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Study of Hardened Properties of Rubcrete Incorporated with SCMs (SF, FA, RHA): A Sustainable Approach

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ABSTRACT- This research focuses on the production of concrete with possible use of agricultural and industrial wastes in combined form as replacement to OPC along with use of waste rubber tire granules as coarse aggregate. The primary objective of this research is to is to check possible use of ternary blend rubcrete in non- structural uses like pavements.

In this research the optimum proportion of combined ternary mix (FA, SF, RHA) as partial replacement of binder/cement in natural aggregate concrete of M35 grade among the selected proportions were evaluated at the end of 7 and 28 days. Among the various proportions, the optimum combined proportion was found to be 40% replacement (10%SF, 10%RHA & 20%FA). The natural coarse aggregates (NA) of the optimum ternary blend were further replaced with waste tire granules (in proportions of 20%, 30% and 40%) and examined at end of 7 and 28 days. The optimum proportion of rubber (RA) in ternary blend rubcrete was found to be 20% as values above this percentage showed tremendous decrease in strength. Detailed experimental study of the fresh concrete property (workability) was performed & the compressive strength, flexural strength tests were carried out at the end of 7 and 28 days. Also, water absorption and loss in weight due to acid attack was examined at the end of 28 days. It is followed by SEM analysis and XRD analysis of the optimum proportions in comparison to control mix which justifies the results of this research. This research paves the way towards sustainable, cost efficient and environment friendly construction.

KEYWORDS- SCM- Supplementary Cementitious Materials, SF- Silica Fume, FA-Fly Ash, RHA- Rice Husk Ash, OPC- Ordinary Portland Cement NA- Natural Aggregate, RA- Rubber Aggregate CSH- Calcium Silicate Hydrate, CH- Calcium Hydroxide, SEM- Scanning Electron Microscopy, XRD- X- Ray Diffraction

I. INTRODUCTION

A high demand of aggregates and cement can be seen owing to its high requirement in construction industry. At the same time, a large quantity of agricultural and industrial wastes such as Silica Fume- SF, Fly Ash- FA, Rice Husk Ash- RHA etc are posing serious problems to the environment due to its disposal. In order to reduce the ill impact of concrete industry by the extreme usage of raw materials, the utilization of these waste is the best solution whose source is both cheap, suitable and reliable. The industrial and agricultural wastes can be used as supplementary cementitious materials SCMs for the replacement of cement in concrete. In the past many researchers have accomplished this task by the utilization of the industrial wastes in concrete like silica fume [3] [13] [23], fly ash [4][17][18] as well as agricultural wastes like rice husk ash [7][15][20].

Figure 1: Representation of SCM induced Rubcrete Beam (a) and Plain cement Concrete Beam (b)

Figure 1 shows the pictorial Representation of SCM induced Rubcrete Beam (above) and Plain cement Concrete Beam (below). Among all the agricultural wastes and by products the use of Rice Husk Ash is very important for countries like India as it is the world's second ranked country in the rice paddy cultivation .Also, the use of Rice husk ash leads to numerous advantages due to its pozzolanic properties such as increase in durability and strength parameters in concrete [22] and leads to reduction in emission of carbon by replacing cement as well as environmental benefits by reduction in disposal related problems. In mass concreting it has been found that the use of RHA significantly reduces the temperature production in comparison to the normal OPC concrete. In addition to the improvement in strength parameters by inclusion of RHA in concrete it has been established that the concrete containing RHA has reduced values of water absorption, heat evolution, thermal cracking and plastic shrinkage [15].

Silica fume, owing to its high silica content, has received importance to be used as a replacement to cement. The first testing of silica fume based OPC concrete was held in the year 1952 and till early 1970s this product was rarely used. Silica fume gained attention when in Norway it was established that the concrete containing silica fume shows high strength and lower porosities. Then after further investigation and research work made it one of the highly used cementitious admixture. It has been well established that the use of Silica fume in concrete gives high early compressive, flexural strengths, increases the toughness of concrete and increases the concretes resistance to acid attack [23].

Improvement in segregation as well as mechanical properties is obtained by the usage of Fly Ash. Due to the presence of low embodied energy, FA is extensively used in mass concreting as to reduce the heat production. It enhances the workability of concrete and thus reduces the water demand [24]. Binders (SF, FA, RA and OPC cement) are shown in Fig 2.

Figure 2: Binding Materials: OPC, SF, FA, RHA

Also, the dumped solid wastes, one of them being waste vehicle tires, can be utilized and used as a coarse aggregate in concrete. The disposal of waste materials is one of the most crucial environmental issues all over the world. Management of waste rubber tires is a global concern as major health and environmental problems are created by the production of millions of waste tyre and its dumping and burning. Discarded waste tires, which keeps on adding, is currently a major concern as it is not an easily biodegradable material by nature One of the alternatives to disposal of waste materials is its use as a construction material [8][12]. Fig 3 shows the coarse aggregates utilizing waste rubber. Other alternatives are its use as an energy

Figure 3: Coarse Aggregates: Both Natural and Rybber

source, fuel material, other construction products etc. Unfortunately, for pavement/road construction, much attention has not been paid to utilize rubber tyre waste in concrete mix as coarse aggregates. Only a limited amount of work has been carried out by researchers till date to elaborate the use of waste tyres as aggregate in conventional concrete. Replacement of coarse aggregate by waste tire chips/granules is reliable and promising due to steep increase in motor vehicle uses which in turn leads to production of waste tyres after end of service life and less utilization of discarded tires.

The idea behind the utilization of small sized waste rubber tire granules into the concrete mix is to prevent the uncontrollable accumulation of rubber wastes which poses a threat to the environment. By incorporating waste rubber tire granules, it is expected that the concrete mixture will become more tough and ductile and will have improved resistance to impact and cracking as inclusion of rubber further increase the elasticity. The addition of silica fume into the ternary blend rubcrete is expected to compensate the loss of strength due to addition of rubber granules and will act as a bridge in regaining the loss of strength Fly Ash, whose particle sizes are relatively spherical as compared to silica fume is expected to maintain the workability which is reduced by the silica fume. Moreover, improvement in segregation as well as mechanical properties is obtained by the usage of Fly Ash. It has been established that concrete containing RHA has reduced values of water absorption, heat evolution, thermal cracking, plastic shrinkage as well as increase in durability which is the reason for it being included in the research work.

In this investigation the study is carried out on the effect of fly ash, silica fume and rice husk ash on the mechanical characteristics such as compressive, flexure strength in ternary blend rubcrete in addition to other durability properties. Due to the extreme fineness of mineral additives and high reactivity, the bridging of the inter-transition zone between the cement paste and aggregate is further facilitated, thus improving the mechanical properties of rubcrete.

A. *Aim & Objective*

This project focuses on the production of concrete with possible use of agricultural and industrial wastes as SCMs-supplementary cementitious material along with use of waste rubber tire granules as coarse aggregate. The aim is to understand the effect of utilization of these wastes by checking the engineering, physical and chemical properties of the concrete. This research work aims in examining the effect of Fly Ash (FA), Rice Husk Ash (RHA) and Silica Fume (SF) in combined proportions as a partial replacement for cement along with partial replacement of coarse aggregate with waste tire granules. The possible use of rubcrete in non- structural uses like pavements is the main objective of this research work.

