ISSN 2321-807X

Volume 13 Number 3

Journal of Advances in Chemistry

Strength Characteristics of Concrete with Indian Mettakaolin and Rice Husk Ash

[1]A.N.Swaminathen[2]S.Robert Ravi

[1]Assistant professor Civil, Sree Sakthi Engineering College, Tamil Nadu, India

Email Id: answaminathen@gmail.com

[2]Head & professor Civil, SSM Institute of Engineering and Technology, Tamil Nadu, India

Email Id: srobertravi@gmail.com

ABSTRACT

Concrete is the most extensively used construction material around the world and its properties have been undergoing changes through technological advancements. Varieties of concrete have been developed to enhance the different properties of concrete. An investigation in to the potential use of partial replacement of mineral admixture in high performance concrete (HPC) has carried out. The engineering properties of fresh and hardenedconcrete are obtained by conducting test on slump, vee-bee, compaction factor and compressive strength, flexural strength, spilt tensile strength and modulus of elasticity, in this project partial replacement of cement bymetakaolin and rice husk ash been used for varying replacement of 0+0%, 5+105, 7.5+10%,10+10%,5+12.5%, 10+12.5%, 5+15%, 7.5+15%, and 10+15%for high strength, workability and also an eco-friendly by less emission of co_2. It has been concluded that strength development of concrete blended with metakaolin and rice hush ash was enhanced. It was found that in 7.5% replacement of metakaolin and 12.5% replacement of rice husk ash appear to be the optimum replacement which exhibited more strength. This investigation has proved that the MK and RHA concrete can be used as structural concrete at suitable replacement.

Key Words: Rice Husk Ash, mettakaolin, workability, Compressive Strength, Split Tensile Strength percentage.

1. Introduction

In the last decade, the use of supplementary cementing materials has become an integral part of high strength and high performance concrete. These can be natural materials, by-products or industrial wastes, or the ones require less energy time to produce. The utilization of fine pozzoloanic materials in high strength concrete leads to a reduction of the crystalline compounds, particularly, calcium hydroxide; consequently there is a reduction of the thickness of the interfacial transition zone in high strength concrete. The densification of the interfacial transition zone allows for efficient load transfer between the cement mortar and the coarse aggregate contributing to the strength of the concrete, for ultra-high strength concrete where the matrix is extremely dense, a week aggregate may become the weak link in concrete strength. In recent years, the high strength concrete are developed by the pozzolonic material like Ground Granulated Blast Furnace Slag, Silica Fume, Fly ash, metakaolin and rice hush ash. The HSC can be enhanced with workability, strength, durability and results in the decrement of permeability. In this work we used Metakiolin (MK) and Rice HuskAsh (RHA) as pozzolonic material, by using a combination of MK and RHA the mechanical properties of concrete was increased.

The performance of HSC is entirely different from ordinary Portland cement (OPC) in terms of its action in fresh and hardened states. The HSC is prepared by the inclusion of supplementary cementing materials and superplasticizer. The proportions made for HSC have a notable difference from OPC. As comparing the HSC to OPC concrete, it has more binding property; the content of water is less, coarser fine aggregate and smaller size of aggregate. Rice Husk Ash (RHA) is an agro waste product of many Asian countries like Malaysia, India, china and Bangladesh etc., are producing tonnes of RHA in every year. The RHA can be obtained by controlled burning and incineration, which gives a super pozzolana. The SiO_2 content is rich in RHA, so it is highly reactive to lime.

