Review on Mechanical and Durability properties of Concrete After Replacing the Aggregate and Cement with Waste Materials

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ABSTRACT

The increase in construction activities, is leading to the depletion and the exploitation of the natural river sand, causing adverse effect on the environment, increase in river bed depth, lowering of the water table, and intrusion of salinity into river. Therefore the need to find the alternative substitute or replacement of Natural River sand. Presently many researchers investigate the suitable waste materials for replacement of RS like Geopolymer Fly Ash Sand (GFS) good particle size distribution according to Zone-I, use of Waste Glass use as fine aggregate up to 20 % and cement partially replace with fly ash up to 20% at variable temperature and environment, Recycle Granulated Steel (RGS) introduced as a replacement of fine aggregate up to 60% by weight, Partially increasing lime percentage up to 10% with cement, using contaminated recycled aggregates which is produced by the degradation of concrete structures due to chlorides and sulphates penetration in structure, using Foundry Sand as a fine aggregate with partially replacement up to 30%, this waste produced by metal casting industries, some researchers found glass fume suitability in concrete with positive results. The research conducted on utilization of industry waste materials by researcher found positive up to 30% of waste material replacement with fine aggregate and cement in respect to mechanical and durability properties of concrete.

Keywords: Durability Properties, GF, GFS, Lime, Mechanical Properties, RGS, etc.

I. INTRODUCTION

The rapid advance of globalization and the growth in the population has resulted in a growth in various constructions that has consequently led to a higher demand of construction materials. River sand is the one the main ingredient used as a fine aggregate in concrete & Mortar production. A rising demand for construction material has led to the overexploitation of river sand and this overexploitation has led to harmful consequences. In addition, the restriction in the extraction of sand by government organization has increased the price of for this reason, finding an alternate material to sand has become vital. Over the last several decades, an enormous amount of research has been carried on the use of industrial waste, including foundry sand, geopolymer fly ash sand, waste glass, recycled granulated steel, increasing lime percentage, glass fume, recycled aggregate as a substitute/ replacement material for fine aggregate, glass fume etc. From the research outcomes, it was suggested that the substitution of industrial waste as an alternative material in concrete making could improve the structural properties of concrete and promote sustainable concrete development.

As modern engineering practices become more demanding, there is a corresponding need for special type of materials with novel properties. Scientist, Engineers and Technologist are continuously on the lookout for materials, which can act as substitute for conventional materials or which posses such properties as would enable new designs and innovations resulting into economy, so that a structure can be built economically. There have been so far many attempts to develop new materials, which is the combination of two or more materials. Such materials are called composite material. Waste glass can also used in place of fine aggregate. Glass is amorphous solid material which is produced at high temperature followed by crystallization. The effective use of waste glass for partial and full replacement of sand as an admixture in cement mortar and concrete has established in the country in recent years.

II. LITERATURE SURVEY

[U.S. Agrawal et. al. 2017] found the (GFS) prepared by using 10 M NaOH and Na2SiO3/NaOH ratio equal to two as geopolymer liquid solution and fly ash in proportion of 1:3 respectively had similar properties as that of natural river sand (NRS). While comparing the properties of the GFS and NRS, they exhibited similar properties in terms of specific gravity, particle size distribution and compressive strength. GFS particles achieved a specific gravity of 2.46 which was comparable with NRS (2.67), however they exhibited a higher specific gravity than fly ash (2.12) due to the bonding provided by the Si-O-Al-O units. The particle size distribution curve of GFS confirmed to zone-I and the coefficient of curvature (Cc = 1.17) and coefficient of uniformity (Cu = 4) classified it as poorly graded soil (SP). In spite of GFS exhibiting higher pH value (12.2) and water absorption (5.61%) as compared to NRS with 8.16 pH value and 0.82% water absorption, the compressive strength properties of the mortar bar at 28 days were not influenced, with GFS achieving 93.6% of the 28 day compressive strength as that of NRS. GFS had a frictional angle of 42, whereas NRS exhibited a frictional angle of 38^{o} indicating GFS particle are angular and densely packed, which is essential for concrete purposes. The durability tests on GFS such as soundness and alkali silica reaction yield 6% weight loss and 0.06% expansion respectively which was within the threshold limits as per the Indian standard code thus indicating that GFS are resistant to weathering action and alkali silica reaction. The XRD and XRF results showed that the major minerals present in GFS are quartz and mullet and the major components are silicon and aluminium respectively. From the SEM image it was observed that GFS particles contained unreached fly ash particles due to the incomplete dissolution of the fly ash particles during synthesis, which may be responsible for the later strength development, also some amount of porosity was observed on the particle surface. With this study, it may be concluded that the GFS could be used suitably as an alternative to NRS in construction activities.

