Peaks of C-S-H gel at 30° and 45° were selected for analysis. For control sample without GGBS, quartz is more as compared to C-S-H. During hydration of cement, C-S-H is formed due to chemical reaction quartz (SiO_2) with lime (CH). The quantity of calcium hydrate (CH) is more than SiO_2 which convert all SiO_2 into C-S-H gel and hence no further Silica (SiO_2) available for the reaction with

CH to C-S-H gel which gives the binding properties. All Silica (SiO_2) convert into C-S-H gel. CH remain unreactive forming weak pockets resulting less strength of concrete. It has been also reported that, CH reactive with other chemical ingredient present in concrete resulting less durable concrete [49]. Also reported that, Pozzolanic materials must be added to utilize CH which is by product form during hydration process of cement in order to obtain high strength durable concrete [49]. BGGS which rich in silica is added to neutralize CH. It can be seen from XRD analysis, that peak of quartz (SiO_2) reduces while the peak of C-S-H is increased as the percentage of GBBS increased. Maximum C-S-H peaks was observed when the substitution of fly ash rate is 30%. It is due to the pozzolanic reaction which convert CH into C-S-H gel.

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Figures

(a)

(b)

Figure 1

(a) Fine Aggregate and (b) Coarse Aggregate

Figure 2

XRY Pattern of GBBS

Figure 3

Slump Results

Figure 4

Fresh Density

Figure 5

Compressive Strength

Figure 6

Relative Analysis of Compressive Strength

Figure 7

Split Tensile Strength

Figure 8

Water Absorption

Figure 9

Acid Resistance

Figure 10

Dry Shrinkage

(a)

(b)

(c)

(d)

Figure 11

(a) R-0, G-0, S-0, (b) R-20, G-10, S-1, (c) R-40, G-20, S-2 and (d) R-60, G-30, S-3

Figure 12

XRD Pattern of Varying Dosages