Metakaolin is considered neither as by-product of industry nor it is available naturally. The inclusion of metakaolin as a supplementary cementing material (SCM) results in the enhancement of strength properties and it reduces the consumption of cement in concrete. The product of MK is undergone by heating the kaolin. The kaolin is a fine particle size, white clay, which is a naturally abundant material used in the production of porcelain. The thickness of interfacial zone and porosity of hardened concrete is reduced by the usage of MK, the adhesion between the aggregate and cement paste is enhanced by the use of MK and also the cement pastes gets hardened. MK is finer than cement particles. The proportion of concrete gets advanced by the inclusion of MK with OPC. The use of MK enhances the workability and mechanical properties of concrete. The two materials namely metakaolin and rice husk ash are useful pozzolanic cementitious materials. In the present research work, the experimental study was carried out to find out the effects of combination of these two materials on workability and strength are presented. M60 grade concrete was made using 53 grades of priya cement, and the mixes were prepared by replacing part of OPC with metakaolin and rice husk ash. The replacement levels were 5%MK+10%RHA, 7.5%MK+10%RHA,10%MK+10%RHA,10%MK+10%RHA,.5%MK+12.5%RHA,10%+12.5%RHA,5%MK+15%RHA,7.5%MK+15RHAand10%MK+15%RHA (by weight)respectively.

2. Experimental work

2.1 Materials

2.1.1 Cement

In this research work, the cement used was Ordinary Portland Cement (OPC) 53 grade Priya cement with specific gravity 3.11 which is easily available in the market. The properties of cement were determined in accordance with IS – 8112: 1989 were: Fineness – 7% (≤10%); Consistency – 34%; Initial setting time -65minutes (≥30 minutes); Final setting time – 360minutes (≤600 minutes).

2.1.2 Coarse aggregate

The hardinert filler materials are termed as aggregate. In this present work 10mm and 12.5mm size coarse aggregates are used. The different characteristics like specific gravity, bulk density, fineness modulus, Flakiness index and Elongation index value of coarse aggregate values were obtained as 2.98, 1886.35kg/$m^{3,}$ 5.5, 19% and 8% respectively.

2.1.3 Fine aggregate

A better quality of river sand (Ennur sand) was used as fine aggregate by sieving through 4.75mm sieve. The tests such as specific gravity, bulk density and fineness modulus values were obtained as 2.37, 1890.81kg/m^3 and 3.78 respectively.

2.2 Chemical admixture

HPC has low water binder ratio (w/b) and has very fine particles in the form of mineral admixtures, such as MK and RHA. Hence effective dispersion of cement, MK and RHA are necessary to achieve proper micro structure of the hardened concrete as well as workability of the concrete, without increasing the unit water content and cement content of the mix. This is achieved with the use of chemical admixture. In the present research work a superplasticizer namely CONPLAST SP 430 has been used for obtaining workable concrete at low water binder ratio. CONPLAST SP 430 complies with BIS: 9103-1999 and BS: 5075 part 3 ASTMC 494 type B as a HRWRA. The properties of superplasticizer are furnished in table 1.

Table: 1 Properties of Superplasticizer

Properties	Result obtained
Type	Sulphonatednapthaline formaldehyde condensate
Specific gravity	1.22 to 1.225 at 30°C
Chloride content	Nil as per IS -456 and BS: 5075
Recommended dosage	0.6 – 1.5 litres per 100kg of cement
Solid content	40%
Workability	Produce high workable concrete flowing concrete mix
Compressive strength	Early strength up to 40 to 50%
Durability	Increase in density and impermeability

2.3 Mineral admixtures

2.3.1 Rice husk ash

Commercially available rice husk ash which was supplied by NK Enterprises Orissa was used in this research work, physical and chemical properties of the rice husk ash were studied...

2.3.2 Mettakaolin

Mettakaolin for the present research work was obtained from Astra Chemicals Chennai, the mettakaolin was sieved and fraction passing 100µ sieve was used in the experiments. The chemical and physical properties of MK, RHA and OPC are presented in table 2.