[Upal Mohammad Towfiqul Quadir et. al. 2016] found the RGS concrete's slump value is observed to increase up to 100% along with the percentage of RGS replacement. This can be attributed to the lesser absorption capacity of RGS than NFA where the effective water cement ratio is fixed for all categories. For this, the amount of suspended water becomes higher in the mix as the RGS content is incrementally increased, resulting in higher slump value. For the compressive strength and splitting tensile strength, the RGS concrete shows higher values than the control concrete specimen for both 28 days and 56 days cases. For both tests the 50% RGS replacement shows the best result. The flexural strength of RGS concrete is found to be higher than that of the control concrete specimen. RGS concrete in the 30% -50% replacement ranges shows the highest value. From all the mechanical property tests, it is concluded that only an optimum replacement level of RGS shows highest value which is found around 30%–50% replacement range. Based on the sulphate test, the compressive strength results show that the RGS concrete provide acceptable strength, though the values are slightly lower than those of the control concrete specimen.

[Prasanna Kumar Acharya et. al. 2016] found the compressive strength of concrete made of PSC and PPC increases on inclusion of lime up to 7 % at all ages, studied at the age of 28, 35 and 42 days. At 10 % lime content the compressive strength decreased in comparison to control concrete at all ages. The flexural strength of PSC and PPC made concrete increases with lime content up to 10 %. However at 7 % lime content, it is highest for both PSC and PPC concrete measured at the age of 28, 35 and 42 days. Consistency is seen to increase with increase in lime content. This indicates more water demand. Initial setting time decreases with addition of lime indicating early start of chemical reaction between cement and water. Final setting time decreases with addition of lime indicating early completion of chemical reaction. Soundness increases with addition of lime. The highest increase is 2 mm with 10 % lime addition measured in Le-Chatelier apparatus against the permissible limit of 10 mm. Hence, addition of lime up to 10 % does not affect the soundness. Workability in terms of slump decreases with addition of lime for both PSC and PPC. It indicates lime addition demands more water. This can be compensated by introducing water reducing admixture, like Plasticizer and Super Plasticizer. Both acid and sulphate resistance increases slightly up to 7 % lime content and thereafter, resistances are seen to decrease.

[Dr. U. Ranga Raju et.al. 2016] found the compressive strengths of concrete (with 0%, 5%, 10%, 15% and 20% of weight replacement of cement with fly ash and 0%, 10%, 20% 30% and 40% of weight replacement of FA with waste glass) cured in Normal water for 7, 28, 56 and 90 days have reached the target mean strength. The split tensile strengths of concrete (with 0%, 5%, 10%, 15% and 20% of weight replacement of cement with fly ash and 0%, 10%, 20% 30% and 40% of weight replacement of FA with waste glass) cured in Normal water for 7, 28, 56 and 90 days have reached the target mean strength. The compressive strengths of concrete (with 0%, 5%, 10%, 15% and 20% of weight replacement of cement with fly ash and 0%, 10%, 20% 30% and 40% of weight replacement of FA with waste glass) cured in 0%, 0.5%, 0.75% and 1% of HCL for 7, 56 and 90 days have reached the target mean strength. On replacement of 10%,20% and 5% ,10% of FA by waste glass and cement by fly ash in concrete mix there is an increase in compressive strength of 4.5% and 5.8% at 7 days, 4.5% and 5.5% at 28 days is observed when compared to control mix. The spilt tensile strength of concrete increases at 10%,20% and 5%,10% replacement of fine aggregate by waste glass and cement by fly ash 2.23% and 4.83% at 7 days ,3.68% and 4.12% at 28 days when compared to control mix. The compressive strengths of concrete cured in different concentrations of (0%, 0.5%, 0.75%) HCL acid solution for 7, 56 and 90 days indicate that at 0.75% of HCL acid there is increase in strength and beyond that the strengths decreases. The strength decreases in acidic environment with age of concrete also with increasing of fly ash and waste glass content in concrete. The compressive strength after exposing the specimens to temperatures of 100^0,200^0,300^0,400^0 and 500^0 c respectively in furnace for 60 minutes there is a nominal decrease in compressive strengths at the elevated temperatures.

