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Utilization of Silica Fume, Fly Ash, Rice Husk Ash as SCMs (A Tertiary Mix) in Plastic Aggregate Concrete

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ABSTRACT- For sustainable development and protection of environment, plastic reuse is the best alternative for plastic waste management. Over the years extensive research has been carried out on the use of plastic in civil constructions. Also, the main challenges in the construction sector are caused by the Portland cement production. The obvious, basic and suitable solution is the less consumption of the same and by partial replacement of cement by SCMs (supplementary cementitious materials). Though utilization of plastic waste, fly ash, rice husk ash, silica fume and reduction in cement usage is advantageous from environmental point of view but their properties and behavior together as a construction material requires extensive investigation.

In this study, keeping in view the environmental effects caused by the plastic wastes, cement production, various industrial and agricultural wastes; an investigation has been carried out to study the effect of partial replacement of cement by three different wastes i.e., Silica Fume, Fly Ash and Rice Husk Ash in combined proportions along with partial coarse aggregate replacement with plastic waste and to obtain optimum proportions of waste replacement. The research is carried out in two stages. In the first stage only the binder/cement is focused upon and replaced by different percentages in combined proportions of SF, FA and RHA. It was found out that the optimum percentage of cement replacement is 40% in which combined proportion is (10%SF, 10%RHA, 20%FA).

In the second stage, the (10%SF, 10%RHA, 20%FA) replacement of cement is kept constant and the natural coarse aggregate is replaced by PP Plastic in proportions 20%, 30% and 40% respectively. Consequently, the optimum proportion of plastic was found to be 20% for the cement replaced plastic induced concrete (CRPIC).

Physical characteristics of this cement replaced plastic-induced concrete (CRPIC) were determined by compressive strength tests, flexural tests, slump test. The chemical and water absorption properties along with weight of hardened concrete was assessed and the latter was compared with traditional concrete. This research, in general, will decrease the amount of natural coarse aggregate and cement quantity that are used in the construction industry and will consequently reduce the waste that is disposed into the surroundings.

KEYWORDS- CRPIC–Cement Replaced Plastic- Induced concrete, FA – Fly Ash, NA – Natural Aggregate, OPC – Ordinary Portland Cement, PA – Plastic Aggregate, PAC – Plastic Aggregate Concrete, RHA – Rice Husk Ash, SCM – Supplementary Cementitious Material, SEM – Scanning Electron Microscopy, SF – Silica Fume, XRD – X Ray Diffraction

I. INTRODUCTION

Sustainable construction is a necessary requirement in today's concrete industry. The hunt for sustainable ways over the years is a result of extreme increase in the human population, urban development, industry and their ill effects on the environment. With the increase in human population and urbanization the increase in waste materials has made it important to carry research on the reuse of waste materials and its successful incorporation in concrete.

One of the main challenges in the construction sector is caused by the Portland cement production. CO_2 emission from cement factories imposes one of the serious environmental threats. The obvious, basic and suitable solution is the less consumption of the same and by partial replacement of cement by mineral admixtures/ SCMs (supplementary cementitious materials) [1], [3].

The accumulation of high volume of waste plastic in the environment is a result of its high consumption and poses hazards to the general population due to its low decomposition property [11]. The dumping of plastic into the water bodies-oceans and rivers has led to the contamination of the same by the transfer of several toxins from plastic into the water under the effect of sunlight and wave force. The plastic presence is continuously rising, and it is estimated that there is more than 8.3 billion tons of plastic in the world and among that around 6.3 billion tons is classified as waste. This value has increased 200 times from 1950- 2015. As per Environmental Protection Agency, the plastic production is estimated to reach an approximate production value of 445.25 million metric tons by 2025 against the production of 350 million metric tons in 2018. As per Govt. of India, in our country alone, 34 lakh tons of plastic generation was recorded in the year 2019-20 and this figure has doubled over the last 5 years with 21.8% of the annual average increase.

For sustainable development and protection of environment plastic recycling is the best alternative for plastic waste management [11]. Nowadays, a strong visible growth can be seen towards the use of waste and recycled materials in the construction sector and hence will contribute to the improvement in Global Warming and overall environmental pollution. Over the years extensive research has been carried out on the use of plastic in civil constructions. Plastic wastes in most of the cases have been used as coarse or fine aggregates in mortar/concrete. A large no. of experiments have been carried out incorporating various varieties of plastic in concrete like polypropylene- PP, polycarbonate, high density polyethylene- HDPE, metalized plastic waste -MPW, polystyrene- PS, low density polyethylene- LDPE, polypropylene PP, polyvinyl chloride- PVC and polyethylene terephthalate -PET.

The properties making plastic waste suitable to be used in concrete and recycled for construction industry is:

- Its effects on workability, lightweight, hardness, durability, high heat insulation of concrete.
- Also, the replacement of natural aggregates by the plastic wastes results in the reduction in depletion of natural resources by mining as well as reduce ill environmental impacts.
- By replacing a proportion of natural aggregates by wastes an economic advantage can be achieved both on the overall cost of the project as well as on the general cost of natural materials. [23], [24]

On the other hand, solid wastes produced from agriculture and industries cause serious problems in terms of disposal. This can also be overtaken by utilizing the same as a replacement to cement in proper proportions. A number of researchers have successfully achieved this goal of sustainability with utilization of agricultural wastes like Rice Husk Ash, Bagasse Ash, Oil palm shell etc and industrial wastes like Fly Ash, Silica Fume, Blast Furnace Slag etc as a replacement of cement. [5], [17], [21], [22]

Though utilization of plastic waste, fly ash, rice husk ash, silica fume and the resulting reduction in cement usage is advantageous from environmental point of view but their properties and behavior together as a construction material requires extensive investigation. As such the physical, mechanical and durability properties of concrete containing all these construction materials needs to be analyzed.

In this study, keeping in view the environmental effects caused by the plastic wastes, cement production, various industrial and agricultural wastes; an investigation has been carried out to study the effect of partial replacement of cement by three different wastes i.e., Silica Fume, Fly Ash and Rice Husk Ash in combined proportions along with partial coarse aggregate replacement with plastic waste.

A. Research *Significance*

Concrete is the most heavily used material in the construction industry especially in rigid pavements and the demand for concrete is increasing day by day owing to the developments and growth in urbanization and road connectivity. Due to the high demand in the Indian market, use of cement and aggregates is being done extensively. Portland cement being one of the most important ingredients of concrete is required in large quantities, is relatively expensive material and contributes a higher portion to the total cost of constriction of a project. Worldwide it is estimated that the cement industry alone generates about 7% of the total carbon dioxide and other greenhouse gases. Also, it is calculated that each ton of cement releases equal amounts of carbon dioxide and other gases into the environment. Thus, the extensive production and use of cement is leading to natural resource depletion on one hand and environmental hazards on the other side. On the other hand, aggregates being a viable material to produce concrete is also depleting day by day, thus the use of natural resources with mining and quarrying causes serious environmental burdens. However, to minimize the ill impacts of the advancement that carries with it the environmental considerations, it becomes inevitable to move towards the consideration of sustainability of construction industry. Now, it has become obligatory for the researchers to look for the sustainable materials that can be used as a substitute for the natural raw materials.

The global issue which has always existed persistently in the life of a mankind is the waste generation and its disposal. Some of the wastes being biodegradable and easily re-convertible doesn’t posses’ serious threats but unfortunately the plastic wastes from various industries are difficult to biodegrade and their production have increased extensively over the years.[11] It is estimated that each year 400 million tons of plastic are generated globally. From 1940s to 2022, the production of plastic has reached about 7 billion tons worldwide, out of which only 9% have been recycled and 12% being incinerated and remaining 79% has been left unprocessed into the environment. Due to the diverse use of plastic in almost every sector there has been an increase in the rapid production annually, thus causing immense disposal problems. Therefore, it becomes the need of the hour to reduce the piles of plastic from the environment by utilizing it in more sustainable ways, one such way out is to utilize plastic waste in the construction industry as a partial replacement for coarse aggregate in cement concrete [19].

At the same time, significant quantities of industrial wastes like silica fume, fly ash and agricultural wastes like rice husk ash are posing serious environmental hazards. With ever increasing quantities of these wastes and by products that are generated globally, solid waste management has become a major environmental concern. Due to the sacristy of dumping sites and landfill spaces, recycling and utilization of these wastes and by products in a more sustainable manner have become an alluring alternative to disposal. [7] Also, these wastes possess pozzolanic properties, hence can be used as a good alternative as a partial replacement to cement in concrete.

