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Experimental Investigation of Compressive Strength of Quaternary Cement Concrete and Mortar

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Abstract: ***Concrete is the most extensively used construction material in the world and is the 2nd most consumed substance in the world behind water. Mostly concrete made of Ordinary Portland Cement (OPC) is used in the construction. Cement is produced from lime and clay in wet and dry process, a large amount of carbon dioxide is also produced in the manufacture of cement and concrete. On the other hand, the depletion of natural resources is causing a severe effect to the environment. One of the efficient method to conserve the natural resources and reduce the environmental impact is to use supplementary cementitious materials (SCMs) like fly ash, ground granulated blast furnace slag, silica fume, rice husk ash, metakaolin, limestone powder, micro-silica etc. The SCMs were used as a partial replacement to cement in OPC concrete because most of the SCMs are produced from waste materials and are pozzolanic in nature. In the present study, the SCMs such as fly ash, rice husk ash, and silica fume were used as a partial replacement to cement. The mechanical properties such as compressive strength of cement at different replacement were studied. Seven concrete and mortar mixtures were developed using SCMs at replacement of 30%, 40% and 50% to cement. The compressive strength, split tensile strength, flexural strength, rapid chloride permeability test of the quaternary blended mortar and M40 grade concrete were studied and compared with control mix. A total of 84 cubes for 1:3 mortars with different replacements and a total of 84 concrete cubes were cast, cured and tested at 3, 7, 28, 56 days and prisms of 21casted for 28days,cyclinders of total 42 casted for 28 days***

Much research is conducted on binary and ternary blended concrete. According to Isaia's studies when a less reactive pozzolon is employed in ternary mixtures together with another one more reactive such as silica fume or rice husk ash, there is a synergy between these pozzolans, thus the obtained results is higher than those verified in the respective quaternary mixtures. So increasing the pozzolan reaction by introducing additional materials in the quaternary blend further improves properties of concrete. The blending of cement with SCMs has always resulted in many advantages such as savings in cement, recycling of waste products, and increase in physical

properties along with increased durability of concrete and reducing impact on the environment by reducing green house gases produced.

The existing standards on cements allow the introduction of small quantities of secondary components, in cements. The main objective of the present study is to achieve information about the effect of simultaneous incorporation of fly ash (FA), rice husk ash(RHA) and silica fume (SF) as partial replacement to the Ordinary Portland cement (OPC) on the strength and durability of concretes and based on the results to propose an optimum proportion of quaternary mix.

Keywords : Fly Ash, Rice Husk Ash , Silica Fume , M30, compressive strength, etc,.

I. INTRODUCTION

Concrete is most used construction material inside the global. The concrete has many excellent properties like ease in casting, precise compressive strength, versatility and precise durability. Mortar has been centuries as imply of adhering bricks or concrete blocks to every different. Cement mortar continues to be used particular sorts of manufacturing. Professional constructing tasks regularly rent mortar because the binder among bricks in partitions, fences and walk approaches etc.

The filler movement includes incorporating supplementary materials which might be finer than the OPC, in order that those occupy small pores formerly left vacant. Heterogeneous nucleation is a bodily method principal to the chemical activation of hydration of OPC such that the cement addition particles act as nucleation centers for the hydrates, as a result improving cement hydration. Pozzolanic motion takes region among the amorphous silica of the cement additive and the calcium hydroxide (CH) produced by using the cement hydration reactions to supply non water soluble calcium silicate hydrates (C-S-H).

Fly ash

Fly ash is one of the coal combustion merchandise, composed of the satisfactory particles which can be pushed out of the boiler with the fuel gases. Ash that falls inside the bottom of the boiler is called bottom ash. Fly ash is also referred to as as pulverized gasoline ash. In modern-day power plants fly ash is normally captured with the aid of electrostatic precipitators earlier than the fuel gases reach the chimneys.

Silica fume

It is an ultrafine powder amassed as a by-product of the silicon and ferrosilicon alloy production and consists of round debris with a median particle diameter of 150 nm. The essential field of utility is as pozzolanic fabric for high performance concrete.