Table 2: Physical and Chemical Properties of MK and RHA

Properties	OPC 53grade	MK	RHA
Physical			
Specific gravity	3.11	2.6	2.22
Average particle size	20µm	2.5µm	7µm
Specific area m^2/kg	325	13000	11250
Colour	Grey	Off- white	Grey
PH	12	5.5	8
Chemical composition %			
SiO_2	21.54	52	85
Al_2O_3	4.68	46	0.50
Fe_2O_3	2.46	0.60	0.26
TiO_2	-	0.65	0.01
CaO	62.58	0.09	1.45
MgO	1.08	0.03	0.6
Na_2O	0.24	0.10	1.8
K_2O	0.87	0.03	3.21
Loss on ignition	2.58	1.00	4% maximum

3 SEM analysis

The SEM analysis of MK and RHA was done at Karunya University Coimbatore which is shown in the fig. 1 for MK and fig 2 for RHA respectively. Figure 1 and 2 shows the scanning electron micrographs of MK and RHA using digital scanning microscope device. It is observed that the particle shape of the RHA are angular, irregular and solid, in the case of MK soft masses are noted, and showing amorphicity of the sample.

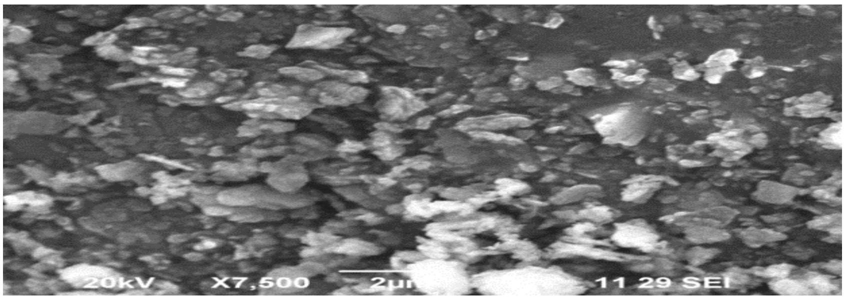

Figure 1 Scanning electron micrographs of MK

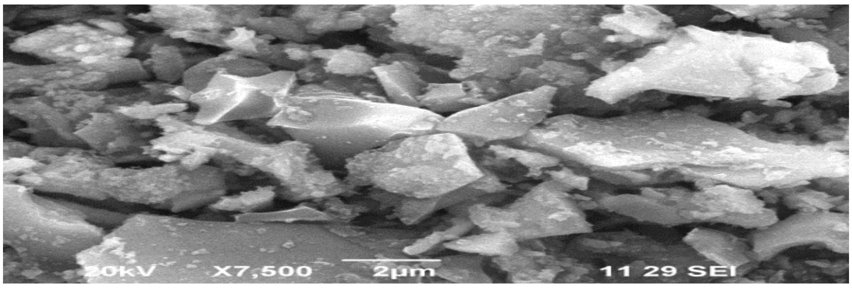

Figure 2 Scanning of electron micrographs of RHA

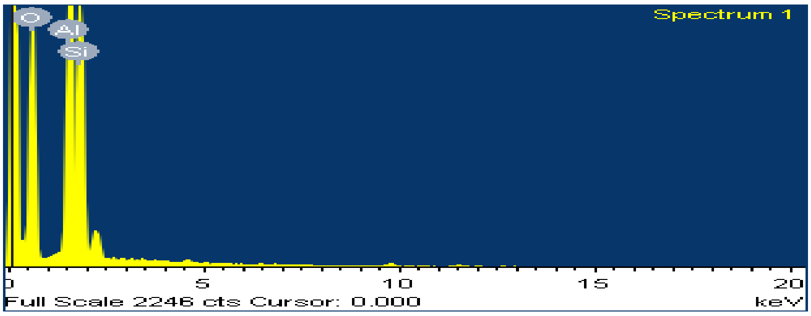

Figure3: EDAXof100%MKParticles

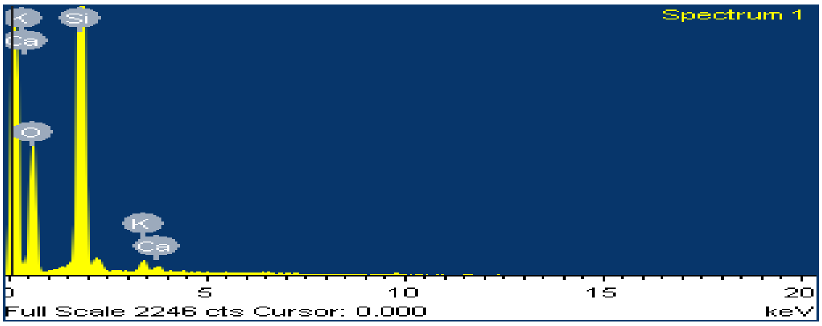

Figure 4: EDAX of 100% RHA Particles

4. Casting of specimen

Hundred and fifty (150) trial specimen with absolute volume method of mix design was followed with different percentage of replacement level of 0, 5%+10%, 7.5%+10%, 10%+10%, 5%+12.5%, 7.5%+12.5%, 10%+12.5%, 5%+15%, 7.5%+15% and 10%+15% of OPC for MK and RHA at w/c ratio of 0.31 for finding the suitability of MK-RHA as partial replacement of OPC in the production of HPC. The trial HPC cubes were immersed in water for 28 days to determine the compressive strength. The mix proportion is shown in table 3. About 150 cube specimens were casted with different replacement levels. The fresh concrete were placed in to a steel mould of size 150x150x150mm and compacted in three layers. The HPC specimens were made in compliance with BS 1881-108:1983.

Table 3 Mix Proportions for Concrete Production