B. *Objective*

- To evaluate the optimum proportion of tertiary mix incorporated with silica fume, fly ash and rice husk ash in combined proportions as a partial replacement of cement in M35 grade concrete.
- To evaluate the optimum proportion of plastic waste as a partial replacement for natural coarse aggregate in the optimum mix of the tertiary blend.
- To study the durability of plastic waste incorporated tertiary blend by comparing it with plain cement concrete with same replacement value by plastic chips.
- To carry out an experimental study on the mechanical parameters (compressive strength and flexural strength), durability characteristics (acid attack), water absorption and to discuss variation in workability.
- To perform preliminary investigation by XRD and SEM analysis of the optimum results.
- To pave way towards sustainable, cost efficient and environment friendly construction.

C. *Aim*

The aim of this project is to procure a concrete mix with feasible use of industrial and agricultural wastes in combined proportions as a partial replacement for cement along with the use of plastic waste as coarse aggregates. The industrial and agricultural wastes as supplementary cementitious materials (SCMs) to be incorporated in this study are Silica fume, Fly ash and Rice husk ash. In this study cement is partially replaced by weight, maintaining the volume, with these SCMs in combined proportions along with partial replacement of coarse aggregates with waste plastic chips. The main focus is to elaborate the idea of utilizing these wastes by working upon their engineering, chemical and physical properties. The primary objective of this research is to check the possible use of plastic induced concrete in non-structural uses like pavements, retaining walls, paths, etc

II. LITERATURE STUDY

A. Silica Fume Incorporated Concrete

Samita. S. et al [4]- in 2021 carried out a study on the durability properties of concrete containing silica fume and rice husk ash. In this investigation two different groups of concrete were observed in which the percentage of silica fume and rice husk ash was used in the proportion of 5%, 10%, 15% and 20% separately as a replacement for cement in concrete. The behavior of RHA was observed to be different from SF, in relation to the hydration process. This research concludes that when silica fume and rice husk ash was added in proportion of 10%, at 28 days the compressive strength is increased by 23.6% and 20.3% respectively in accordance to the control mix. However, at 90 days the strength is further enhanced to 31.7% and 30.95% respectively. Thus 10% is considered as an optimum proportion for the replacement, but after 15% replacement the strength starts to decrease. Also, sulphuric acid attack resistance increases with the increase in the percentage of the replacement. Water permeability and porosity of concrete is also decreased with the increase in percentage replacement which is attributed to the compactness of silica fume and rice husk aah based concrete mix.

Lakhbir Singh et al [21] in 2016 carried an investigation on the partial replacement of cement by silica fume. In this study cement has been replaced by silica fume in the proportions of 5%,10% and 15%. Strength and durability parameters have been computed in this study. This literature concludes that the optimum strength of cube was observed at 10% replacement for all 7,14 and 28 days respectively. And, for split tensile strength the optimum proportion was at 10% replacement.

B. Effects of Rice Husk Ash in Concrete

Kartini, K. et al [9]- in 2012 examined the effect of silica in rice husk ash when incorporated in high strength concrete. The replacement proportions of RHA were 10%, 20%, 30%, 40% and 50% by weight of cement. This research concluded that the optimum proportion of replacement of cement by rice husk ash was ought to be 10% for achieving the targeted strength, moreover for the durability parameters higher replacement levels up to 50% could be attained decreasing the water absorption. RHA incorporated concrete showed better resistance to chlorine ion penetration and is more impermeable.

Ayesha. S. et al - in 2018 [22] carried out a study on concrete incorporated with rice husk ash. This paper gave a comparative study on the incorporation of rice husk ash as a partial replacement for cement in concrete. The replacement percentages were 0%, 10% and 15%. This research concludes that the slump of the concrete containing RHA decreased and the water demand increased with the increase in percentage of RHA because of the very fine individual particle size of RHA, the density of concrete containing RHA was almost same when compared to the conventional concrete. Compressive, tensile and flexural strength of specimen containing 10% RHA were comparable to control mix. With higher replacement of RHA decrease in strength was observed.

C. Plastic Waste as Aggregate in Concrete

Xuemiao Li et al [11]- in 2019 gave a review on use of plastic/ rubber wastes as a replacement for aggregate in concrete. The main aim of this paper was to give a comparative review on the impact of utilization of rubber and plastic waste as eco- friendly aggregates and on the properties of concrete such as fresh and hardened properties and durability performance. This review concludes that the addition of plastic/ rubber decreases the workability of concrete, increases the pore structure thus reducing the matrix density and mechanical strength. Apart from enhancing the ductility, low acoustical, thermal and electrical conductivity has been eminent thus producing sound and thermal insulated concrete. Compressive strength was reduced due to the inclusion of rubber as well as plastic because of the weak bonding between the replaced aggregate and cement matrix. It is suggested to use lower content of these waste aggregate with maximum 20% replacement levels to avoid the excessive reduction of strength in concrete.

S. Suriya et al - in 2020 [19] investigated the strength parameters of concrete - M30 grade containing plastic waste as replacement for coarse aggregates. Plastic was replaced in the proportion of 5%, 10% and 15%. Reduction in compressive strength was observed when conventional concrete was compared with concrete containing plastic as a replacement. When 5% plastic was replaced, 29.5% reduction in strength was observed, for 10% replacement 49.2% reduction and for 15% replacement 63.96% reduction in strength was observed. It was concluded that plastic can be used as an alternative for coarse aggregate but in small proportions as it is economical and reduces the consumption of natural coarse aggregate. It is to be noted that plastic waste aggregate as a replacement for natural coarse aggregate is only suitable for non-structural members, PCC road works, floor slabs, pavements and other non-load bearing structures.

C. R. Enrique et al - in 2020 [13] worked on the manufacturing of light weight concrete with plastic waste as artificial aggregate. The objective of this study was to produce a light weight concrete of density 1800 kg/m^3 having a compressive strength of 20 to 25 MPa at 28 days and 10 MPa as 1day compressive strength. In this investigation optimum percentage of replacement of natural aggregate with plastic waste was found to be 15% of the natural aggregate by weight, which around equals to about 37.1% of the volume of natural aggregate. These mixes are not recommended for structural concrete, high performance concrete or for infrastructural projects. This literature concludes that artificial aggregate i.e., plastic waste reduces the density but at the same time jeopardizes the workability of fresh concrete mix. Therefore, admixtures were necessary to be added to obtain a workable concrete mix. Inclusion of plastic waste aggregate reduces the compressive strength of concrete but increases the flexural strength and ductility.

D. Fly Ash Incorporated Concrete

Rishab Joshi [8] in 2017 carried an investigation to study the compressive strength of concrete by partial replacement of cement with fly ash. This research concludes that 10% and 20% replacement of cement with fly ash showed good compressive strength at 28-day testing. After 30% replacement the ultimate compressive strength started to decrease. Hence 30% replacement is considered as the optimum proportion according to this literature and after 30% the strength decreases gradually.

Vishal. B. et al [2] - in 2021 characterized the functional and physio- chemical properties of concrete incorporated with fly ash. In this research cement of M20 grade concrete was partially replaced with fly ash in proportion from 5 to 20%. This research concludes that concrete mixes with 20% fly ash obtained the acceptable properties for workability and strength. In the view of reducing the consumption of cement in concrete, 20% fly ash induced concrete mix with longer curing period appeared to be valuable from economic and environmental considerations. The physio- chemical properties and the quality of fly ash depends on the quality of coal used in the thermal power plants for the production of fly ash and hence it varies for individual civil engineering parameter significant for the construction industry.