[G. Ganesh Prabhu et. al. 2015] found the reuse of foundry sand as a substitute for natural sand in concrete production was evaluated based on the mechanical and durability properties of the resulting concrete. Based on the extensive tests carried out on the six mixtures, the Conclusion has been made are- The chemical analysis of FS indicated that FS can be a very suitable material for concrete production. However, the fineness and high water absorption of FS increases the water demand of the concrete by water absorption, decreasing the workability of the concrete, although the effect was profound beyond the substitution rate of 30%. In all ages of concrete, the mechanical properties of concrete mixtures containing FS up to 30% was relatively equal to the strength value of the CM. Compared to the mixture with FS 30%, the CM had showed its mechanical properties by 6.3% higher on average. The chloride penetration value of the CM was 420 coulombs, whereas the mixture FS 30% achieved the value of 621 coulombs at the age of 180 days, which is much less than the maximum value recommended in ASTM C1202-97. Since the carbonation coefficient of the concrete mixture with a substitution rate of up to 30% was never exceeded the value of 6 mm/month0.5, it can be considered as a good concrete. The CM increased electrical resistivity by only 10.37% and 14.62%, respectively, when compared to the FS 20% and FS 30% mixtures, at the age of 180 days. The presence of sulphur traces in the FS increased the strength of the NaSO4 and MgSO4 solution and enhanced the ettringite formation, causing the deterioration of concrete. It is recommended that the FS with a substitution rate up to 30% is favourable for the concrete production without adversely affecting the strength and durability criteria.

III. RESULT ANALYSIS

3.1 Characteristic study of geopolymer fly ash sand- In this research U.S. Agrawal et. al. found after replacing geopolymer fly ash sand (GFS) with natural sand and properties are compared with each other which yield satisfactory results in terms of physical, chemical, mechanical and durability properties. GFS has comparable specific gravity (2.46), good particle size distribution (zone-I) and frictional angle (42) as compared to natural river sand (NRS). Though GFS has pH (12.2) value and water absorption (5.61%) value slightly higher than the NRS, the soundness and the alkali silica reaction are within limits as per Indian Standard code. The mortar specimens with GFS achieved 93.6% at 28 day compressive strength as compared to NRS, indicating GFS has the potential to replace natural river sand in construction activities. Test conducted on after replacement are-

3.1.1 Specific gravity and water absorption-The average specific gravity and the water absorption of the GFS and NRS was determined as per IS 2386 (Part-III): 1963 and it was observed that GFS had specific gravity of

IJARSE
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2.43 which is less as compared to NRS having specific gravity as 2.67, making GFS light-weight as compared NRS. There was an increase in the specific gravity of the GFS as compared to that of the fly ash, due to the bonding provided by Si-O-Al-O units. Similar results were observed by Rao et. al. they reported specific gravity of fly ash geopolymer sand (FAPS) as 2.59, which was higher than that of fly ash (2.15). The water absorption of the GFS was observed as 5.61% which is higher than NRS (0.82%), which may indicate the porous nature of GFS.

3.1.2 Particle size distribution-The average particle size distribution curve for the GFS and the NRS was determined as per IS 2386 (Part-I):1963 and compared to the upper and lower limits of the standard sand of zone-I as per IS 383: 2016 and observed that the particle size distribution curve of GFS and NRS was similar and are within the upper and lower limits of standards and thus confirming as zone-I as per IS 383: 2016. The Coefficient of uniformity (Cu) and coefficient of curvature (Cc) for GFS and NRS was determined as per IS 1498: 1970. It was observed that GFS has Cu = 4 and Cc = 1.17; and NRS had Cu = 3.714 and Cc = 0.80 classifying both as poorly graded soil (for well graded sand Cu > 6 and Cc = 1–3 as per IS 1498 (1970).

3.1.3 Direct shear test & pH-The frictional properties of the GFS and the NRS were determined by direct shear test as per IS 2720 (Part 13): 1986 by subjecting the specimen to 0.25 mm/min strain rate and sheared under a normal stress of 32.9 kPa and 49.4 kPa. The slope of the line indicates the frictional angle of the soil sample. The frictional angle of GFS and NRS was observed as 42^o and 38^o. Respectively indicating GFS particles could be more of angular in shape (27^o indicate rounded loosely packed grains whereas 45^o indicate angular densely packed grain as per IS 2720 (Part 13): 1986. The pH of the GFS and NRS was determined as per IS 2720 (Part26): 1987 using ELICO LI 610 pH meter. A pH of 12.12 was observed in GFS which was higher than NRS with pH of 8.16 and induces the alkaline environment when mixed with cement. However this may not hamper the mechanical properties of concrete as cement hydration also induce the pH value of 12.8–13.3 during hydration.