The optimum replacement proportion of binder materials i.e SF, RHA, FA individually is 10% as per the available literature. As such, this fact frames the base of our research which aims in identifying the suitable combined proportion of OPC replacement above this 10% individual replacement. As such minimum replacement of OPC is fixed at 30% which includes 10%FA, 10%SF,10%RHA and is increased till 40%. Since SF and RHA both are not beneficial to the concrete above 10% replacement as such they are fixed at this percentage and FA is increased in increments of 5%. The effects on fresh and hardened properties are studied to be further put into practical use. The following are the objectives of the research:

- To evaluate the optimum proportion of ternary mix (FA, SF, RHA) as partial replacement of cement (replacement ranging from 30%- 40% in combined form) in natural aggregate concrete of M35 grade among the selected proportions as supported by literature.
- To evaluate the optimum proportions of waste tire granules as replacement to natural coarse aggregate (replacement range 20%-40%) in the optimum mix of ternary blend cement concrete.
- To perform a detailed experimental investigation on the mechanical properties like compressive strength, flexural strength and durability characteristics like water absorption, acid attack and to study the variation in workability with slump test.
- To study the strength parameters of rubber incorporated ternary blend concrete by comparing it with plain cement concrete with same coarse aggregate replacement by rubber granules.
- To perform preliminary investigation by XRD and SEM analysis.

B. *Statement of Problem*

- Ordinary Portland Cement being an important ingredient of concrete, contributes to the greater portion of the total cost of project construction owing to its high prices in the market. The extensive production and use of Portland cement is responsible for the environmental concerns on one hand and the depletion of natural resource on the other hand. It is an estimated fact that 7% of the entire carbon dioxide is alone generated by the cement industries. Moreover, equal quantities of carbon dioxide and other greenhouse gases are released into the atmosphere with the production of each ton of cement. Extensive use of natural resources with mining and quarrying causes environmental burdens. This all suggests that the construction industry has come to be a victim of its own fulfillment and success and consequently it is now facing remarkable challenges for sustainable improvement of production and construction materials. This danger to environment and ecology made researchers to focus on utilization of agricultural and industrial wastes/by products as SCMs (as they possess pozzolanic properties.
- Solid waste control has additionally become a principle surrounding challenge with ever increasing quantities of industrial wastes in terms of waste materials generated globally. The safe disposal of waste tyre, presently, is a major problem in waste management. It is estimated that more than 3 billion tyres are produced globally in each year. It is anticipated that 27% of post client tires are stockpiled/dumped or sent to landfill and 11% are exported with only 4% being used in projects related to civil engineering. One of the alternatives to disposal of waste materials by construction industry is its use as a construction material. Replacement of coarse aggregate by waste tire granules is reliable and promising due to steep increase in motor vehicle uses. In this research work elaborate use of tyre waste as aggregate in conventional concrete is carried out.

II. EXPERIMENTAL PROGRAMME

The aim of this study is to evaluate the properties of concrete incorporated with waste tire granules in different proportions as part replacement to coarse aggregate as well as partial replacement of cement with three different types of wastes (SCMs); i.e Silica Fume -SF, Fly Ash- FA, Rice Husk Ash- RHA; in combined proportions.

- The proportion of Silica Fume is fixed at 10% (This proportion is selected based on literature. This is the optimum replacement value of cement by silica fume)
- The proportion of Fly Ash is varied from 10% to 20% in increments of 5% (Backed by previous literature as the optimum replacement value of cement by fly ash ranges from 10% to 30%)
- The proportion of Rice Husk Ash is also fixed at 10%. (This proportion is selected based on literature. This is the optimum replacement value of cement by RHA)
- Thus, using the above proportions in combined form, the binder i.e cement is replaced from 30% to 40% in M35 grade concrete.
- Among the above proportions of cement replacements, the one that is optimum (showing better physical, mechanical and durability properties) is selected for further testing and evaluation. In the selected proportion natural coarse aggregates are replacement by waste tire granules ranging from 20% to 40%.

A. *Tests*

1) *Specific Gravity Test*

Cement/ SCMs
As per IS 4031(Part 11) 1988 specific gravity tests were done. Density and viscosity of binding materials is determined with this test. In this test specific gravity of cement, silica fume, rice husk ash and fly ash is carried out using Le Chateliers or Specific Gravity bottle apparatus.
Fine aggregate/ Sand:

- As per IS 2386 part 3 the specific gravity of fine aggregates was determined. To carry out this test pycnometer instrument was used, following the standard procedure and precautions.
- Coarse Aggregate (Crushed stone 20mm&10mm) and Rubber Granules:
- The specific gravity test of rubber granules and natural coarse aggregates was done in accordance with IS2386 Part 3. To carry out this test standard procedure was followed taking all the necessary precautions.

2) *Gradation*

Coarse Aggregate/ Rubber Granules:
Gradation of aggregates was done through sieve analysis as per IS 383(1970). 60% of natural coarse aggregates of 20mm size were taken and 40% were of 10mm size. Size of rubber granules were fixed between 7mm-10mm.

3) *Determination of Zone of Sand*

In the research work, river sand was made to pass through 4.75mm sieve to separate any bigger sized particles. Fine aggregates could be categorized as fine sand, medium sand and coarse sand depending upon their size. According to IS

383 (1970) fine aggregates have been divided into four grading zones ranging from grade I to grade IV, higher the grade, finer is the sand. Sieve analysis was performed and the zone of sand was ascertained to be of Grade II.

4) Water Absorption Test

In accordance to IS 2386 (Part III)- method III and I, water absorption of coarse aggregates and sand was determined by these tests. Water absorption of rubber tire granules was found out by method I from the same code.

5) Slump Test

Workability of the concrete mixes was determined by slump test. As per IS 720-1974 slump test was done for plain concrete control mix, ternary mix concrete and for ternary mix rubcrete.

6) Casting & Testing

Compression specimens:
For performing the compression test, specimen of the size 15x15x15 cm were casted. Quantity of the materials were measured according to the mix design and then thoroughly dry mixed in mixer. In the beginning binder materials i.e., OPC, SF, FA, RHA and aggregates both crushed stones and rubber granules and sand were thoroughly mixed. Admixture was then added to the dry mix by diluting it in water. Casted cubes were then demolded after 24 hours from the time of casting and then placed in the curing tank. After the curing period of 7 days and 28 days tests were carried out on the cubes. For each mix 6 cubes were casted out of which each 3 cubes for testing on 7 and 3 for 28 days. Compression test was performed on AIMIL ACTM and also on a 300-ton CTM machine with a total loading capacity of 100 and 300 tons respectively. In accordance to IS516-1959 all the tests were carried out.
Flexure Beams:

Figure 4: Flexure beams to be put in curing tank

Beams specimens of sizes 100x100x500 mm were casted for performing the flexural strength test as sown in Fig 4. According to mix design, quantity of materials were weighed and dry mixed in mixer. Initially binders(cement/SF/FA/RHA), aggregates (crushed stone/rubber granules) were thoroughly mixed. Admixture was added to the water and was then added to dry mix. For each mix a total of 6 beams were casted, 3 beams for 7-day test and 28-day test respectively. IS 516-1959 was referred for carrying out the testing and the test were performed on a German manufactured machine brand- WERKSTOFFPROFMASCHINEN LEIPZIG having a capacity of 40 ton.