Mix	W/C	% Replacement		Mass of Cement (Kg/m^3)	Weight of MK (Kg/m^3)	Weight of RHA (Kg/m^3)	Weight of fine aggregate (Kg/m^3)	Weight of course aggregate (Kg/m^3)	Water (Lit/m^3)	Sp Dosage %
		MK	RHA							
Mc	0.31	0	0	560	0	0	639.39	1100	152.06	2.5
M1	0.31	5	10	476	28	56	616.65	1100	152.06	2.6
M2	0.31	7.5	10	462	42	56	614.41	1100	152.06	2.7
M3	0.31	10	10	448	56	56	612.17	1100	152.06	2.8
M4	0.31	5	12.5	462	28	70	612.08	1100	152.06	2.7
M5	0.31	7.5	12.5	448	42	70	609.84	1100	152.06	2.8
M6	0.31	10	12.5	434	56	70	607.60	1100	152.06	2.9
M7	0.31	5	15	448	28	84	607.51	1100	152.06	2.8
M8	0.31	7.5	15	434	37.5	75	619.13	1100	152.06	2.9
M9	0.31	10	15	420	50	75	618.27	1100	152.06	3.0

.

5. Result and discussion

5.1 Workability

The workability of concrete is governed by the water requirements at the time of mixing. In the case of conventional concrete it is decided on the basis of maximum size of aggregate used. The physical characteristics of concrete were greatly influence the water demand and workability of mix; the reason is concrete mix containing MK and RHA with very high fineness and more surface area. But in order to maintain the workability interns of slump value of 50 to 100mm, the superplasticizers are added. The inclusion of superplasticizer are adsorbed on to the cement particles, and produce a strong negative charge, which helps to reduce the surface tension of the excess water present in the concrete considerably and thereby fluidity of the concrete enhanced. The workability results obtained in this study are also in line with studies conducted by [2-4] Figure 5, 6 and 7 shows the slump, compaction factor values and vee-bee degree values for different percentage of replacement of MK and RHA by OPC.

Table 4 Slump, Compaction factor and Vee-bee degree values

Mix Designation	% Replacement		Slump Value In mm	Compaction Factor	Vee-bee degree in Sec
	MK	RHA			
MC	0	0	110	0.96	7
M1	5	10	95	0.95	8
M2	7.5	10	80	0.94	9
M3	10	10	74	0.93	10
M4	5	12.5	72	0.92	11
M5	7.5	12.5	50	0.84	15
M6	10	12.5	42	0.83	21
M7	5	15	40	0.86	23
M8	7.5	15	35	0.78	25
M9	10	15	20	0.70	35