It is sometimes harassed with fumed silica(pyrogenic silica) particle traits and fields of packages of fumed silica are all one-of-a-kind from those of silica fume. And the unique surface location of silica fume may be measured with the nitrogen adsorption method. It typically tiers from 15000 to 30000 square metre/kg.

Rice husk

The rice husk is also called the rice hull, is the coating on a seed or grain of rice. It is formed by hard materials including silica and lignin, to protect the seed during the growing season. Rice husk in its loose form is mostly used for energy production, such as combustion and gasification. Combustion is the process of burning carbon in the rice husk which emits Co_2 and generates heat energy for further purpose.

Rice husk ash is the remaining by-product after combustion is done. The amount of carbon remains in ash depends on the combustion performance, and also used as additive in cement and steel.

Objective and scope

Utilization of SCMs for creation shall no longer most effective solves waste issues, but also provide a brand new resource for construction functions. In this studies, use of fly ash, Rice husk ash and Silica fume as partial substitute of cement has been tried. The precise goals of the research are as follows

1. To study the influence of SCMs at the residences of cement matrix.

2. To review the present test methods for evaluating the performance of quaternary combined cement with recognize to electricity and sturdiness.

3. To discover the best concrete mix in terms of percent of fly ash, Rice husk ash and Silica fume that would satisfy the necessities of the plastic country and that produces the best strength of concrete in compression, anxiety and flexure.

4. To look at the microstructure of the concrete mixes and confirm the consequences from electricity and sturdiness assessments.

5 To encourage the usage of quaternary mixed cement in well known construction and to recognize the capability monetary and environmental advantages of this mix.

6. To look at the physical properties of quaternary blended cement mortar (cement, fly ash, rice husk ash and silica fume) of ratio 1:3.

7. To study the mechanical houses of quaternary combined concrete of grade M40 with partial replacement of cement with RHA, FA, and SF for one of a kind proportions, and examine the effects with manage concrete.

II.LITERATURE REVIEW

Dhivakar S [2017] studied the mechanical homes of M30 grade ternary mixed concrete in that GGBs and fly ash replaces the cement at 10%, 20%, 30%, 40%, 50% and quarry sand replaces the herbal sand at 10%, 20%, 30%, forty%, 50%. They studied the compressive, flexural and split tensile power test for M30 grade of concrete at curing

intervals of seven, 14, 21 and 28 days. From the results it changed into located that cement replaced with 20% fly ash and GGBS is elevated its compressive energy 20% than control concrete and additionally the authors concluded that The Compressive energy ,cut up tensile energy and flexural strength values 20% alternative is occurring everyday concrete power.

Swapna S , [2015] studied the mechanical properties which include compressive and cut up tensile strength of binary and ternary blended concrete by means of changing cement with fly ash and GGBS. M30 grade concrete was evolved via replacing cement with fly ash, GGBS and each (fly ash + GGBS) at 10, 20, 30 and 40 percentage and in comparison with manage concrete. The target energy of M30 grade concrete became obtained even at 40% replacement of cement with FA, GGBS and each (FA+GGBS). They concluded that the compressive and break up tensile energy is discovered to be most at 30% replacement of cement with fly ash , GGBS and both (fly ash + GGBS).

Vijaya Sekhar M, [2016] studied the compressive strength concrete by means of partial substitute of cement with alccofine and fly ash for M40 grade concrete at 7 and 28 days. The substitute of cement with elegance F fly ash became utilized in 0%, 5%, 10%, 15%, 20% and that of alccofine via zero%, 5%, 10%, 15%, and 20%. The consequences revealed that the maximum compressive power of M40 grade concrete became expanded via 32.60 MPa and 52.00 MPa with the aid of partial alternative of cement by way of 20% alccofine and fly ash.

III. EXPERIMENTAL ANALYSIS

The materials applied as a part of the existing observe are cement, three supplementary cementitious materials, great mixture, coarse mixture and admixtures were examined inside the laboratory. The specs and houses of these materials have been offered on this bankruptcy. The mix layout of M40 grade concrete is executed in step with IS 10262:2009. Every the sort of materials is tried within the studies centre to set up their bodily and mechanical properties according to the determination of Indian Standards.