3.1.4 Soundness test-The soundness test of aggregates is the indication of the resistance of aggregates to weathering action. An unsound aggregate leads to the deterioration of the concrete. The soundness test of the GFS was carried out as per IS 2386 (Part V): 1986 to determine the behaviour of GFS when subjected to weathering action. The specimen was subjected to alternate wetting and drying for a total of 14 cycles by immersing it into saturated sodium sulphate (Na2SO4) and then drying in oven at ($110^o \pm 5^o$) C for 4 to16 hrs. Till a constant weight difference of 0.1% was achieved. An average decrease of 6% in weight of GFS was observed based on five cycles, which is within the limits as per IS 383: 2016 (10% after 5 cycles). Therefore GFS may resist the volume changes when subjected to weathering action. It was observed that there was not much change in the particle size and shape indicating GFS particles may resist weathering action.

3.1.5 Alkali silicate reaction (expansion test)-To determine the alkali silica reaction, the mortar bar of size 280 mm x 25 mm x 25 mm was prepared by mixing GFS with cement as per ASTM C1260. The specimens were immersed in 1 M NaOH solution for a period of 14 days at 80^oC temperature to measure the percent expansion of the sample when exposed to alkaline environment. The average expansion of the mortar bar was observed as 0.06% after 16 days which was less than the threshold limit as per IS 383: 2016 (0.1% after 16 days. The alkali silica reaction gel is generally formed due to the chemical reactions between alkali from OPC and siliceous content from the aggregates which when exposed to NaOH, the alkali in Portland Cement lead to the depolymerisation of the silica in aggregate generating alkali-silica gel, however in case of geopolymer concrete the fly ash utilize the alkali involved in the chemical reaction to form a cementitious binders providing a good interfacial bond between the aggregate and the paste interface thus increasing the tensile strength of geopolymer concrete, which may also be the case in GFS. From the visual examination of the sample very small amount of cracking and leaching was observed on the mortar bar surface. X ray diffraction (XRD).The XRD of the GFS and fly ash was determined using XPERT PRO powder diffractometer. It was observed that GFS has quartz, mullite, alumina and sodium peaks whereas fly ash showed the presence of quartz, mullite, alumina and calcium. Also a broad hump was observed in fly ash between 0 and 20^o, which was not observed in the case of GFS. When fly ash is mixed in the alkaline solution, it releases the silicon and aluminium ions into the alkaline solution, which leads to the formation of alumino-silicate bond, which act as a hard binder for imparting strength to the geopolymer material. The presence of sodium in GFS was due to the addition of NaOH and Na2SiO3 in the fly ash particles. However calcium peak was not observed in GFS indicating that some part of calcium was also utilized during the geopolymeric reaction.

3.1.6 Scanning electron micrograph-The scanning electron micrograph (SEM) of GFS was determined using JSM 6380A. It can be observed that the particles are irregular in shape, as well as unreacted fly ash particles due to the incomplete dissolution of fly ash during the synthesis process were observed on the GSF surface.

3.1.7 X-ray fluorescence (XRF)-The chemical analysis of geopolymer sand was done using XRF. It was observed that the major components of geopolymer sand are silicon (SiO2) and aluminium (Al2O3) with 55.46% and 20.77% composition respectively. An increase in SiO_2 and Na2O was observed in GSF particles as compared to fly ash due to the addition of the alkaline liquid. All other Components remained nearly same as that of fly ash.

3.1.8 Compressive strength-The compressive strength of the GFS and NRS mortar was determined as per IS 2386 (Part VI): 1986 by preparing three replicate cubes of size 70.7 x 70.7 mm x 70.7 mm and curing it for 3, 7 and 28 days .To prepare the mortar cubes, the GFS and NRS confirming to zone-I was mixed with cement and water with w/c = 0.6 to achieve a flow of 100 ± 5 mm respectively. The compressive strength test results of GFS and NRS are observed that the 3 day and 7 day strength of the GFS was less as compared to NRS, however it achieved a compressive strength of 93.6% of NRS at 28 days (GFS = 22.406 MPa, NRS = 23.94 MPa). It may be attributed to the unreached fly ash particles present in the GFS as observed it may have reacted with the cement hydration product such as lime and may have contributed to the later strength.