E. Materials

Silica Fume: Silica fume when added in optimal proportions have shown to increase the performance of concrete as it contains high content of silicon dioxide in amorphous form [7]. Silica Fume SF is produced in the silicon and ferrosilicon industries as a byproduct of the smelting process. Silica Fume has proven to produce high strength in the concrete as the addition of SF into the concrete has shown remarkable improvement in terms of early high compressive strength, flexural, tensile as well as has its effect on the toughness of the concrete. [4], [17]

Fly Ash: Segregation and strength of concrete can be improved with the addition/ partial replacement of cement with Fly Ash. Partial replacement of cement with Fly Ash has shown strong benefits from the environmental and economic point of view [3]. It is because Fly ash is a waste from the thermal power plants by coal burning and is available in the market at an extremely low price and replacement of cement with FA leads to decrease in the production of carbon into the environment. [1], [2]

Figure 1: Binders used in research: OPC, FA, SF, RHA

Rice Husk Ash: In India rice paddy production of about 158.4 million tons takes place annually and a single ton of paddy has a potential to produce 40kgs of Rice Husk Ash. The disposal of rice husk has created number of disposal problem as it occupies a large area of land and burning causes air pollution. In Delhi-NCR this problem is always at the peak during the beginning of each year as burning of paddy wastes causes extreme air pollution. RHA is an active pozzolanic material as it reacts well with the free calcium hydroxide molecules present in cement and can be successfully used as a cement replacement [9]. As it reacts, formation of secondary CSH (calcium silicate hydrate) takes place which leads to the increase in the hardening properties of concrete. Many researches have concluded that a replacement range of 5% -30% of cement by RHA leads to better compressive properties [16, [18]. Moreover, the inclusion of RHA produces dense and homogeneous concrete which makes the concrete more water resistant. [17]

Plastic Waste as aggregate: Plastic is an extensively used material for various purposes due to its easy processing, high strength, durability [11]. But, on the other hand, being a non-degradable material, it poses a serious threat to the environment after its use. Eco friendly construction, the new motto of civil engineers, can be achieved by utilizing this plastic wastes from the environment in various constructions [19].

Figure 2: Plastic Aggregates- PA (10& 20mm)

Plastic wastes can be used after a small processing and can help in reducing the disposal problems related to plastic wastes. Plastic is not much affected by chemicals since is it almost an inert material and the density of the concrete can be significantly reduced by plastic incorporation [6].

F. Selection of Proportioning

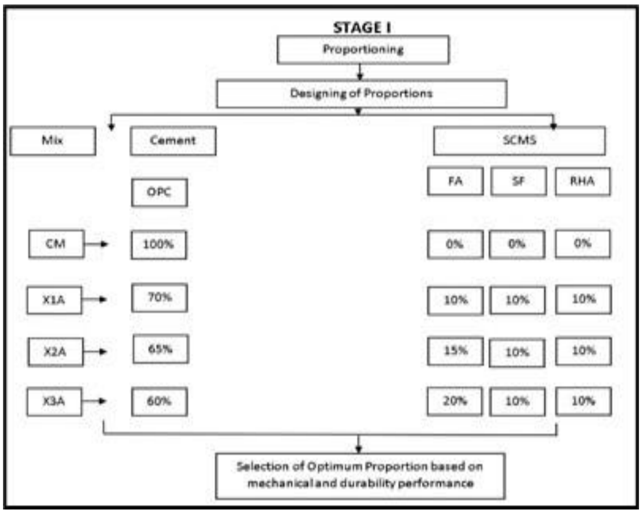


Figure 3: Methodology Stage I

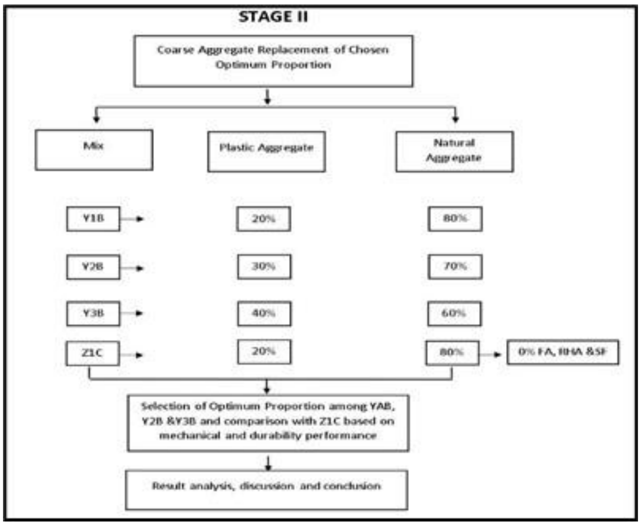


Figure 4: Methodology Stage II

It is pertinent to mention that these SCMs are used individually or in different proportions in various published researches but none of the studies to authors knowledge is found in the proportions and varieties worked in this paper along with replacement of coarse aggregate.

III. EXPERIMENTAL INVESTIGATION

A. *Experimental Methods*

1) *Gradation of Aggregates*

Gradation of aggregates both plastic as well as natural crushed aggregates was done through sieve analysis as per IS 383(1970). 60% aggregates were of 20mm size and 40% were of 10mm size.

Figure 5: Specific Gravity-Test

2) *Determination of Zone of Sand*

IS 383 (1970) has divided the fine aggregates into four grading zones (Grade I to IV). The higher the grade, finer is the sand. Fine aggregates can be classified as coarse sand, medium sand and fine sands depending upon their size. Sieve analysis was carried out and the zone of sand was found to be of Grade II. River Sand was used passing through 4.75mm sieve to remove any greater sized particle.

3) *Specific Gravity of Materials*

For the specific gravity of binder materials specific gravity test was carried out as per IS 4031(Part 11) 1988. It is an important test to determine the density and viscosity of binding materials. Le Chateliers method was used to carry out the specific gravity of cement, Fly Ash, Rice Husk Ash and Silica fume.

Specific gravity of fine aggregate was found out in accordance with IS 2386 part 3. Pycnometer instrument was used to carry out this test strictly following all the standard procedure and precautions.

IS2386 Part 3 was followed for performing the specific gravity test of natural coarse aggregates as well as plastic chips. Method I of this code was followed which includes weighing samples placed in wire basket immersed in distilled water. The test procedure was followed properly and all precautions were taken.

4) *Water Absorption Test*

Water absorption of sand and coarse aggregates were also determined by tests as per IS 2386 (Part III) method III and I respectively. Water absorption for plastic chips were determined by method I of the same code.

5) *Mix Design*

The concrete mix was designed as per IS 10262- 2009 and IS 456-2000. M35 grade of concrete was prepared by the mix designs. Several trial mixes were initially prepared to check the water cement ratio, workability and the amount of admixture required.

The replacement of cement by different SCMs was done by volume calculations on the basis of density of materials being incorporated.

The mix design adopted is as follows:
Grade Designation: M35
Type of cement: 43 grade OPC (Khyber Cement)
Maximum nominal size aggregate: 20mm
Minimum cement content: 340kg/m^3
Maximum water cement ratio: 0.35
Workability, slump value: 30-70mm
Exposure: Severe (since designed for pavement)
Method of placing: Normal
Degree of supervision: Good
Type of aggregate: Angular Crushed Aggregate
Maximum cement content: 450kg/m^3
Chemical Admixture type: Superplasticizer (Masterpel 777)

- Test Data of Materials:

Specific Gravity of Cement: 3.07
Specific Gravity of Sand (fine aggregate): 2.6
Specific Gravity of natural crushed aggregate (coarse aggregate): 2.7
Specific Gravity of Fly Ash: 2.77
Specific Gravity of Silica Fume: 2.23
Specific Gravity of Rice Husk Ash: 2.16
Specific Gravity of Tire Rubber Granules:
Specific Gravity of Admixture (Masterpel 777 Superplasticizer): 1.035

- Determination of Target Strength:

$f_{target} = f_{ck} + 1.65 \times S$
$f_{target} = 35 + 1.65 \times 5$
$f_{target} = 35 + 8.25$
$f_{target} = 43.25\ N/mm^2$
where, f_{target}= target average compressive strength at the end of 28 days

f_{ck} = characteristic compressive strength at the end of 28 days
S = standard deviation
According to table 1, IS 10262-2009, page no. 2
Standard Deviation, S = 5 N/mm^2 for M35 mix concrete
Therefore, target compressive strength at the end of 28 days= 43.25 N/mm^2

- Selection of Water Cement Ratio:

Adopted W/C Ratio = 0.38 (as per IS 10262- 1982, Figure 2)
As per IS 456-2000, Table 5, Page 20
For plain concrete & Very Severe Exposure of pavements, Maximum W/C Ratio = 0.45
Since, 0.38< 0.45 Hence O.K

- Determination of Water Content:

As per table 2 of IS 10262- 2009, Page 3
When Nominal maximum size of aggregate is 20mm and for 25- 50 mm slump range,
Maximum Water Content = 186 kgs
As per Clause 4.2, page 2 of IS 10262- 2009,
Water content is increased by 3% with increase of each 25 mm slump,
Therefore, 186 + (6/100) * 186 = 197.16 ~ 197 Litres
Also, As per Clause 4.2, page 2 of IS 10262- 2009, use of Superplasticizer can reduce water content by 20% and above.
Therefore, reducing water content by 23% in our case,
197 – (23/100) * 197 = 151.69 ~ **151.7 litres**