Cement : Cement used turned into everyday Portland Cement (OPC) of 53-grade from a single batch became used for entire work and care has been taken that it has to been saved in air tight bins to prevent by means of atmosphere and humidity.

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OPC 53 GRADE CEMENT

Physical properties of ordinary Portland cement

Sl. No	Particulars of test	Recommended IS CODE	Code requirement	Test value
1	Consistency of cement	IS:4031-1988 PART-4	33-35 CM	33%
2	Initial setting time Final setting time	IS:4031-1988 PART-5	>30 mins <600 mins	120 mins 240 mins
3	Specific gravity	IS:4031-1968	3.1-3.18	3.18
4	Soundness	IS:4031 1988PART-4	2.33	
5	Fineness	IS:4031-1988 PART-2	7.69	>10%

Fine aggregate [IS 383-1970]

If the combination is passing maximum of which passes 4.75 mm IS sieve and consists of remarkable so much coarser as is allowed to specification. According to deliver nice combination can be defined as; Natural sand: it is the mixture because of the disintegration of herbal rock and that is deposited with the useful aid of streams or glacial corporations.

Fine Aggregates

Properties of fine aggregate.

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Sl.no	Particular of test	Recommended IS CODE	Value
1	Specific gravity	IS:2386-1963 PART-3	2.62
2	Water absorption	IS:2386-1963 PART-3	0.4%
3	Loose bulk density Robbed bulk density	IS:2386-1963 PART-3	1512 1753

Coarse aggregate:

If the aggregate maximum of that is retained on 4.75 mm IS sieve and contains a lot finer material as is allowed by specification. According to source, coarse combination may be defined as: Uncrushed stone: it outcomes from herbal disintegration of rock. Crushed stone: it consequences from crushing of gravel or hard stone Partially overwhelmed stone: it's far a product of blending of the above two mixture.

Properties of Coarse aggregate.

Sl.no	Particular of test	Value	IS CODE recommended
1	Specific gravity	2.76	IS 2386 (Part-3)-1963
2	Water absorption	0.4%	IS 2386 (Part-3)-1963
3	Bulk density Robbed bulk density Loose bulk density	1611 1463	IS 2386 (Part-3)-1963

Supplementary cementitious materials

Fly ash: Fly ash is finely grained residue as a result of the combustion of ground or powdered coal. And it changed into located; Mean particle length is about 0.1 to zero.2 μm and finer than cement. Other than the environmental advantages fly ash improves the overall performance and remarkable of concrete. Fly ash impacts the plastic houses of concrete with the aid of the usage of improving workability, lowering water name for, reducing segregation and bleeding, and lowering warmth of hydration.

Fly ash

Physical properties of Fly ash

Sl.no	Particulars of test	Test results
1	Specific gravity	2.2
2	Fineness	5%

Silica fume : Physical properties of Silica fume

sl.no	Particulars of test	Test results
1	Specific gravity	2.5
2	fineness	4%
3	Particle size	150µm
4	Surface area	15000-3000 m2/kg

Rice husk ash:

Rice husk ash is an agro-waste material abundantly to be had in all rice generating nations. It constitutes 20% of the 5 hundred million thousands of paddy produced in the global. It is usually recommended that for every ton of rice produced, approximately 0.23 thousands of RHA, which, on combustion produces approximately 0.04 lots of ash.

Super plasticizer: One of the brand new generations of copolymer-primarily based wonderful plasticizer, designed for the Production of High Performance Concrete is used i.E., SP-430.

Properties:

Appearance: brown liquid

Specific gravity: 1.18

Chloride content: nil

Air entrainment: much less than 2 percentage in ordinary dosages by way of weight.

IV.RESULTS AND DISCUSSIONS

Slump cone test

For m40 grade concrete

The exams which are carried out on slump cone test to test the consistency of cement of freshly made concrete Consistency refers to the ease with concrete flows.