Acid attack specimens:

Figure 5: Estimating volume of H2S04 required to make 1L of 0.5pH and 2 pH respectively

To check the durability of plain concrete, ternary blend concrete as well as ternary blend rubcrete, the acid attack test had to be carried out. For the test to be performed, specimens were casted of dimension 100x100x100 mm. For each mix a total of 6 specimens were casted, to be checked for acid attack at the end of 28 days curing period. Before exposing the specimens to sulphuric acid solution (H_2SO_4) of 2% concentration, they were oven dried for 24 hours and then weighed. Two solutions of different concentrations were prepared as shown in Fig 5 and in each solution 3 specimens were immersed for a period of 4 weeks. When required, the solutions were replaced to maintain the concentration. The pH of one solution was maintained at 0.75 and the other was maintained at 2. After every 7 days the specimens were taken out from the solution, rinsed and removed of any loose surface. All the specimens were oven dried at 100±5C and then weighed after 4 weeks. After the exposure to the acidic solution the resistance to acid attack is assessed in terms of weight loss.
Water absorption:
Amount of absorbed water is an important parameter of concrete. One of the properties of a quality concrete is its low permeability. Concrete with low permeability is not prone to thawing and freezing as it resists water ingress. For each mix, 3 cubical specimens of size 100x100x100 mm were casted and the test was performed according to ASTM C 642-13 in different curing intervals. The cubical specimens were oven dried at 100±5C, cooled at room temperature and then weighed. After weighing the cubes were immersed in water. Periodically, the specimens were taken out of the tank, surface dried and weighed until a fixed/constant weight was achieved. Finally, the constant saturated weight was noted down and the water absorption is expressed in percentage of water absorbed by the specimen.

B. Methodology

Methodology is depicted in the below Flow chart (Fig 6)

Figure 6: Methodology Flow Chart

1) *Mix Design*

IS 10262- 2009 and 456-2000 was referred for carrying out the concrete mix design. The mix design was used to prepare M35 grade of concrete. properties such as workability, w/c ratio and the quantitative requirement of admixture were checked by preparing a no. of trial mixes (table 1).

Table 1: Mix Proportioning

Mix	Mix Type	Cement (Kg)	Fine Agg (Kg)	Coarse Agg. (Kg)	FA (Kg)	RHA (Kg)	SF (Kg)	Rubber Agg. (Kgs)
CM00	Control Mix	399.21	621.6	1183.5	--	--	--	--
FA10	10%SF, 10%RHA, 10%FA	279.4	621.6	1183.5	36.01	28.08	28.99	--
FA15	10%SF, 10%RHA, 15%FA	259.49	621.6	1183.5	54.03	28.08	28.99	--
FA20	10%SF, 10%RHA, 20%FA	239.53	621.6	1183.5	72.02	28.08	28.99	--
RB20	10%SF, 10%RHA, 20%FA, R.A 20%	239.6	621.6	946.8	72.02	28.08	28.99	100.82
RB30	10%SF, 10%RHA, 20%FA, R.A 30%	239.6	621.6	828.45	72.02	28.08	28.99	151.23
RB40	10%SF, 10%RHA, 20%FA, R.A 40%	239.6	621.6	710.1	72.02	28.08	28.99	201.63
CM01	Control Mix with 20% aggregate replacement	399.21	621.6	946.8	--	--	--	100.82

**Mix design was done on the basis of volume,
**Water cement ratio fixed at 0.38,
**SP used @0.75-1% of the total binder.

III. RESULTS & DISCUSION

A. *Property of Fresh Concrete Mix*

Slump cone test was performed to determine the workability characteristics of fresh concrete mix. It was observed that the workability is reduced significantly with the replacement of cement by RHA and SF, on contrary the incorporation of FA increases the same. The slump value significantly decreased from 76mm to 58mm that is about 24% for the control mix CM00, when cement was replacement by 30% (10% SF,10%RHA and 10%FA) in the mix FA10. However, workability increases significantly in relation to the increase in FA proportion above 10% as shown in Fig 7. The workability increased gradually on increasing the proportion of FA in the increments of 5% in mix FA15 and FA20 respectively, such that the workability of mix FA15 shows a jump of 17.2% (comparison to FA10) and for FA20 the workability further increases by 16% (comparison to FA15) and as a result the slump value is higher than that of CM00 due to the higher presence of FA (20%) by 8.4%. The observed results are possibly owing to the fact that the reduction in workability is due to the higher specific surface area of silica fume. The higher fineness of rice husk ash leads to an increase in the stiffness of the concrete and greater cohesiveness of the concrete mixture. On the other hand, the workability is increased marginally in case of fly ash owing to its spherically shaped particles causing a lubricating effect on the concrete matrix.

The incorporation of rubber granules for the replacement of natural coarse aggregates in the concrete mixes, having binder fixed in the proportion of: 60%OPC, 20%FA, 10% RHA, 10%SF, caused the reduction in the workability that is clearly represented in the figure 8. The replacement of natural aggregate NA by 20% rubber granules in mix RB20 causes a decrease of slump by about 15 % and 7% in comparison to mix FA20 and CM00 respectively. Additionally, increase in percentage of rubber aggregates in the proportion of 30% and 40% further reduces the slump value to 60mm and 45mm that is 28% and 46% reduction when compared to FA20 and 21% and 41% lower value than CM00. This loss in workability can be attributed to the following reasons:

a) Increased interparticle friction between the rubber granules and other ingredients of the concrete matrix.

b) Small particle size of granules (7mm-10mm) overall increases the surface area as compared to 20mm natural aggregates leading to decrease in workability. This can be rectified by incorporation or larger size of rubber granules around 20mm.

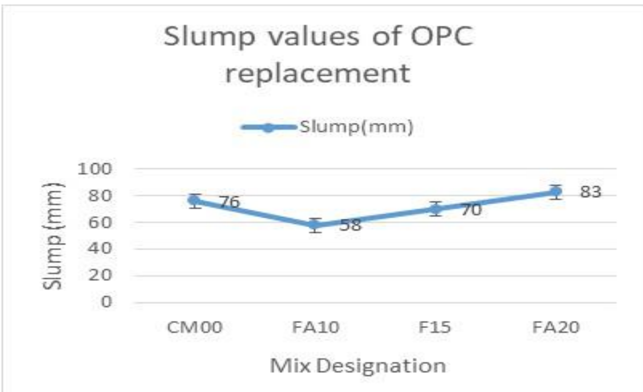

Figure 7: Slump of OPC replacement

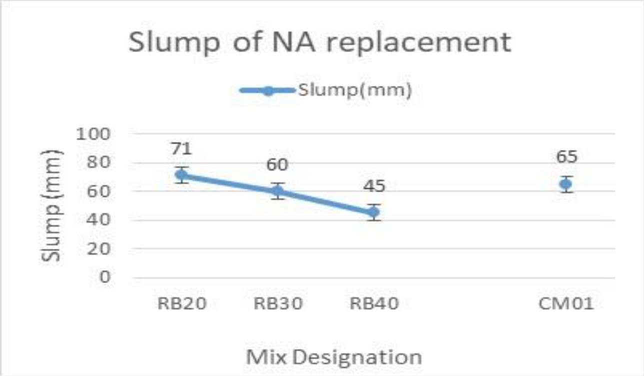

Figure 8: Slump of NA replacement

Note: It should be noted from the above figures that the workability of mix RB20 is similar to that of CM00. The reduction in workability by SF, RHA and rubber granules is overcomed by the larger proportion of FA in mix RB20 which cause the mix to show similar properties as that of control mix in terms of workability/slump. Comparing RB20 with CM01 (plain concrete -100%OPC- with 20% replacement of NA with Rubber granules) it can be seen that the workability of RB20 is better in comparison to CM01. This feature of RB20 is due to the presence of mineral cementitious materials particularly FA.