- Calculation of Cement Content

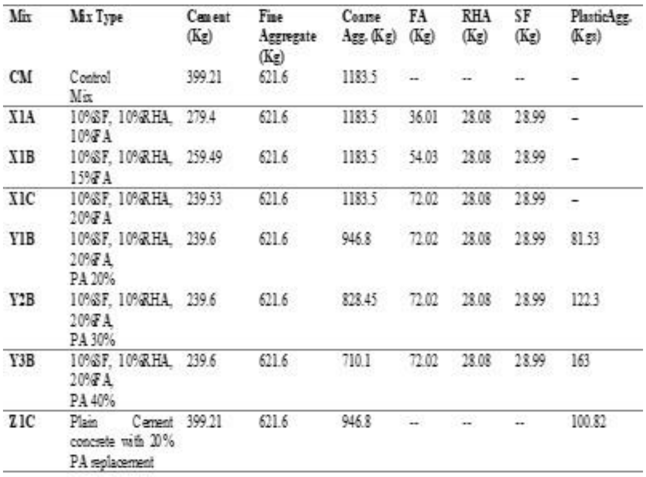
According to Table 5, IS 456- 2000, Page 20
For Very Severe conditions and plain concrete,
Minimum cement content = 260 Kg/m^3
Now, Adopted w/c ratio = 0.38
Water content = 151.7 litres
Therefore, Cement Content = $\frac{\text{Water Content}}{\text{water cement ratio}}$
Cement Content= 151.7/0.38 = 399.21 Kg/m^3 > 300Kg/m^3
Hence O.K

- Calculation for Volume of Coarse Aggregate and Fine Aggregate

As per IS Table 3 of 10262: 2009, Page no. 3
For 20mm Nominal maximum size of aggregate for Zone II fine aggregate,
Volume of Coarse Aggregate per Unit of total volume of aggregate for w/c ratio of 0.5 =0.64
However, adopted w/c ratio = 0.38 which is less by 0.12
The proportion of volume of coarse aggregate is increase by 0.024 (which is at the rate of 0.01 for every change of 0.05 change in w/c ratio)
Therefore, Volume of Coarse Aggregate per Unit of total volume of aggregate for w/c ratio of 0.38 = 0.64 + 0.64 * 0.024 = 0.655 ~ 0.655
Volume of Coarse Aggregate per Unit of total volume of aggregate= 0.655
Also, Volume of Fine Aggregate per unit of total volume of aggregate = 1 – 0.655
Volume of Fine Aggregate per unit of total volume of aggregate= 0.344

- Final Calculations of Mix Design
- Concrete Volume = 1m3
- Volume of Cement = $\frac{\text{Mass of cement}}{\text{S.G of cement}*1000} = \frac{399.21}{3.07 \text{ x } 1000}$ = 0.13 m3
- Volume of Water = $\frac{\text{Mass of water}}{\text{S.G of water} * 1000} = \frac{151.7}{1 \text{ x } 1000}$ = 0.152 m3
- Volume of Admixture (Superplasticizer- Masterpel 777) = $\frac{\text{Mass of admixture}}{\text{S.G of admixture} * 1000}$
- Assuming the maximum dosage of 0.6% by weight of cementitious material/binder.
- Specific gravity of Superplasticizer- Masterpel 777 = 1.035
- Therefore, Volume of Superplasticizer = $\frac{\left(\frac{0.6}{100}\right) * 399.21}{1.035 * 1000}$ = 0.00231 ~ 0.00231m3
- Volume of entrapped air = 2% for 20mm Coarse aggregate
- = 0.02m3
- As per IS10262-2009, volume of entrapped air is zero. However practically 2% is taken.
- Total volume of aggregate (coarse + fine) = Volume of concrete – (volume of cement + volume of entrapped air + volume of water + volume of admixture)
- Therefore, total volume of aggregate = 1- (0.13+0.02+0.152+0.00231)
- = 1- (0.304)
- = 0.695m3
- Mass of coarse aggregate = Volume of total aggregate * Volume of coarse aggregate * S.G of coarse aggregate * 1000
- Therefore, mass of coarse aggregate= 0.695 * 0.655 * 2.6 * 1000 = 1183.5 Kgs
- Mass of fine aggregate = Volume of total aggregate * Volume of fine aggregate * S.G of fine aggregate * 1000
- Therefore, mass of fine aggregate= 0.695 * 0.344 * 2.6 * 1000 = 621.6 Kgs
- Final Ratio: 399.21: 621.6: 1183.5 OR 1: 1.55: 2.96 (by weight)

Table 1: Mix Proportioning



Mix	Mix Type	Cement (Kg)	Fine Aggregate (Kg)	Coarse Agg. (Kg)	FA (Kg)	RHA (Kg)	SF (Kg)	PlasticAgg. (Kgs)
CM	Control Mix	399.21	621.6	1183.5	--	--	--	-
X1A	10%SF, 10%RHA, 10%FA	279.4	621.6	1183.5	36.01	28.08	28.99	-
X1B	10%SF, 10%RHA, 15%FA	259.49	621.6	1183.5	54.03	28.08	28.99	-
X1C	10%SF, 10%RHA, 20%FA	239.53	621.6	1183.5	72.02	28.08	28.99	-
Y1B	10%SF, 10%RHA, 20%FA, PA 20%	239.6	621.6	946.8	72.02	28.08	28.99	81.53
Y2B	10%SF, 10%RHA, 20%FA, PA 30%	239.6	621.6	828.45	72.02	28.08	28.99	122.3
Y3B	10%SF, 10%RHA, 20%FA, PA 40%	239.6	621.6	710.1	72.02	28.08	28.99	163
Z1C	Plain Cement concrete with 20% PA replacement	399.21	621.6	946.8	--	--	--	100.82

**Water cement ratio= 0.38
**Superplasticizer range 0.75-1% of total binder

6) *Slump Test*

For control mix plain concrete, ternary blend concrete containing SF, RHA, FA as well as for ternary blend rubcrete slump tests were carried out to determine the workability of all the mixes. Slump test was carried out in accordance to IS 7320-1974.

B. *Testing Procedure*

Compression specimens:

150x150x150 mm specimens were casted for compression test. According to mix design, quantity of materials was weighed and dry mixed in mixer. Initially binders(cement/SF/FA/RHA), aggregates (crushed stone/plastic chips) were thoroughly mixed. Admixture was added to the water and was then added to dry mix. After a time period of 24 hrs., the cubes were demolded and placed in curing tank. Tests were carried out after a curing period of 7 and 28 days. A total of 6 cubes were casted for each mix, each 3 cubes for testing on 7 and 28 days respectively. The compression test was carried out on AIMIL ACTM, CTM machine with a loading capacity of 100 ton and 300 tons respectively. The tests were carried out in accordance to IS516-1959.

Flexure Beams:

Beams specimens of sizes 100x100x500 mm were casted for performing the flexural strength test. According to mix design, quantity of materials were weighed and dry mixed in mixer. Initially binders(cement/SF/FA/RHA), aggregates (crushed stone/plastic chips) 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 40-ton capacity German manufactured machine brand- WERKSTOFFPROFMASCHINEN LEIPZIG.

Figure 6: Flexure testing machine

1) *Acid Attack Specimens*

Figure 7: Cubes in 0.75pH acid solution

One of the most vital engineering properties of the concrete regulating its durability is the resistance to aggressive chemicals. Chemical attacks are classified into acidic attack, carbonation, alkali attack, sulphate attack, chloride attack and leaching. Acid attack on the properties of hardened concrete have drawn recent attention owing to the extensive damage of concrete structures caused by these acids worldwide. natural acidic water, acid rain, acidic waste water and silage effluents are some of the sources of acid attack. 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(H_2SO_4) 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±5°C and weighed. The resistance to acid attack is assessed in terms of loss in weight/mass.

Water absorption:

Figure 8: Oven drying samples for water absorption test

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±5°C, 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.