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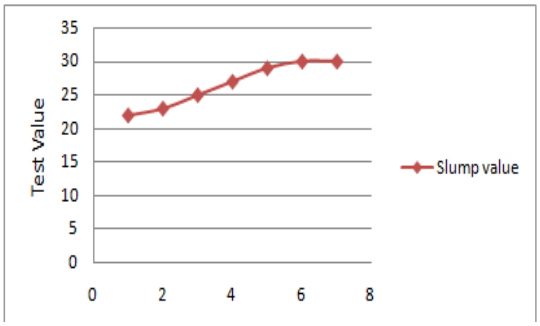
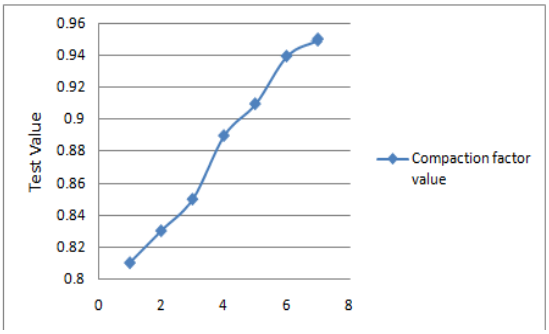
Sl. No	% of replacement	Slump value
1	C100	22
2	C70FA10RHA15SF5	23
3	C70FA15RHA10SF5	25
4	C60FA25RHA10SF5	27
5	C60FA10RHA25SF5	29
6	C50FA30RHA15SF5	30
7	C50FA15RHA30SF5	30



Compaction factor test

The compaction aspect take a look at is performed to discover the workability of concrete. Compaction aspect take a look at used for concrete mixes of very low workability.

Sl. No	% of replacement	Compaction factor value
1	C100	0.81
2	C70FA10RHA15SF5	0.83
3	C70FA15RHA10SF5	0.85
4	C60FA25RHA10SF5	0.89
5	C60FA10RHA25SF5	0.91
6	C50FA30RHA15SF5	0.94
7	C50FA15RHA30SF5	0.95

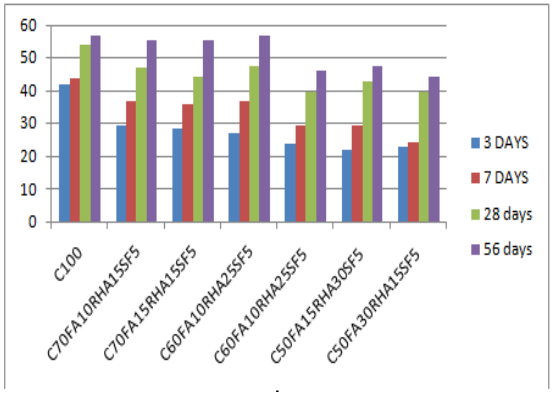


Compressive strength of quaternary blended concrete

Quaternary mixed concrete mixes organized with 30%, 40% and 50% replacement of cement with fly ash, Rice husk ash and silica fume had been examined for 3, 7,27,56 days and have been compared with the manipulate concrete

Compressive strength of m40 quaternary blended concrete

% of replacement	3 DAYS	7 DAYS	28 days	56 days
C100	42.17	44.3	54.22	56.69
C70FA10RHA15SF5	29.63	36.74	47.26	55.56
C70FA15RHA15SF5	28.65	36.15	44.44	55.56
C60FA10RHA25SF5	27.26	36.81	47.72	56.89
C60FA10RHA25SF5	24.07	29.63	39.7	46.67
C50FA15RHA30SF5	22.04	29.63	43.41	47.78
C50FA30RHA15SF5	23.26	24.33	39.85	44.67



Compressive strength of quaternary blended mortar

Compressive strength and % of compressive energy with respect to govern mortar are mentioned. At 0.45 water/cement ratio, Compressive strength of quaternary binders with 30%, 40% and 50% alternative with rice husk

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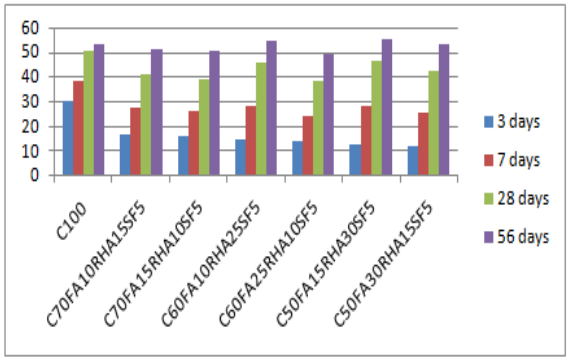
ash, fly ash and silica fume confirmed good sized electricity quaternary mixes showed increase in power 5-10% while as compared with control concrete.