B. Compression Test

The compression test values are represented in the figures 9 and 10. With the increase in the replacement levels of OPC, the compressive strength of the concrete cubes is reduced. At the end of 7 days and 28 days the compressive strength of the mix FA10 is 30.9 N/mm^2 and 40 N/mm^2 which is 3.5% and 9.1% lower than that of CM00. Further increasing the replacement of OPC by 35% and 40% in mix FA15 & FA20 the strength is reduced but the loss in strength can be considered less when compared to the high values of

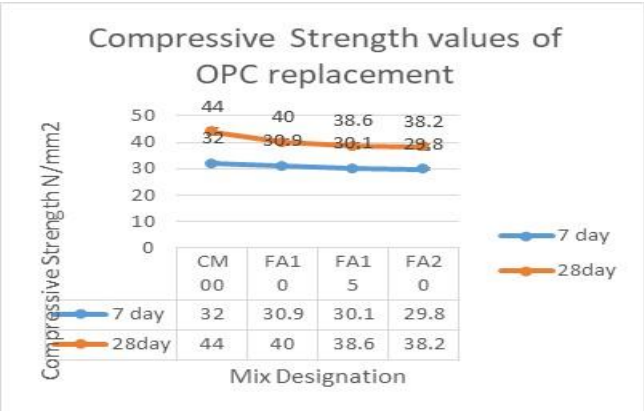

Figure 9: Compressive Strength values of OPC replacement

replacement. The strength of FA15 at 7 days and 28 days is 30.1 & 38.6 which is reduced by 2.6% and 3.5% comparative to FA10. And, for FA20, the strength at 7 days and 28 days is 29.8 N/mm^2 and 38.2 N/mm^2 which is lower by 1% and 1% comparative to FA15. Comparing FA20 to CM00 it is clear that a reduction of 6.9% and 13.2% takes place at the end of 7 days and 28 days which is easily justifiable because of 40% of replacement of OPC. Moreover, the attainment of early strength is reduced owing to the presence of higher FA content in the concrete mix but the 28 days strength is increased considerably. Hence, considering 40% replacement of OPC in mix FA20, the strength is considered optimum and therefore the mix is put forward for natural coarse aggregate replacement.

In the second stage, where binder is fixed as (60%OPC, 20%FA, 10%SF &10%RHA), the coarse aggregate is replaced by 20%, 30% and 40% in mixes RB20, RB30, RB40 respectively. The strength comparisons are hence made with mix FA20. A rapid decrease in strength can be seen with the increase in replacement of NA by Rubber granules. In mix RB20 the 7 days and 28 days strength are 20 N/mm^2 and 32.9 N/mm^2 which is reduced by 32.9% and 13.9% respectively in comparison to FA20. Further increase in replacements are unacceptable causing a 7 days strength decrease of 66.1 %& 72.9% and 28 days decrease of 39.8%& 62% for mixes RB30 &RB40 respectively.

Comparing RB20 with CM01, it can be concluded that the compressive strength of ternary blend rubcrete (containing OPC 60%, FA20%, RHA 10%, sf 10%) is better than plain cement rubcrete (containing 100% OPC, 20% rubber granules).

Figure 10: Compressive Strength values of NA replacement

C. Flexure Test

The effect of replacement of OPC by combined ternary blend can be seen in the Fig 11. It can clearly be seen in the graph that with the increase in cement replacement flexural strength decreases. The downward graph shows the decrease in strength both in 7days and 28 days curing but the downward curve is stabilized with the increase in FA content. For the mix FA20, the 7 and 28-days strength is decreased by only 8.7% and 6.4% respectively in comparison to CM00. Thus, the strength of mix FA20 at 7 and 28 Days (which are 7.45 N/mm^2 and 9.55 N/mm^2) is optimum considering 40 percent replacement of OPC

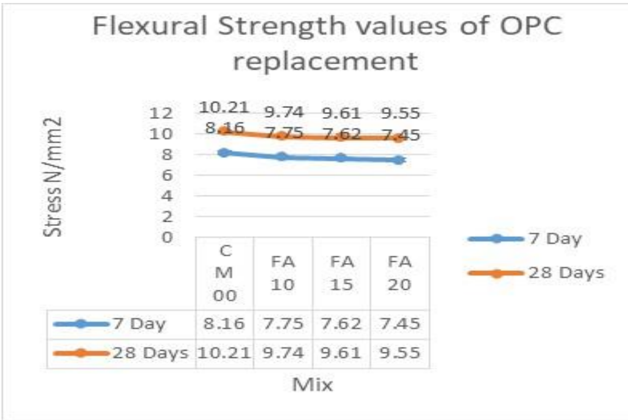

Figure 11: Flexural Strength values of OPC replacement

The optimum proportion of ternary blend cement concrete with natural aggregates is further put forward for aggregate replacement by rubber granules which can be seen in figure 12.

Utilizing rubber granules as coarse aggregates in the optimum ternary blend cement concrete, the flexural strength is slightly increased for 20% replacements but then reduced drastically. The 28 days flexural strength of RB20 is 9.71 N/mm^2 which is increased by 1.7% in comparison to FA20. Also, this strength is higher by 10% in comparison to plain cement concrete (CM01) containing 20% coarse aggregate replacement by rubber granules. Though for mix RB20, 7 days strength is comparatively less which is attributed to the presence of high FA content leading to low early strength.