IV. DISCUSSION AND RESULTS

A. *Effect on Workability*

STAGE I: In order to determine the workability characteristics of fresh concrete mix slump cone test was performed as shown in Fig 9. The slump value of the control mix CM was found out to be 83mm which significantly decreased by 15% with the replacement of 30% OPC by 10% SF,10%RHA and 10%FA in mix X1A. It is found that the replacement of cement by RHA and SF has significantly reduced the workability whereas the addition of FA leads to the increase of this property which can be seen in mixes X2A, X3A. Upon increasing the percentage of FA in increments of 5% in mix X2A and X3A respectively the workability increases progressively to an extent that the workability of mix X2A shows a jump of 4.2% (comparison to X1A) and for X3A the workability further increases by 13% (comparison to X2A) and thus the slump value is greater than that of CM due to the higher presence of FA (30%). The higher specific surface area of SF can be the contributing cause in reduction of workability. In case of RHA, the higher fineness leads to an increase in the cohesiveness of the concrete as well as the stiffness of the mixture is increased. Whereas, in case of FA, the workability is increased marginally due to its lubricating effect on the concrete mix by the spherically shaped FA particles.

Figure 9: Effect on workability (Slump test)

STAGE II: Also, the inclusion of waste plastic chips replacing natural aggregates in the mixes (having binder fixed in the form: 60%OPC, 20%FA, 10% SF, 10%RHA) further increases the workability which is clearly depicted in the same (Fig 10). The replacement of natural aggregate NA by 20% waste plastic chips in mix Y1B cause an increase in slump by about 6 % in comparison to mix X3A. Additionally, increase in percentage of plastic chips as 30% and 40% increases the slump to 94.5mm and 97mm which is 11.2% and 14.2 % reduction in comparison to X3A and these values if compared with CM are 13.25% and 16.9% greater than CM. This gain in workability can be due to the following reasons:

- Due to the hydrophobic nature of plastic chips.
- Loss of interparticle friction between the plastic chips and other constituents of the concrete mixture.
- Smooth surface of plastic chips

B. Effect on Compressive Strength

The compression test values are represented in the Fig 10. The compressive strength of the concrete cubes decreases with the increase in the replacement values of OPC. The strength of mix X1A at the end of 7 days and 28 days is 30N/mm^2 and 39.2N/mm^2 which is 3.3% and 13% lower than the CM. With further replacement of OPC by 35% and 40% in mix X2A & X3A the strength decreases but the loss in strength is less comparative to the to the high values of replacement. The strength of X2A at 7 days and 28 days is 29.5N/mm^2 & 38N/mm^2 which is reduced by 1.7% and 3% comparative to XA1. And, for X3A, the strength at 7 days and 28 days is 23N/mm^2 and 37.5N/mm^2 which is lower by 22% and 1.3% comparative to X2A. Comparing X3A to CM it is clear that a reduction of 25.8% and 16.5% takes place at the end of 7 days and 28 days which is justifiable because of 40% of replacement of OPC. Moreover, due to the presence of higher FA content in mix X3A the gain in early strength is reduced but the strength at 28 days is increased considerably. Hence, considering 40% OPC replacement in mix X3A, the strength is optimum and hence the mix is put forward for coarse aggregate replacement.

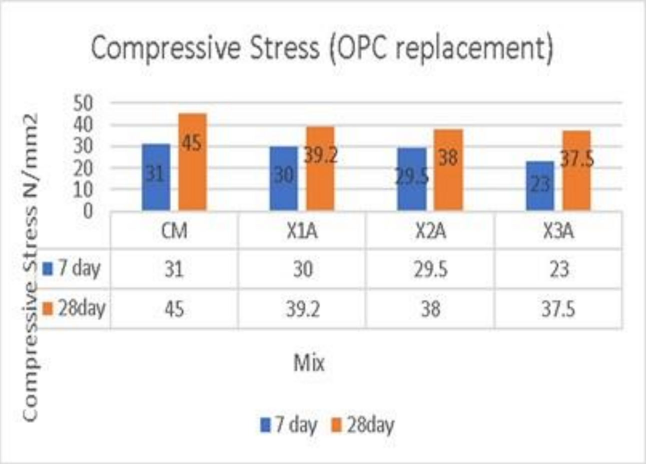


Figure 10: Compressive stress of OPC replacement

STAGE II: 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 Y1B, Y2B, Y3B respectively, shown in Fig 11. The strength comparisons are hence made with mix X3A. A small decrease in strength can be seen with the increase in replacement of natural aggregate by waste plastic chips. In mix Y1B the 7 days and 28 days strength are 22N/mm^2 and 35.3N/mm^2 which is reduced by 4.3% and 5.9% respectively in comparison to X3A. Further increase in replacements causes rapid decrease in strength. The 7 days strength decrease of 21.8 %& 33.6% and 28 days decrease of 30.7%& 41.4% for mixes Y2B &Y3B respectively.

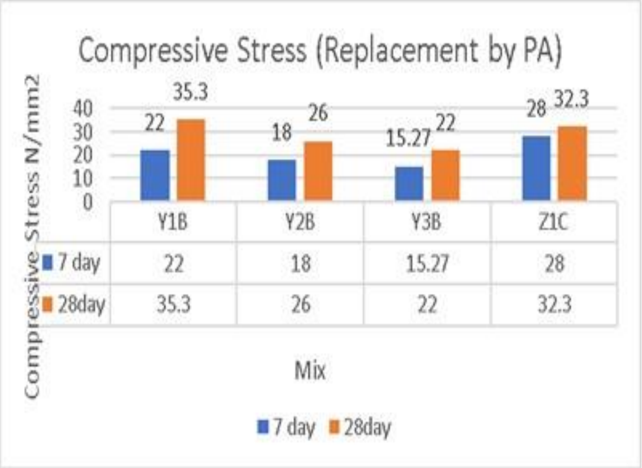


Figure 11: Compression test (replacement of NA by PA)

C. Effect on Flexural Strength

The effect on flexural strength by the incorporation of combined ternary blend as replacement to OPC can be seen in the Fig 12. The graph depicts that with the increase in the replacement proportions of cement with ternary blend SCMs decreases the flexural strength. The decrease in strength is shown by the downward both in 7days and 28 days testing. But with the increase in content of Fly ash, the downward curve is stabilized. For the mix X3A, the 7- and 28-days strength is 7.52N/mm^2 & 9.62N/mm^2 respectively which is decreased by 8.6% and 6.42% respectively in comparison to CM. Considering higher replacement value of 40% of OPC in comparison to the strength obtained the mix, X3A is chosen to be optimum.

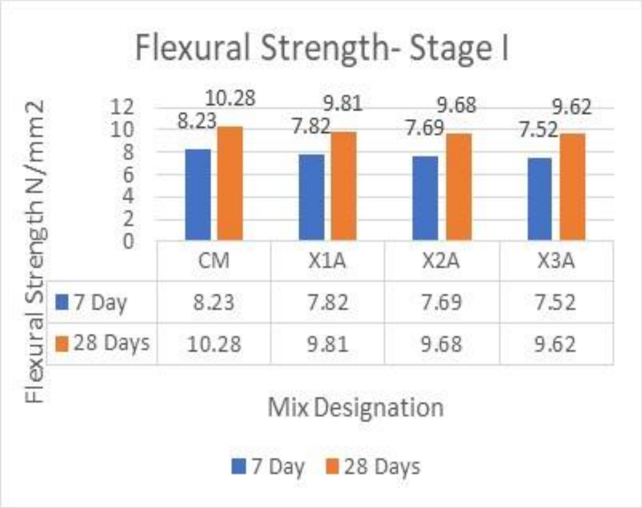


Figure 12: Flexural Strength Stage I

Mix X3A, which is the optimum mix, is further put forward for aggregate replacement by plastic chips in increments of 20%,30% and 40% which can be seen in Fig 13. The use of plastic chips as coarse aggregates leads to a continuous decrease in the flexural strength. However, the decrease in strength is less in 20% replacement in comparison to 30% and 40% replacements. After 20% replacement severe reduction in the strength was noticed. The 7- day and 28-days flexural strength of Y1B is 6.93N/mm^2 and 9.71N/mm^2 which is reduced by 7.5% and 3.3% respectively in comparison to X3A. It was noticed that the final strength of mix Y1B is higher by around 4% in comparison to plain cement concrete (Z1C) containing 20% coarse aggregate replacement by plastic chips. Also, the 7 days strength of Y1B is comparatively less which is attributed to the presence of high FA content leading to low early strength

With the incorporation of plastic chips, it was observed that under failure the two parts of the specimen did not separate after it exceeded its elastic range. Thus, it can be concluded that the specimens have a slight tendency to support additional load even after failure.