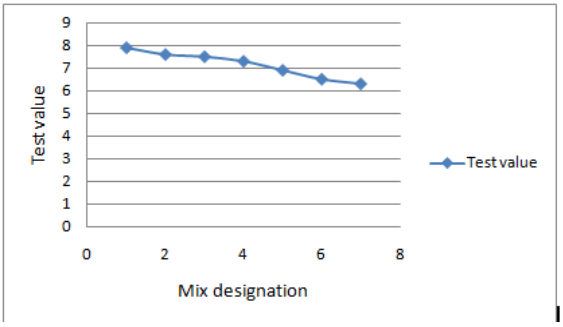
% of replacement	COMPRESSIVE STRENGTH(MPa)			
	3 days	7 days	28 days	56 days
C100	30.1	38.2	50.23	53.1
C70FA10RHA15SF5	16.99	27.71	41.12	51.35
C70FA15RHA10SF5	16.45	26.56	39.41	50.27
C60FA10RHA25SF5	14.97	28.43	45.69	54.73
C60FA25RHA10SF5	14.31	24.44	38.23	48.94
C50FA15RHA30SF5	12.84	28.1	46.64	55.1
C50FA30RHA15SF5	12.36	25.31	42.54	53.48



Flexure strength test.

The static flexural energy take a look at outcomes of all quaternary concretes at given take a look at days. Quaternary blend combinations containing Fly ash, rice husk ash, silica fume have shown first-rate performance of mineral admixtures.

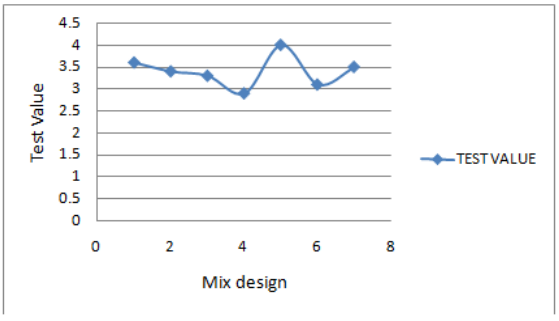
Sl. No	% of replacement	Test value
1	C100	7.9
2	C70FA10RHA15SF5	7.6
3	C70FA15RHA10SF5	7.5
4	C60FA10RHA25SF5	7.3
5	C60FA25RHA10SF5	6.9
6	C50FA30RHA15SF5	6.5
7	C50FA15RHA30SF5	6.3



Split tensile strength test

The quaternary mixtures on the tensile strength is clear, almost similar behavior was observed with the 30%,40% and 50% replacement of OPC with supplementary cementitious materials.

Sl. No	% of replacement	TEST VALUE
1	C100	3.6
2	C70FA10RHA15SF5	3.4
3	C70FA15RHA10SF5	3.3
4	C60FA10RHA25SF5	2.9
5	C60FA25RHA10SF5	4.0
6	C50FA30RHA15SF5	3.1
7	C50FA15RHA30SF5	3.5



Rapid chloride permeability test (cylinders).

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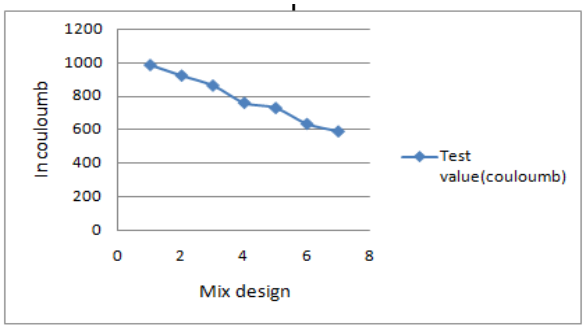
From this check, we get consequences from reduction in chloride permeability designates the advanced resistance to chloride ion penetration. Pozzolanic fabric replaces with cement caused fantastic discounts within the speedy chloride permeability of the concretes.