3.2 Mechanical and Durability Properties of concrete using recycle granulated steel- In this research Upal Mohammad Towfiqul Quadir et. al. investigate the Mechanical And Durability Properties of concrete using recycle granulated steel after conducting the following experiments.

3.2.1 Fresh concrete properties-The air content is measured according to ASTM C138. From the experiment the value of slump is calculate, slump value remains the same as for the control mix for up to 20% RGS mix. The slump value is found to be increasing with the RGS up to a value of 92 mm for 60% RGS. This is most likely attributed to the fact that, with the incremental increase of RGS content, the increased amount of steel in

IJARSE
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the concrete reduces the water absorption capacity compared to NFA. Since the w/c ratio is fixed for all the mixes, the amount of slump is higher in mixes containing higher amounts of RGS. On the other hand, it can also be seen that the air content is also increased with the increasing amount of RGS. This is mainly due to the flaky and irregular shapes of RGS grains, which results in a greater volume of voids. However, although the air content increases, the highest value is found to be 2.59%, which still falls within the acceptable range.

3.2.2 Compressive strength-The compressive strength test is performed at 28 and 56 days in a total of seven batches, six specimens from each batch are tested at 28 days and three specimens from each batch are tested at 56 days, with the compressive test data of the cylinders note down, respectively. it can be seen that the incremental replacement of NFA with RGS decreases the compressive strength of the concrete compared to the control specimen beyond 20% RGS replacement. After this 20% threshold has been reached, the incremental RGS replacement results in a gradual increase in the compressive strength, which even surpasses the compressive strength (37.68 MPa for 50% RGS) of the control specimen (33.72 MPa). 28 days compressive strength is increased by 4.2% and 11.7% compared to the control mix at 40% and 50% replacement level of NFA, respectively. Similar trend was observed in for 56 days compressive strength. Compressive strength is increased by 3.4% and 12.6% for 40% and 50% replacement of NFA, respectively than those of the control concrete specimens. The increase in compressive strength is mainly due to the rough texture of RGS compared to the NFA. The rough texture of RGS compared to NFA particles leads to a stronger bond between the binder and the fine aggregate. Another reason of this increase is due to the densification of concrete matrix. However, once RGS replacement exceeds 50%, a slight decrease (3%) in compressive strength is observed. The increase in compressive strength demonstrates that 50% NFA replacement yields the best results compared to other mixes. The compressive strength results at 28 days and 56 days also indicate that higher than an optimum amount of RGS (which is 50% for this case) leads to greater volume of voids and weak bonding which results in lower value of compressive strength. However, all the concrete mixes exceeded the target 28-day compressive strength which was 25 MPa. This test outcome thus leads to the conclusion that only an optimum amount of RGS replacement can produce satisfactory results by achieving proper bonding with other components of the concrete. 28-day compressive strength of 10% and 20% RGS concrete are 15.9% and 14.6% lower compared to the control concrete, respectively but they are higher than the 28 days target compressive strength. The lower compressive strength value is mainly due to the lower absorption capacity of RGS compared to NFA which might increase the effective water-cement ratio, and thereby decreasing the strength. However, 28 days compressive strength is increased up to a 50.7% for 50% RGS concrete compared to the design compressive strength.

3.2.3 Splitting tensile strength-The mean, standard deviation (SD) and coefficient of variation (COV) of the splitting tensile strength tests for 28 and 56 days calculated, and shown with the incremental replacement of NFA with RGS, the splitting tensile strength is initially observed to be lower than that of the control specimen. However, at 50% RGS replacement, the value reaches a satisfactory level which is almost equal to the value of the control specimen. It is also observed that the value begins to decrease for RGS replacement quantities exceeding 50%. The tensile strength decreased by 15.1% at 10% RGS replacement compared to the control specimen. When the NFA replacement level increases (from 20% to 50%), the splitting tensile strength reduces by 2%–6%. This occurs for a similar reason as explained above with respect to compressive strength. The 50% RGS replacement provides optimum void ratio and bonding in concrete, resulting in highest value of splitting tensile strength (i.e., 3.63 MPa). The more irregular and rougher surface of RGS particles also contributes to the increase of strength. 56 days splitting tensile strength test results for 50% RGS concrete show slightly better performance (i.e., 3% increase) compared to the control concrete mix. This might be attributed to the rough texture of RGS and good interface bonding between cement mortar and RGS. The rate of increase in tensile strength for different RGS concrete mixes (30–60%) are also higher compared to the control concrete mix for 28 days and 56 days curing.