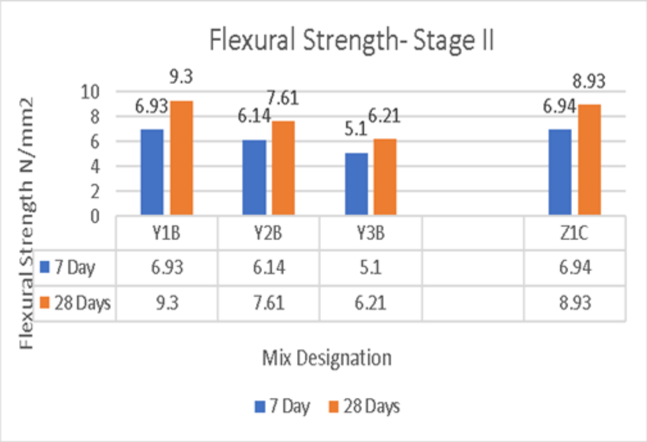


Figure 13: Flexural Strength Stage II

D. Loss in Weight Due to Acid Attack

The resistance to aggressive chemicals of the concrete is examined through the chemical attack by immersing the specimen in the acid solution and this resistance is assessed in terms of loss in weight after exposure to acid.

The acid solution of 0.5 pH and 2 pH was prepared and the loss in weight was determined as shown in the graph of Fig 14.

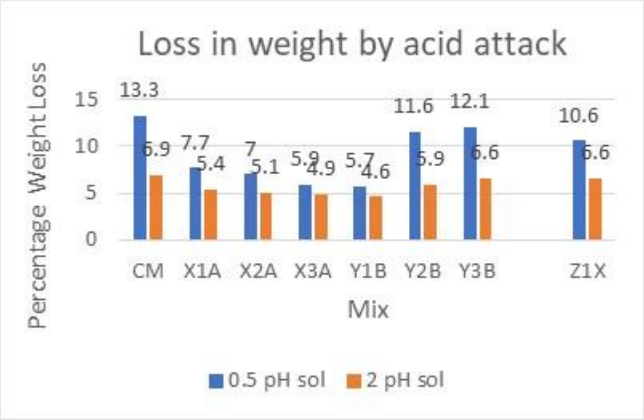


Figure 14: Weight variation by Acid attack

It is observed that the incorporation of SCMs significantly reduced the loss in mass due to its pozzolanic reaction. Permeability of concrete induced with SCMs is reduced which helps in decreasing the detrimental effect of aggressive chemicals. Presence of silica fume, rice husk ash and fly ash in the concrete makes the matrix dense hence reducing the leaching effect. The weight loss for mixes X1A, X2A, X3A decreases with the increasing replacement of OPC. The weight loss of CM is 13.3% and 6.9% which reduces to a minimum of 5.9% and 4.9% for ternary blend concrete mix X3A for solutions of 0.5 pH and 2pH respectively.

The replacement of natural aggregates by plastic chips in ternary blend concrete causes a further decrease in the weight loss. However, with the increase in plastic aggregate percentage above 20% the weight loss increases significantly. This might be due to the increase in the cracks caused by the higher presence of plastic chips in the concrete matrix. These cracks provide path to acid solution to penetrate and leads to weight loss. It can be seen that the weight loss for mix Y1B is 5.7% and 4.6% which increases with further replacement of natural aggregates by plastic chips. Moreover, comparing Y1B with Z1X it can be clearly understood that the weight loss of plastic aggregate mix incorporated with SCMs is significantly lower in comparison to plain OPC concrete having same replacement of aggregate by plastic.

Figure 15: Effect of acid on cube surface

E. Water Absorption Characteristic

The property of water absorption by hardened concrete plays a vital role in terms of concrete durability. In service condition, especially in aggressive one, long term performance can be enhanced marginally by decreasing the water absorption. Many researchers believe that deterioration of the concrete exposed to frequent cycles of carbonation, freezing and thawing can be estimated by studying the water absorption characteristics of the same. Fig 16 represents the percentage of water absorption. It can be clearly seen that the water absorption decreases with the increase in the replacement of OPC. Mix X3A shows a reduction of about 12.5% in water absorption property in comparison to control mix CM. This reduction further decreases with the incorporation of waste plastic chips as replacement to natural aggregate. Mix Y1B shows a decrease of 16.4% in comparison to control mix and with further increase in plastic chips in mixes Y2B &Y3B the reductions are 25.9% and 32.3% respectively.

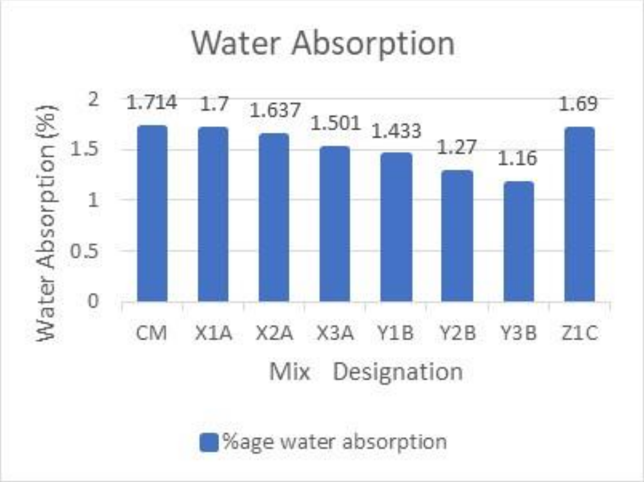


Figure 16: Water absorption characteristics

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 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.
- The incorporation of plastic chips may have caused decrease in absorption because of its hydrophobic nature. Thus, plastic does not absorb water and leads to overall decrease of water absorption of concrete.

F. Weight Variation of Hardened Concrete

After a curing period of 56 days, the hardened concrete cubes were oven dried for a period of 24±1 hours to perform a basic analysis of its weight. The aim was to perform an experiment to get a general idea of the weight loss/gain of hardened concrete. 100x100x100mm sized specimens of different mixes were oven dried for a period of 24 hours after the completion of curing time of 56 days. Proper dimensions and uniform compaction were assured during the casting of these specimens, which were then cross checked by measuring the dimensions of hardened concrete at the time of weighing.

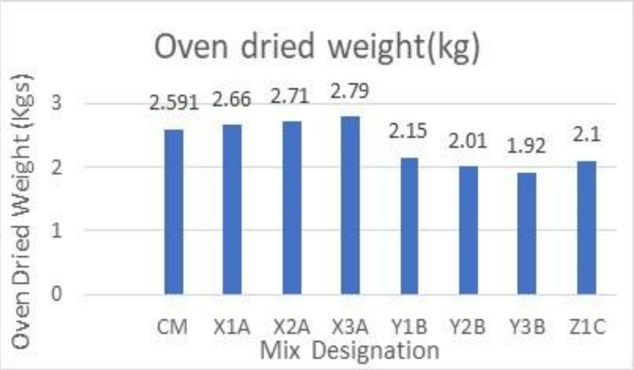


Figure 17: Avg. weight variation of hardened concrete

It is found that the weight of hardened concrete cube increases with the increase in the %age replacement of OPC by the SCMs as shown in Fig 17. The weight of X1A, X2A, X3A is increased by 2.66%,4.6% and 7.68% in comparison to CM. This could be attributed to the fact that the SCMs incorporated are finer as compared to OPC and hence absorbs more water. Also because of formation of more CSH compounds due to the presence of SCMs, weight increases. However, with the incorporation of plastic aggregates the weight decreases with the increase in the percentage replacement. The weight of mix Y1B is 17% lower than that of CM while for mixes Y2B and Y3B the weights are decreased by 22.43% and 25.9%. This reduction in weight is because of light weight plastic aggregate replacement.

Comparing Z1C with Y1B: It can be seen that the plain plastic concrete Z1C has less weight in comparison to ternary blend plastic aggregate concrete Y1B though both of them have same natural aggregate replacement of 20% by plastic chips. This can be due to the higher water absorbing property of the SCMs.

G. XRD Analysis

Concrete specimen of control mix CM and optimum ternary blend consisting of silica fume, fly ash and rice husk ash (X3A) were prepared and cured for 28 days. X-Ray Diffraction was carried out for these samples at CRF Lab, NIT Srinagar. Analysis of X- Ray Diffraction test was conducted using open license software- PROFEX 5.0.0. (Fig 18, 19).