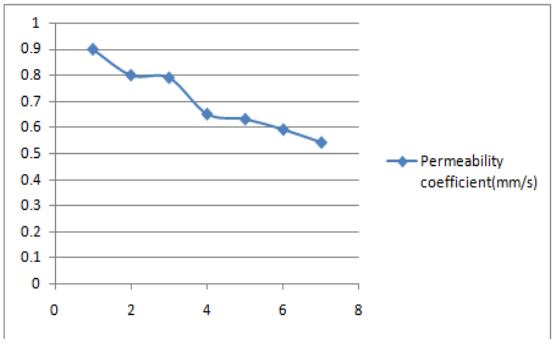
Sl. No	% of replacement	Test value(coulomb)
1	C100	987
2	C70FA10RHA15SF5	923
3	C70FA15RHA10SF5	863
4	C60FA10RHA25SF5	759
5	C60FA25RHA10SF5	728
6	C50FA30RHA15SF5	632
7	C50FA15RHA30SF5	587



Effect of aggregate particle size on permeability

The combination of 20 mm used, and the permeability coefficient of the specimen extended with the growth of combination length under the a few situations. The relation of permeability coefficient, porosity and mixture particle size at the identical water cement ratio at the curing of 28 days.

Sl. No	% of replacement	Permeability coefficient(mm/s)
1	C100	0.9
2	C70FA10RHA15SF5	0.8
3	C70FA15RHA10SF5	0.79
4	C60FA10RHA25SF5	0.65
5	C60FA25RHA10SF5	0.63
6	C50FA30RHA15SF5	0.59
7	C50FA15RHA30SF5	0.54



V. CONCLUSIONS

This study investigates the behaviour of quaternary blends after incorporating Fly ash, silica fume, and rice husk ash. The experimental outcomes found out that the addition of supplementary cementitious substances, consisting of, FA, RHA and SF in cement impacts the properties of concrete mortar. Based on the test results, the following conclusions have been be drawn

1. The compressive strength of quaternary mixed concrete accelerated with the addition of pozzolanic substances at long term durations. The mixes C70FA15RAH10SF5 and C70FA10RHA15SF5 performed better than other mixes.

2. The compressive strength of quaternary concrete with Mix C60FA10RHA25SF5 mix improved by using 0.34% at 56 days. From the consequences it was concluded that the cement changed between 30- 40% with SCMs is done higher at long time intervals.

3. The compressive strength of quaternary combined mortar decreased with boom in fly ash substitute.

4. Based at the compressive strength consequences, the everyday Portland cement may be better changed with 60% OPC + 10% FA + 25% RHA + 5% SF or 50% OPC + 15% FA + 30% RHA + 5% SF.

5. The percent increase in energy for 60% OPC + 10% FA + 25% RHA + 5% SF and for 50% OPC + 15% FA + 30% RHA + 5% SF are 3.06% and 3.76% respectively at fifty six days.

6. For every 10% substitute of OPC with SF and RHA, there has been an growth in compressive strength by using approximately 12% which became no longer visible in OPC with 10%RHA and 5% SF. There turned into a drop in the compressive strength values beyond every 15% substitute of RHA and SF. Also there has been a drop in compressive strength when unequal probabilities of RHA and SF were brought. Therefore, blending of RHA and FA were completed in equal chances for split tensile, flexure and durability assessments.

7. The water absorption effects indicated that quaternary structures decreased the water absorption by way of about 15%, whilst as compared to the manage device.

8. The quaternary system concerning replacement of OPC with 5% SFand 10% RHA (PRL10) led to 40 % more cut up tensile strength, 5% more flexural strength and 15% more bond energy of concrete than the manage specimen, appearing better than the ternary mixes. Therefore, the further durability tests have been restricted to OPC with alternative of SF and RHA.

9. RCPT check outcomes show that, while compared to the manipulate concrete (OPC), all the quaternary combined concrete specimens confirmed lesser chloride ion penetrability values of 850 Coulombs at the stop of fifty six days. In case of quaternary blending, there has been an boom in compressive, cut up tensile and flexural strength for cement with 20% fly ash, 5% of SF and 10% of RHA making it perform better than all different systems which changed into showed by means of the durability tests and microstructural research.

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