3.2.4 Flexural strength-A summary of the quasi-static flexural properties for each batch is not down. It is observed that concrete with RGS replacement have higher flexural strength compared to the control Specimen. Unlike the compressive and splitting tensile strength, where 50% RGS concrete shows the highest value, it is observed that 30% RGS shows the highest value in the case of flexural strength (4.75 MPa). Also, concrete with 40% RGS and 50% RGS shows flexural strength of more than 4 MPa. In summary, the flexural strength is increased up to 31.7% at 30% RGS, which indicates that RGS improves the flexural property significantly. The reason can be explained as the RGS acts as micro fibre reinforcement in concrete, and provides increased flexural capacity. Flexural strengths were increased by 3.7%, 66%, 31.7%, 16.4%, and 8.2% compared to the control concrete mix at 10%, 20%, 30%, 40%, 50% and 60% replacement level of NFA, respectively. One of the flexural strength tested beam specimen (after failure) is illustrated. The specimen toughness for each category is found from the Respective load versus deflection graph. According to ASTM 1609, the toughness, TD 150, indicates the total area under the load versus deflection curve up to a net deflection of L/150. All the RGS replacement specimens show greater toughness values than the control specimen. The equivalent flexural strength ratio RD T, 150 indicates the ratio of toughness to first peak strength of the particular category. It shows higher values for the RGS replacement specimens. This ratio is calculated as per ASTM 1609.

3.2.5 Sulphate test-Sulphate test bears significance in determining the resistance of concrete to sulphate corrosion. This test also represents the general resistance property of concrete. So, for a new type of concrete such as RGS concrete, a sulphate test can be an effective mean to assess the concrete's resisting capacity. Sulphate-rich environment has an adverse effect on concrete. When concrete structures are exposed to sulphate-rich environment, SO4 - ions penetrate into concrete matrix, and dissolute the cement hydrates (i.e. portlandite, Ca (OH)2) and C3A to form expansive products like gypsum and ettringite. In the initial stage, ettringite provides early strength filling the pores in the concrete. However, in the later stage, ettringite causes expansion and cracking in the concrete matrix, thus reducing the strength of concrete. In this study the effect of the sulphate rich environment on the RGS concrete was evaluated in terms of mechanical strength, physical impact (i.e., linear and volumetric shrinkage), and micro-structural transformation of concrete specimens through Scanning Electron Micrograph (SEM) images. A comparison was also performed with the unexposed specimens. Concrete specimens were immersed in a sodium sulphate solution to be tested in compression according to ASTM C452 and ASTM C102. For the present study, a sulphate bath is prepared one day before the use with 5% sodium sulphate and stored at $23 \pm 2^{o}C$. In the storage container the ratio of volume of sulphate solution to the volume of concrete cylinder is 4 ± 0.5. After this preparation, 28 day water-cured cylindrical specimens are immersed in sodium sulphate solution for a period of another 28 days to investigate the impact of sulphate exposure. During this period, sulphuric acid is added every day to maintain a pH for the sulphate bath around 6.5–7. Finally, the specimens are removed from the sulphate bath to examine compressive strength, physical degradation, and the effects of sulphate exposure are verified through SEM images. The sulphate durability test is oriented with the mechanical strength loss as well as the change in external and internal structure of the specimens. These results are discussed in detail in the following sections.

3.2.6 Change in volume and height-The dimensions of the cylinders are measured before and after the sulphate test in order to evaluate the change. We observe the changes in volume and height do not follow any strong sequential trend. 40% RGS replacement shows the highest percentage of volume change, whereas 30% RGS replacement shows the lowest. Volume is changed by 3.56% for 60% RGS compared to the control specimen, but the other 4 mixes show relatively similar results to one another. Another finding of note is that 60% RGS replacement shows the lowest height change, but a significant change in volume is observed. This data analysis suggests that a change in the dimensions of specimens may occur in two dimensions. RGS concrete specimens experienced maximum 4.38% volume change after sulphate exposure due to the formation of ettringite while the control specimens experienced 1.93% volume change. Another reason of volume expansion in RGS concrete is due to swelling of expansive product, gypsum.