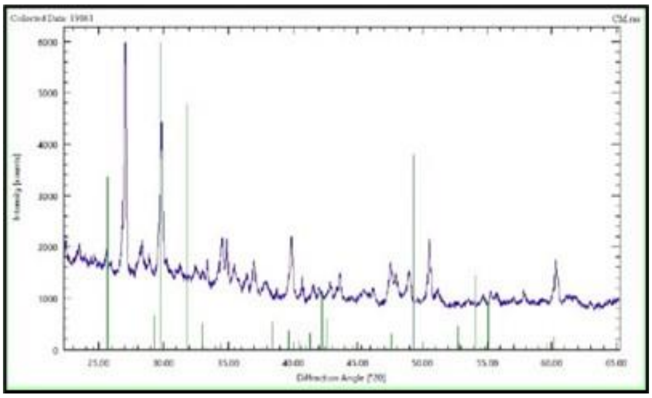


Figure 18: XRD result analysis of plain concrete

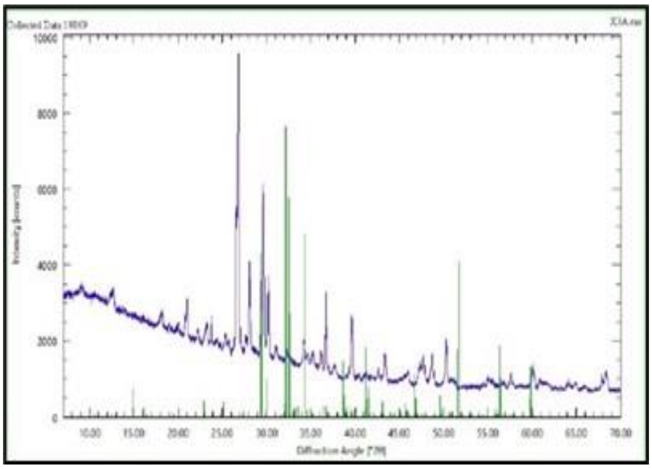


Figure 19: XRD result of tertiary blend concrete

Table 3 depicts the Quantitative-Phase-Analysis of the control specimen and that of optimum ternary blend is shown in table 4.

It was observed that with the addition of micromaterials in the ternary blend, the quantity of CSH is significantly higher than the control mix. After 28 days curing OPC showed the formation of Portlandite, ettringite, calcite and CSH, however addition of supplementary cementitious materials leads to the formation of C-A-S-H gel related phases due to the additional silica and alumina from these SCMs. Silica fume and fly ash makes the matrix denser and increases the long-term strength and durability due to less permeable structure of concrete. The additional silica of these SCMs react with Calcium hydroxide and free lime to form Calcium Silicate hydrate thus reducing the quantity of CH in control mix and increasing the quantity of CSH in optimum ternary blend mix. Moreover, small quantity of other materials was 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 2: Quantitative analysis of XRD for control specimen

S.No	Quantity of Hydrated Cement Compounds	Quantity Percentage	Reference
1.	C-S-H	53.4% ± 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	18.5 ± 5%	
3.	MgO	6% ± 3%	
4.	Ca0	5.8% ± 3%	
5.	Gypsum	7.1% ± 3%	

Table 3: Quantitative phase analysis of ternary blend specimen

S.No	Quantity of Hydrated Cement Compounds	Quantity Percentage	Reference
1.	C-S-H	78.4% ± 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	13 ± 5%	
3.	MgO	6.1% ± 3%	
4.	Ca0	6.3% ± 3%	
5.	Gypsum	5.3% ± 3%	

H. SEM Analysis

Study of Microstructure by FESEM (FE-Scanning Electron Microscopy)

Figure 20: SEM analysis of control specimen

Fe Scanning Electron was performed at NIT, Srinagar using the Gemini SEM500 instrument. The radiation of Cu with 2θ ranging from 7degree- 70 degree were set as experimental parameters. The Figs 20,21,22 shows FESEM output of Control mix CM, optimum ternary blend mix X3A and optimum ternary blend with incorporated plastic Y1B respectively.

The enhanced microstructure of the combined ternary mix X3A in comparison to control mix CM is due to presence of SCMs having fine particle size resulting in less pores in the microstructure and is clearly visible in the fig 21.

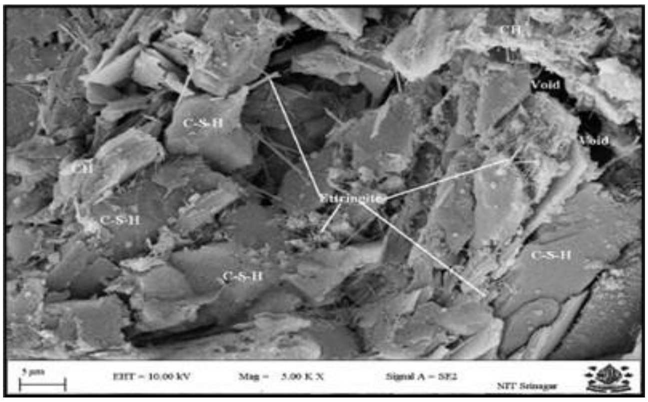


Figure 21: SEM analysis of optimum tertiary mix

It can also be seen that the CSH compounds are present in larger quantities in comparison to control mix which enhances the durability property and the strength parameters.

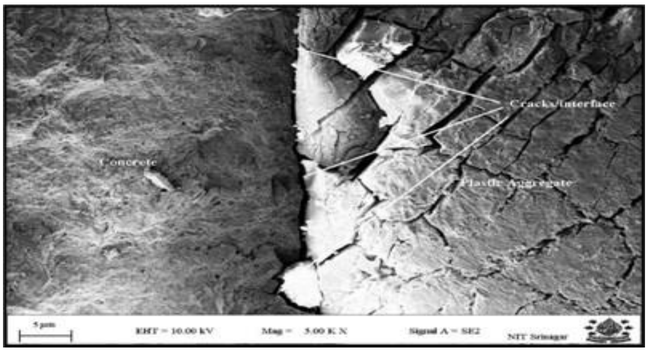


Figure 22: SEM analysis of PA tertiary mix concrete

From figure 22 it can be seen that the ternary blend concrete incorporated with plastic shows an additional interface between the concrete constituents and the plastic material which may lead to bond cracks under loading, thus decreasing compressive strength as confirmed by the compression test results. The lack of proper bond between the plastic and other constituents is the major drawback which needs further improvement to be used in structural purposes.

V. SUMMARY & CONCLUSION

Sustainable construction is a necessary requirement in today's concrete industry. The hunt for sustainable ways over the years is a result of extreme increase in the human-population, urban development, industry and their ill effects on the environment. With the increase in human population and urbanization the increase in waste materials has made it important to carry research on the reuse of waste materials and its successful incorporation in concrete. The following conclusions are derived from the experimental results of this research:

- The results concluded that the replacement of cement by rice husk ash and silica fume significantly reduced the workability of the concrete whereas the addition of fly ash increased the same. Further increasing the percentage of fly ash in increments of 5% a progressive increase in the workability was noted. The reduction in workability by silica fume and rice husk ash can be due to the higher specific surface area of SF and higher fineness of RHA respectively. On the other hand, due to the lubricating effect on concrete and spherically shaped particles of FA increased the workability to a greater extent. In stage II the incorporation of waste plastic chips as a replacement for natural aggregates in the mixes (having binder fixed in the form: 60%OPC, 20%FA, 10% SF, 10%RHA) further increased the workability. Increasing the percentage of plastic chips as a replacement the slump values are also increased. And it can be concluded that higher the percentage of plastic aggregates higher is the slump value. This gain in workability can be due to the following reasons:
- Due to the hydrophobic nature of plastic chips.
- Loss of interparticle friction between the plastic chips and other constituents of the concrete mixture.
- Smooth surface of plastic chips
- The compressive strength of the concrete cubes decreases with the increase in the total replacement values of OPC. Due to the presence of higher FA content in mix X3A the gain in early strength is reduced but the strength at 28 days is increased considerably. Hence, in view of 40% OPC replacement in mix X3A, the strength is optimum. In stage II: A small decrease in strength can be seen with the increase in replacement of NA by waste PA chips. In mix Y1B (having 20% replacement of NA by PA) the 7 days and 28 days strength are 22N/mm2 and 35.3N/mm2 which is reduced by 4.3% and 5.9% respectively in comparison to X3A. Further increase in replacements causes rapid decrease in strength. Comparing Y1B with Z1C, it can be concluded that the compressive strength of CRIP is better than 100% OPC plastic aggregate concrete (both having 20% NA replacement by PA).
- With the increase in the percentage of cement replacement by RHA, SF and FA the flexural strength also decreases. For the mix X3A, the 7- and 28-days strength is 7.52N/mm2 & 9.62N/mm2 respectively which is decreased by 8.6% and 6.42% respectively in comparison to CM. The use of plastic chips as coarse aggregates leads to a continuous decrease in the flexural strength. However, the decrease in strength is less in 20% replacement in comparison to 30% and 40% replacements. After 20% replacement severe reduction in the strength was noticed. It was seen that the final strength of mix Y1B (CRPIC) is higher by around 4% in comparison to plain cement concrete (Z1C) containing 20% coarse aggregate replacement by plastic chips.
- It was observed that the incorporation of SCMs significantly reduced the loss in mass due to its pozzolanic reaction when exposed to the acidic solution. Permeability of concrete induced with silica fume, rice husk ash and fly ash is reduced which helps in decreasing the detrimental effect of aggressive chemical and makes the matrix dense hence reducing the leaching effect. The weight loss for mixes X1A, X2A, X3A decreases with the increasing replacement of OPC.