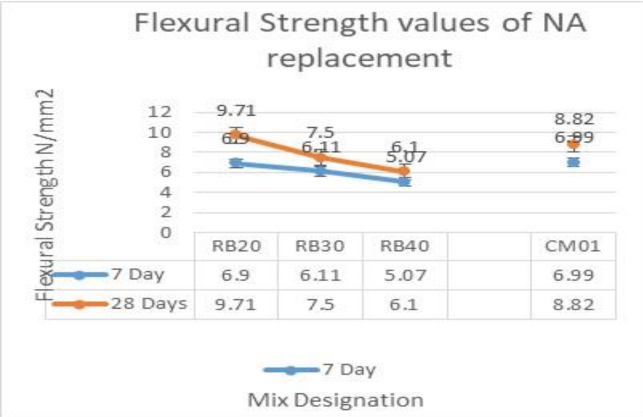

Figure 12: Flexural Strength values of NA replacement

D. Loss in Weight by Acid Attack

The loss in weight of concrete specimen after being exposed to the solution of sulphuric acid for a particular period of time is the most common way to represent the resistance of concrete that is exposed to aggressive conditions. For that purpose, specimens of dimensions 100x100x100 mm were casted, kept for a curing period of 28 days, oven dried for 24 hours and then weighed before exposure to sulphuric acid solution(H2SO4) of 2% concentration. Two different solutions were prepared and 3 specimens were immersed in each solution for a period of 4 weeks After the completion of 4 weeks, the specimens were oven dried at 100±5C and weighed. The resistance to acid attack is assessed in terms of loss in weight after exposure to the acidic solution of 0.75 pH and 2 pH as shown in fig 13. The weight loss for control mix with natural aggregates (CM00) is 12.6% and 5.7% which reduces to 6.8% and 3.6% for ternary blend concrete mix FA10 for solutions of 0.75 pH and 2pH respectively. The minimum weight loss is obtained for the mix FA20 which is only 5.9% for 0.75 pH and 3.3% for 2pH.

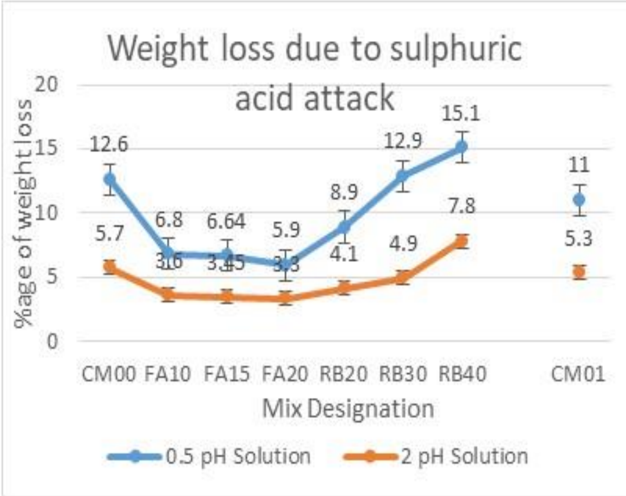

Figure 13: Loss in weight due to acid attack

he replacement of natural aggregates by rubber granules in ternary blend concrete causes an increase in the weight loss due to acid attack. This could be due to the fact that rubber granules are uncapable of forming proper bond with the concrete matrix leading to interfacial cracks. These cracks provide path to acid solution to penetrate and cause the surface to deteriorate. The weight loss increase with the increase in the percentage of rubber granules as can be seen for mixes RB20, RB30 and RB40. The figure 13 shows the weight loss for mix FA20 is 5.9% and 3.3% and for mix CM01 the weight loss is 11% and 5.3% for solutions of 0.75 pH and 2pH respectively. This implies that the weight loss of ternary blend mix with 20% replacement of aggregates with rubber (RB20) is lower by around 19.1% in comparison to plain concrete having same 20% replacement of aggregate by rubber (CM01). Effect of acid on cubes is sown in Fig 14.

Figure 14: Effect of acid on cubes

E. Water Absorption

For the durability of concrete, the property of absorption of water by the hardened concrete plays a vital role. In the service state, particularly in extreme conditions, long term performance can be enhanced significantly by reducing the water absorption. Many researchers consider that the deterioration of concrete exposed to frequent cycles of freezing and thawing, carbonation, etc. can be evaluated by studying the water absorption characteristics of the concrete. Figure 15 shows the percentage of water absorption. It can be clearly seen that the water absorption decreases with the increase in the replacement of OPC.

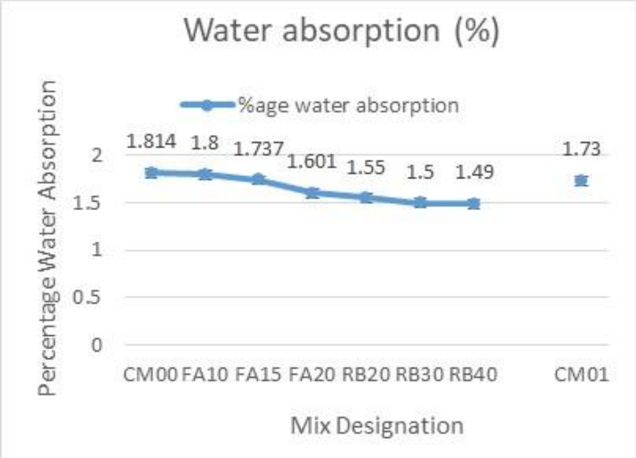

Figure 15: Percentage water absorption

Mix FA20 shows a reduction of about 11.75% in water absorption property in comparison to control mix CM00. This reduction further decreases with the incorporation of rubber granules. Mix RB20 shows a decrease of 14.6% in comparison to control mix and with further increase in rubber in mixes RB30 & RB40 the reductions are 17.3% and 17.8% respectively. There could be a number of reasons for reduction in water absorption with replacement of OPC by SF, FA an RHA.

- Due to the pozzolanic nature of SF, FA &RHA, additional CSH gel forms in the concrete which occupies the pore spaces in the matrix
- High fineness of SF, FA& RHA leads to pore blockage and microstructural densification.
- The incorporation of rubber granules may have caused decrease in absorption because of:
- Small size of rubber granules 7mm-10mm causing less voids in the concrete.
- Since rubber is hydrophobic and does not absorb water.
- The water absorption test was performed after 28 days, however available literature hints towards further reduction in water absorption characteristics after prolonged curing periods greater than 56 days due to formation of more CSH gel due to incorporation of SCMs.

F. Variation in Weight of Hardened Concrete

A basic analysis of the weight of hardened concrete cubes was carried out at the end of 56 days. This experiment was performed to get a general idea of the loss or gain in weight of the hardened concrete. Concrete specimens of size 10x10x10 cm were oven dried for a period of 24 hours and then weighed after the completion of curing period of 56days.The cubes were precisely measured and checked for proper dimensions before weighing. The fresh mix was also uniformly mixed and compacted so as to get uniform concrete cubes for comparison.

Table 2: Weight variation of concrete cubes

S.NO	MIX	SIZE OF SPECIMEN (MM)	CURING TIME (DAYS)	OVEN DRIED WEIGHT (KG)
1	CM00	100x100x100	56	2.62
2	FA10	100x100x100	56	2.66
3	FA15	100x100x100	56	2.69
4	FA20	100x100x100	56	2.71
5	RB20	100x100x100	56	2.434
6	RB30	100x100x100	56	2.345
7	RB40	100x100x100	56	2.17
8	CM01	100x100x100	56	2.412

It was found that with the increase in the percentage replacement of OPC by the SCMs the weight of hardened concrete increases(table 2). The weight of F10, F15, F20 is increased by 1.53%, 2.67% and 3.45% when compared to CM00. It can be attributed to the fact that SCMs are finer and more water absorbing as compared to OPC and also because of the formation of more CSH compounds due to the presence of SCMs. With replacement of natural coarse aggregate by rubber granules the weight is decreased significantly. The weight of mixes RB20, RB30, RB40 is decreased by 7.1%, 11.9% and 17.2% by inclusion of 20%, 30% and 40% rubber granules respectively. Rubber being a light weight material has led to this decrease in the weight of concrete. Weight of CM01 can be seen less than that of RB20.