3.2.7 Change in compressive strength-The change in compressive strength of concrete with different RGS replacements is observed and the range of compressive strength with average and standard deviation values. All the mixes show a reduction in strength except the control specimen, which has a slight increase of about 4.49%. Here all the RGS replacements show reduction in compressive strength of 0.29%, 1.46%, 15.23%, 6.87%, 15.03%, and 5.92%—following sulphate exposure. When concrete structure is exposed to sulphate-rich environment, it experiences two types of damage: volumetric expansion of concrete matrix which causes cracking due to the formation of expansive products (gypsum and ettringite), and strength reduction due to the dissolution of cement hydrates. The reduction in compressive strength after sulphate exposure is mainly attributed to the reduction of $Ca(OH)_2$ from the concrete matrix which increases the porosity of the cement paste. Sulphate ions penetrate into concrete matrix, and produces gypsum and ettringite through chemical reaction. This also increases the ITZ in the concrete matrix, and thus produces lower strength concrete. However, the formation of secondary C-S-H due to pozzolanic reaction has a counter effect against sulphate attack, which delays the reduction in compressive strength. The results of this study also revealed that the compressive strength of concrete containing RGS reduced by 20% compared to the control concrete at 10% replacement level (i.e., 10% RGS) when exposed to 5% sodium sulphate solution for 28 days. The most significant point here is that all of the RGS modified specimens still exceed the target compressive of 25 MPa after sulphate exposure. The results of the compressive strength reveal that the sulphate exposure does not have significant negative impact on the compressive strength. This indicates the compatibility of RGS to be used as a partial replacement of fine aggregate in concrete.

3.2.8 Microstructure analysis-In order to explain the observed improvement of microstructure in the experimental specimens due to sulphate exposure, the concrete specimens is examined using SEM imaging (JEOL, Model JSM-6490 LA and Japan). Typical micrographs with different zooming capacities are demonstrated. The microstructures of 28 day cured concrete specimens are noted. These results illustrate the change in microstructure after 28 days of curing. Due to the lower specific gravity of natural fine aggregate than RGS, the control specimen usually possesses a higher void ratio than the other six modified mixes with RGS Thus; these specimens offer enough available space for the formation of ettringite in their voids due to sulphate exposure. On the contrary, due to having a higher density, RGS modified specimens offer paucity in available spaces for the formation of ettringite in their voids, and consequently, such specimens experience cracking due to expansion of volume. This transformation of microstructure in the sulphate-treated specimens is shown.RGS increases from 10% to 60%. It is clear that sulphate exposure densified the microstructure of the control specimen due to formation of ettringite resulting in the increase in compressive strength compared to the RGS concrete. In the contrary, RGS concrete as less void, therefore, the formation of ettringite in the microstructure causes crack resulting in lower compressive Strength. SEM images of different concrete mixes before sulphate exposure reveal that with the increase of the replacement level (from 30% to 50% RGS), densified concrete was produced which results in higher flexural strength and toughness. From the micro-structural analyses, it is evident that sulphate exposure fills the empty cell of control specimens into crystalline products such as gypsum ($CaSO_4$) and ettringite. RGS has higher specific gravity compared to the NFA, therefore, increasing the percentage of RGS in concrete mixing produces denser matrix by filling the pores. When sulphate ion penetrates the RGS concrete, it reacts with the cement matrix, thus produces gypsum and ettringite. However, RGS concrete fails to accommodate these expansive compounds due to insufficient pores inside the matrix. Hence, the formation of ettringite causes expansion and crack in RGS concrete specimen when exposed to sulphate-rich environment resulting in lower compressive strength. On the contrary, the control mix easily accommodates the formation of cementitious products (i.e. ettringite), and prevents the formation of crack in the micro-structure resulting in higher compressive strength.

IV. CONCLUSION

As per the review of several papers the investigation approaches to positive result up to certain limits maximum 30% of waste materials uses after 30% uses the strength of concrete is decrease & the percentage of various waste materials which are used in concrete manufacturing partial replacement of cement and fine aggregate are investigate after various mechanical and durability tests. In this study Geopolymer Fly Ash sand found for effective because it’s fully replace the aggregate. The several investigation reaches the partially replacement of waste material. Presently few researchers are working on to find the complete replacement of fine aggregate by waste material to resolve the shortage problem to the construction industry.

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