- Replacement of natural aggregates by plastic chips by 20% in ternary blend concrete caused a decrease in the weight loss. However, with the increase in plastic aggregate percentage above 20%, the weight loss increased significantly. This might be due to the increase in the cracks caused by the higher presence of plastic chips that provided path for the acid to penetrate in the concrete matrix. Moreover, while comparing Y1B with Z1X it was concluded that the weight loss of plastic aggregate mix incorporated with SCMs (CRPIC)was significantly lower in comparison to plain OPC concrete having same the replacement of aggregate by plastic.
- The water absorption decreases with the increase in the replacement of OPC. Mix X3A shows a reduction of about 12.5% in water absorption property in comparison to control mix CM. This reduction further decreases with the incorporation of waste plastic chips as replacement to natural aggregate because of its hydrophobic nature. Since plastic does not absorb water and leads to overall decrease of water absorption of concrete. 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 weight of hardened concrete cube increased with the increase in the %age replacement of OPC by the SCMs. The weight of X1A, X2A, X3A is increased by 2.66%,4.6% and 7.68% in comparison to CM. This could be attributed to the fact that the SCMs are more water absorbing as they are finer as compared to OPC and also because of formation of more CSH compounds due to the presence of SCMs. However, with the incorporation of plastic aggregates the weight decreases with the increase in the percentage replacement. The reduction in weight is because of light weight plastic aggregate replacement. Plain plastic concrete Z1C had less weight in comparison to ternary blend plastic aggregate concrete Y1B though both had same natural aggregate replacement of 20% by plastic chips. This could be due to the higher water absorbing property of the SCMs.
- The XRD test results concluded 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 resulting in the increased long-term strength and 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.
- The FeSEM results concluded that the enhanced microstructure of the combined ternary mix X3A in comparison to control mix CM was due to presence of SCMs having fine particle size resulting in less pores in the microstructure. The results showed that CSH compounds were present in larger quantities in comparison to control mix which enhances the durability property and the strength parameters. Also, the ternary blend concrete incorporated with plastic showed an additional interface between the concrete constituents and the plastic material which may lead to bond cracks under loading, thus decreasing compressive strength as confirmed by the compression test results. The lack of proper bond between the plastic and other constituents is the major drawback which needs further improvement to be used in structural purposes.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

[1] Behaviour of M60 grade concrete by partial replacement of cement with fly ash, rice husk ash and silica fume. Sathi Kranthi Vijaya, Kalla Jagadeeswari, Karri Srinivas. July 2020. s.l. : Materials Today: Proceeding https://doi.org/10.1016/j.matpr.2020.07.523, July 2020.

[2] Characterization of physico-chemical and functional properties of fly ash concrete mix. Vishal Behl, Vinay Singh, Vijay Dahiya, Ajazy Kumar. 2021. s.l. : Materials Today, 2021.

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

[4] Durability properties of concrete with silica fume and rice husk ash. Smita Sahoo, Pravat Kumar Parhi, Bikash Chandra Panda. March 2021. March 2021, Cleaner Engineering and Technology 2 (2021) 100067 https://doi.org/10.1016/j.clet.2021.100067.

[5] DURABILITY PROPERTIES OF SELF-COMPACTING CONCRETE USING DIFFERENT MINERAL POWDERS ADDITIONS IN TERNARY BLENDS. PEERZADA DANISH, MOHAN GANESH G. 2020. 2020, Romanian Journal of Materials 2020, 50(3), 369 - 378.

[6] Effect of polypropylene plastic on concrete properties as a partial replacement to Stone and Brick aggregate. Md. Jahidul Islam, Md. Shahjalal. s.l. : Case Studies in Construction Materials 15 (2021) e00627.

[7] Effect of Rice Husk Ash, silica fume & GGBFS on compressive strength of performance based concrete. Mohit Gupta, Dr. Ritu Raj, Anil Kumar Sahu. April 2022. April 2022. Materials Today: Proceedings.

[8] Effect on Compressive Strength of Concrete by Partial Replacement of Cement with Fly Ash. Joshi, Rishab. 2017. 2, s.l. : International Research Journal of Engineering and Technology (IRJET), 2017, Vol. 4.

[9] Effects of Silica in Rice Husk Ash (RHA) in producing High Strength Concrete. Kartini, K., Nurul Nazierah. 2012. s.l. : International Journal of Engineering and Technology, 2012, Vols. 2, No. 12.

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

[11] Functions and impacts of plastic/rubber wastes as eco-friendly aggregate in concrete – A review. Xuemiao Li, Tung-Chai Ling, , Kim Hung Mo. s.l. : Construction and Building Materials 240 (2020) 117869.

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

[13] Light-weight concrete with artificial aggregate manufactured from plastic waste . Enrique del Rey Castillo, Nasser Almesfer, Opinder Saggi, Jason M. Ingham. s.l. : Construction and Building Materials 265 (2020) 120199.

[14] Mechanical and durability characteristics of high performance self compacting concrete containing flyash, silica fume and graphene oxide. Manikanta Damma, Durga Prasad Ravella, Sri

Rama Chand M., Janardhan Yadav M. February 2021. February 2021, Materials Today: Proceedings 43 (2021) 2361–2367.

[15] Mechanical Properties of Silica Fume Modified High-Volume Fly Ash Rubberized Self-Compacting Concrete. S.W., Alaloul, et al. May 2021. May 2021, Sustainability 2021, 13, 5571 .

[16] Mix Design of Grade M35 by Replacement of Cement with Rice Husk Ash in Concrete. Savita Chaudhary, Aditya Pratab Singh. International Journal of Engineering and Management Research Volume-8, Issue-3, June 2018.

[17] Pozzolanic Reactivity of Silica Fume and Ground Rice Husk Ash as Reactive Silica in a Cementitious System: A Comparative Study. Weiting Xu, Tommy Yiu, Wang, Weilun, Dong Ouyang, Wang Penggang, Feng Xing. Feb 2016. Feb 2016, Materials 2016, 9(3), 146; https://doi.org/10.3390/ma9030146.

[18] Rice husk ash as a partial replacement of cement in high strength concrete containing Micro silica: Evaluating durability and mechanical properties. Seyed Alireza Zareei, Farshad Ameri, Farzan Dorostkar, Mojtaba Ahmadi. May 2017. May 2017, Case Studies in Construction Materials https://dx.doi.org/doi:10.1016/j.cscm.2017.05.001.

[19] Strength studies on FRC with partial replacement of plastic waste as coarse aggregate. S. Suriya, M.

[20] Madhan Kumar. Nov 2020. s.l. : Materials Tody:Proceeding, Nov 2020.

[21] STUDY OF PARTIAL REPLACEMENT OF CEMENT BY SILICA FUME. Lakhbir Singh, Arjun Kumar, Anil Singh. Juy 2016. Juy 2016, International Journal of Advanced Research.

[22] Study on concrete with rice husk ash. Ayesha Siddika, Md. Abdullah Al Mamun, Md. Hedayet Ali. Innovative Infrastructure Solutions (2018) 3:18 https://doi.org/10.1007/s41062-018-0127-6.

[23] Use of Plastic Aggregte in Concrete. Azad Khajuria, Puneet Sharma. November 2019. s.l. : International Journal of Innovative Technology and Exploring Engineering (IJITEE)ISSN: 2278-3075, Volume-9 Issue-1, November 2019, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN:2278- 3075 Vol 9 Issue 1 .

[24] Utilisation of plastic waste as aggregate in construction materials: A review. Nur Hanis Zulkernain, Paran Gani, Ng Chuck Chuan , Turkeswari Uvarajan. s.l. : Construction and Building Materials 296 (2021) 123669

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