G. Micro Structural Studies

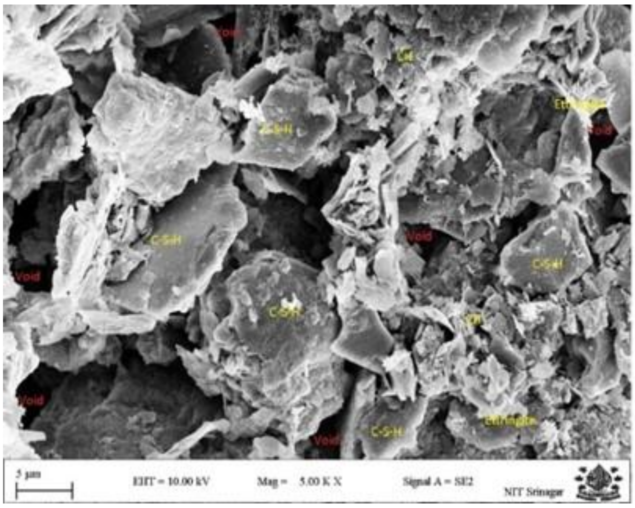

Figure 13:SEM image of plain cement concrete (100% OPC)

FE-Scanning Electron Microscopy:
SEM micro structural studies were carried out using Gemini SEM500 at CRF Lab, NIT, Srinagar, JK.
As an experimental parameter the radiation of Cu with 2θ ranging from 7degree- 70 degree were set.

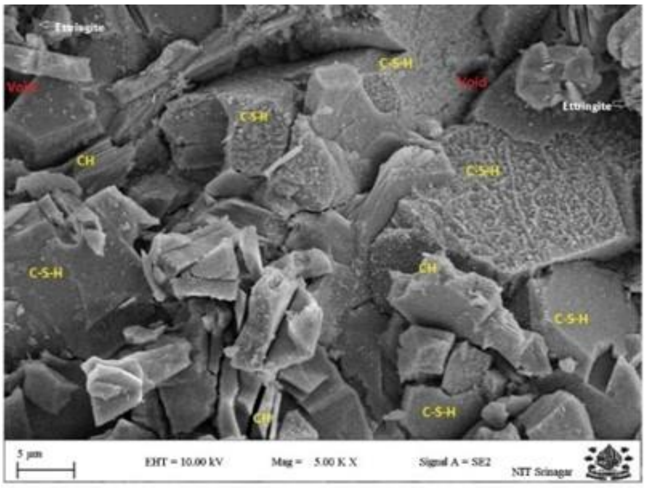

Figure 17: SEM image of ternary blend concrete

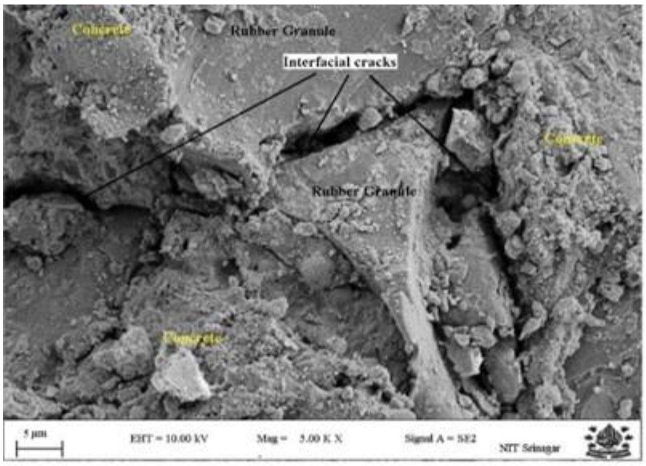

Figure 18: SEM image of Rubber incorporated ternary blend concrete

The Fig (16) represents the FESEM output of the Control mix CM00, Fig (17)- optimum ternary blend mix FA20, Fig (18)- optimum ternary blend incorporated with rubber RB20.

The FESEM results suggests that ternary blend FA20 has an improved microstructure with significant lowering of pore structure as compared to control mix CM00. In this ternary blend concrete the voids are filled with additional CSH compounds which in turn reduces the porous nature of the concrete. It can also be taken into account that the CSH compounds are present in greater quantities in the ternary blend when compared to control mix which in turn improves the strength parameters and durability properties of the concrete. Silica fume present in the ternary blend also fills the pores present in CSH compounds and acts as a central nucleus firmly bonding with CSH gel. SF, FA and RHA all encourages the pozzolanic reactions which help in enhancing the strength development and act as fillers as well.

An addition of rubber granules to the ternary blend (RB20) shows increased number of interfaces between the rubber granules and constituents of concrete. This is due to the fact that the granules incorporated in this mix are significantly smaller in size as compared to the natural aggregates. This result in increased interfacial cracks and less efficient microstructure then control specimen and hence results in much reduction of compressive strength.

H. XRD Analysis

XRD test is the primary method to find the composition of concrete. Minerals such as CSH – Calcium Silicate Hydrate, Ca(OH)2 -Portlandite, Ettringite ,CASH-Calcium aluminosilicate hydrate can be quantitatively found out using this technique.

X-Ray Diffraction test was carried out at CRF Lab, NIT, Srinagar for the control mix-CM00 and for the optimum ternary blend concrete specimens.

X-Ray Diffraction results were analyzed using open license software- PROFEX 5.0.0 as shown in Fig 19, 20.

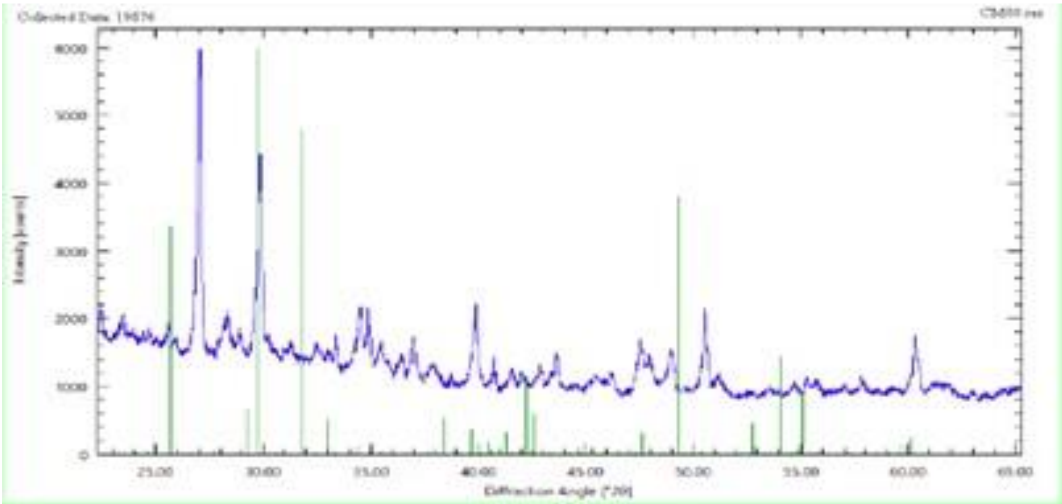

Figure 19: XRD Result analysis for control mix (plain cement concrete)

The quantitative phase analysis of the control specimen is tabulated in Table 3 and that of the optimum ternary blend in Table 4.

It was observed that the quantity of C-S-H is significantly higher in ternary blend concrete than control mix. This is due to the replacement of OPC by micro materials like SF, FA, RHA. The presence of such materials in the matrix does not react itself with water but react with the hydration product (CH) to form more calcium silicate hydrate gel.

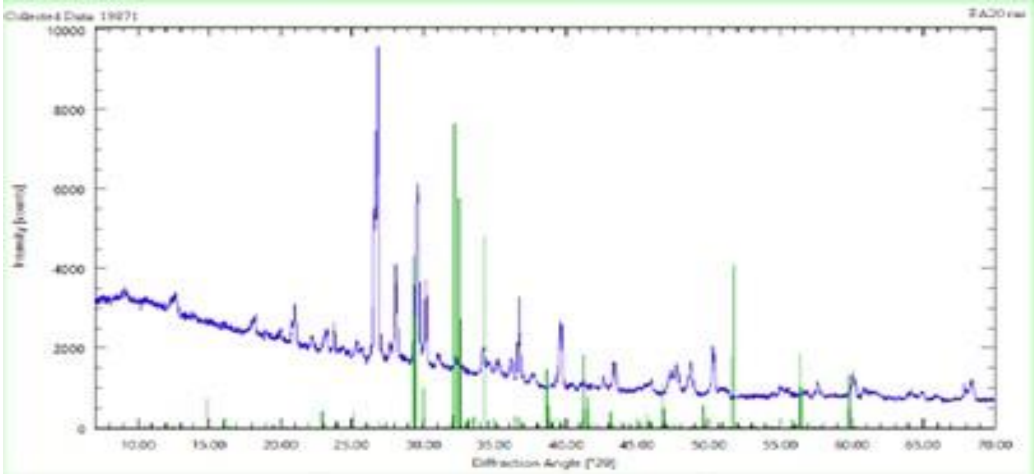

Figure 20: XRD result analysis for ternary blend concrete

Thus, it results in increase in long term strength as well as increase in durability due to less permeability in concrete. Also, the quantity of CH and free lime was found to be less in ternary blend concrete in comparison to the control mix. Moreover, small quantity of other materials were also found in the quantitative analysis of both the specimens but were not considered in the comparative analysis study for their insignificant quantities. Some of them are arcanite, thenardite, langbeinite, mirabilite etc.

Table 3: Quantitative analysis of XRD for control specimen

S.No	Quantity of Hydrated Cement Compounds	Quantity Percentage	Reference
1.	C-S-H	48.4% ± 5%	C-S-H - (50-60%)- contributes to hardening/ strength gaining CH – (20-25%) – maintain the pH Aluminates, ettringite & monosulphates – leads to early strength
2.	CH	20.5 ± 5%	
3.	MgO	7% ± 3%	
4.	Ca0	6.8% ± 3%	
5.	Gypsum	6.9% ± 3%	

Table 4: Quantitative phase analysis of ternary blend specimen

S.No	Quantity of Hydrated Cement Compounds	Quantity Percentage	Reference
1.	C-S-H	80.% ± 5%	C-S-H - (50-60%)- contributes to hardening/ strength gaining CH – (20-25%) – maintain the pH Aluminates, ettringite & monosulphates – leads to early strength
2.	CH	11 ± 5%	
3.	MgO	5.1% ± 3%	
4.	Ca0	5.1% ± 3%	
5.	Gypsum	5.3% ± 3%	

IV. CONCLUSIONS

From the experimental results of this research work the following conclusion are derived:

- Workability: Inclusion of silica fume and rice husk ash decreased the workability of the concrete on the other hand inclusion of fly ash increased this property. Increasing the proportions of fly ash increased the workability gradually and for FA20 mix (having 20%FA,10%SF, 10% RHA) the workability increased by 16% in comparison to the control mix (CM00). The incorporation of rubber granules as a replacement for natural coarse aggregates in the concrete mixes (having binder fixed in the proportion of: 60%OPC, 20%FA, 10% SF, 10%RHA) reduced the workability. The loss in workability can be due to the increase of interparticle friction between the rubber granules. It was found that the workability of 20% rubber replacement was similar to that of control mix. Comparing ternary blend rubcrete having 20% rubber with plain cement concrete having same replacement of rubber, it can be concluded that the former mix has better workability than latter.
- With the increase in the replacement of OPC, the compressive strength of the concrete decreases. Due to the higher percentage of FA content in mix FA20 (having 60%OPC, 20%FA, 10% SF, 10%RHA) the development in the early strength is reduced but on the other hand the attainment of strength at 28 days is increased considerably. Therefore, taking into consideration the 40% replacement of OPC in mix FA20, the strength was considered as optimum and as a result this mix was put forward for the replacement of coarse aggregate. Incorporating different percentages of rubber aggregates in mix FA20 a rapid decrease in strength was noted. The optimum compressive strength was obtained at 20% replacement in the ternary blend (RB20). Due to the extreme reduction in strength further increase in the replacement levels were unacceptable. Comparing CM01 with RB20, it can be summerized that the compressive strength of ternary blend rubcrete (containing OPC 60%, FA20%, RHA 10%, SF10%, 20% rubber granules) is better than plain cement rubcrete (containing 100% OPC, 20% rubber granules).

- Flexural strength decreases with increase in %age of cement replacement. The strength of the mix FA20 at 7 days and 28 days which is 7.45 N/mm2and 9.55 N/mm2 is optimum considering 40% replacement of OPC. In the mix containing rubber granules as coarse aggregates in optimum ternary blend cement concrete, the flexural strength is slightly increased for 20% replacement level (RB20) but then reduced drastically. Also, this strength is higher by 10% in comparison to plain cement concrete (CM01) containing 20% rubber granules as coarse aggregate.
- The loss of weight in control mix CM00 after being exposed to the solution of sulphuric acid was greater in comparison to ternary blend concrete mix FA20. In terms of loss in weight the resistance to acid attack is assessed after exposure to the acidic solution, thus the results concluded that the optimum ternary blend is more durable as compared to the control mix as it showed better resistance to the acid attack. Moreover, the increase in the weight loss due to acid attack is due to the replacement of natural aggregates by rubber granules in ternary blend concrete. This could be due to the fact that rubber granules were uncapable of forming proper bond with the concrete matrix leading to interfacial cracks. The loss in weight increased with the increase in the percentage replacement with rubber granules. Also, the weight loss of ternary blend mix with 20% replacement of aggregates with rubber granules RB20 was lower by around 40% in comparison to plain concrete having same 20% replacement of aggregates by rubber (CM01).
- The absorption of water by concrete is decreased with the increase in the replacement levels of OPC. In Comparison to control mix CM00, mix FA20 showed a reduction in the property of water absorption of about 11.75%. Due to incorporation of rubber granules further reduction can been seen. In comparison the control mix, the mix RB20 showed a decrease of 14.6% and with further increase in rubber content in mixes RB30 &RB40 the reductions were 17.3% and 17.6% respectively.
- Percentage replacement of OPC by SCMs is directly proportional to the weight of hardened concrete cube. So, in comparison to CM weight of F10, F15, F20 was respectively increased by 1.53%, 2.67%, and 3.45%. This can be imputed to the fact as compared to OPC SCMs are finer and more water absorbing and also because of formation of more CSH compounds due to the presence of SCMs. With replacement of natural aggregate by rubber granules the weight is decreased marginally. Rubber being a light weight material has led to this decrease in the weight of concrete and the weight of control mix (CM01) was less than that of RB20.
- The FESEM results concluded that the ternary blend FA20 had an improved microstructure with significant lowering of pore structure as compared to control mix CM. In the optimum ternary blend concrete the voids are filled with additional CSH compounds which in turn reduces the porous nature of the concrete and enhances the durability property and overall strength parameters. Moreover, the addition of rubber granules to the ternary blend (RB20) showed increased number of interfaces between the rubber granules and constituents of concrete because of the smaller size of rubber granules as compared to the natural aggregates thus resulted in less efficient microstructure and lower compressive strength then control specimen.
- As compared to the control mix the XRD test results concluded that the quantity of C-S-H is comparatively higher in ternary blend concrete. The durability and strength are also increased due to the less permeability in concrete, this is due to the replacement of OPC by micro materials like SF, FA, RHA. Even the quantity of CH and free lime is more in control mix rather than in ternary blend concrete.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest involved with this research.

REFERENCES

[1] Adeyemi Adesina, S. D. (December 2020). Performance of engineered cementitious composites incorporating crumb rubber as aggregate. Construction and Building Materials 274 (2021) 122033

[2] Abdelaziz Meddah, M. B. (March 2014). Use of shredded rubber tire aggregates for roller compacted concrete pavement. Journal of Cleaner Production 72 (2014) 187-192

[3] Adil, G. K. (June 2020). Influence of silica fume on mechanical and durability of pervious concrete. Construction and Building Materials, Volume 247, 118453 https://www.sciencedirect.com/science/article/abs/pii/S095006182030458X?via%3Dihub.

[4] Alaloul S.W., M. A. (May 2021). Mechanical Properties of Silica Fume Modified High-Volume Fly Ash Rubberized Self-Compacting Concrete. Sustainability 2021, 13, 5571.

[5] Alireza Joshaghani, S., & and Mohammad Amin Moeini, S. (July 2018). Evaluating the Effects of Sugarcane-Bagasse Ash and Rice-Husk Ash on the Mechanical and Durability Properties of Mortar. Journal of Materials in Civil Engineering , Vol 30 Issue 7 https://doi.org/10.1061/(ASCE)MT.1943-5533.0002317.

[6] Asheeka A, I. P. (2018). UTILISATION OF WASTE TYRE RUBBER IN CONCRETE AND POSSIBLITY OF INCLUDINGTHEM AS AGGREGATES IN RIGID PAVEMENT –A LITERATURE REVIEW. JETIR Volume 5, Issue 9 (ISSN-2349-5162).

[7] Ayesha Siddika, M. A. (n.d.). Study on concrete with rice husk ash. Innovative Infrastructure Solutions (2018) 3:18 https://doi.org/10.1007/s41062-018-0127-6.

[8] Blessen Skariah Thomas, R. C. (2015). A comprehensive review on the applications of waste tire rubber in cement concrete. Renewable and Sustainable Energy Reviews 54 (2016) 1323–1333.

[9] Eldhose C., D. S. (December 2014). Studies on Scrap Tyre Added Concrete for Rigid Pavements. International Journal of Engineering Research, Volume No.3, Issue No.12, pp : 777-779.

[10] Fethi Abbassi, F. A. (June 2020). Behavior Analysis of Concrete with Recycled Tire Rubber as Aggregate using 3D Digital Image Correlation. Journal of Cleaner Production, https://doi.org/10.1016/j.jclepro.2020.123074.

[11] Kotresh KM, M. G. (2014). Study on Waste Tyre Rubber as Concrete Aggregates. http://www.academia.edu/%206614811/.

[12] Kristina Strukar, T. K. (2019). Potential use of rubber as aggregate in structural reinforced concrete element- A review. Engineering Structures 188 (2019) 452–468.

[13] Lakhbir Singh, A. K. (Juy 2016). STUDY OF PARTIAL REPLACEMENT OF CEMENT BY SILICA FUME. International Journal of Advanced Research.

[14] Manikanta Damma, D. P. (February 2021). Mechanical and durability characteristics of high performance self compacting concrete containing flyash, silica fume and graphene oxide. Materials Today: Proceedings 43 (2021) 2361–2367.

[15] Mohit Gupta, D. R. (April 2022). Effect of Rice Husk Ash, silica fume & GGBFS on compressive strength of performance based concrete. Materials Today: Proceedings.

[16] PEERZADA DANISH, M. G. (2020). Durability properties of self-compacting concrete using different mineral powders additions in ternary blends. Romanian Journal of Materials 2020, 50(3), 369 - 378.

[17] Sathi Kranthi Vijaya, K. J. (July 2020). Behaviour of M60 grade concrete by partial replacement of cement with fly ash, rice husk ash and silica fume. Materials Today: Proceedings. Elsevier.

[18] Satish H. Sathawanea, V. S. (2013). Combine Effect of Rice Husk Ash and Fly Ash on Concrete by 30% Cement Replacement. Procedia Engineering 51 (2013) 35 – 44.

[19] Savita Chaudhary, A. P. (2018). Mix Design of Grade M35 by Replacement of Cement with Rice Husk Ash in Concrete. International Journal of Engineering and Management Research Volume-8, Issue-3, June 2018.

[20] Seyed Alireza Zareei, F. A. (May 2017). Rice husk ash as a partial replacement of cement in high strength concrete containing micro silica: Evaluating durability and mechanical properties. Case Studies in Construction Materials https://dx.doi.org/doi:10.1016/j.cscm.2017.05.001.

[21] Sharma, R. (n.d.). Partial Replacement Of Cement By Silica Fume. IJEDR 2018 Volume 6, Issue 4 ISSN: 2321-9939.

[22] Smita Sahoo, P. K. (March 2021). Durability properties of concrete with silica fume and rice husk ash. Cleaner Engineering and Technology 2 (2021) 100067 https://doi.org/10.1016/j.clet.2021.100067.

[23] V.V. Sai Chand, B. K. (2020). Investigation on chloride penetration in concrete mixes of different cement replacement percentages with fly ash and silica fume. Material Today Proceedings https://doi.org/10.1016/j.matpr.2020.06.270.

[24] Vishal Behl, V. S. (2021). Characterization of physico-chemical and functional properties of fly ash concrete mix. Materials Today: Proceedings https://doi.org/10.1016/j.matpr.2021.06.353.

[25] Weiting Xu, T. Y. (Feb 2016). Pozzolanic Reactivity of Silica Fume and Ground Rice Husk Ash as Reactive Silica in a Cementitious System: A Comparative Study. Materials 2016, 9(3), 146; https://doi.org/10.3390/ma9030146.

[26] Yang Li, S. Z. (2019). Potential use of waste tire rubber as aggregate in cement concrete – A comprehensive review. Construction and Building Materials 225 (2019) 1183–1201.

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