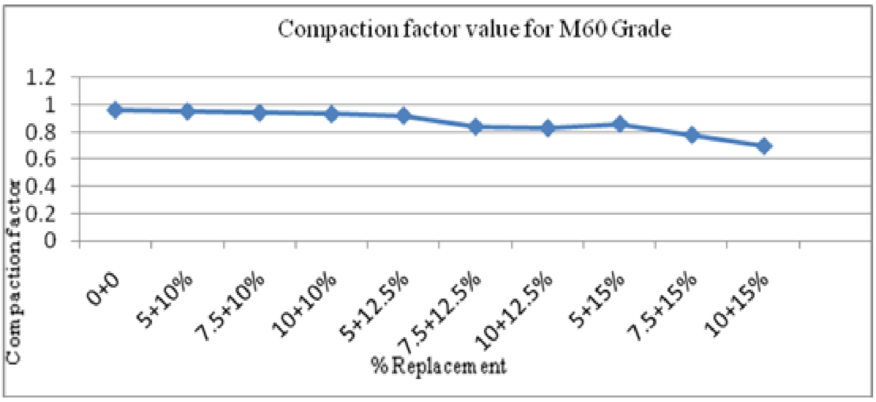

Figure 5 Compaction factor values

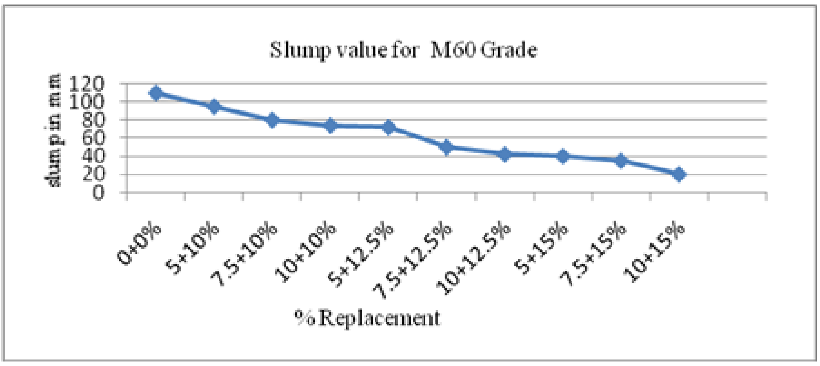

Figure 6 Slump values

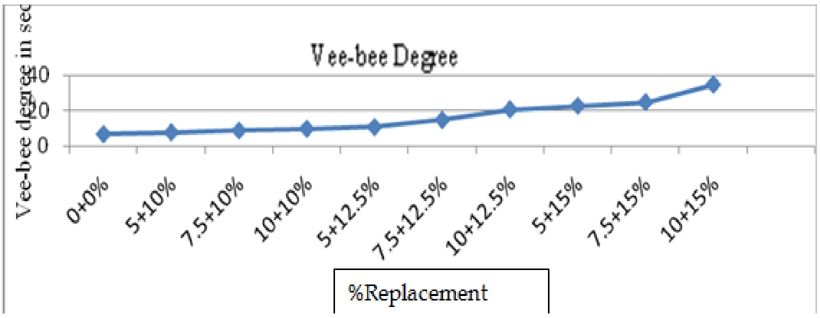

Figure 7 Vee – bee degree values

5.2 Cube compressive strength

The graph showing the difference of compressive strength of concrete, made using MK and RHA combination, with various MK and RHA content are given in fig 8. The graph indicates the difference in strength at 7, 14 and 28 days. It is observed that the compressive strength at the age of 7 days for M60 grade concrete mixes containing 0, 5+10%, 7.5+10%, 10+10%, 5+12.5%, 7.5+12.5%, 10+12.5%, 5+15%, 7.5+15% and 10+15% cement replacements were 38.91, 42.20, 47.65, 45.77, 49.31, 52.88, 56.42, 53.31, 50.95, 48.59 and 45.74N/mm^2 respectively. The compressive strength of the M60 grade mixes at the age of 28 days were 52.31, 55.58, 59.10, 59.91, 69.88, 71.42, 66.50, 63.16, 62.22, and 61.18N/mm^2 respectively. The cube compressive strength at the age of 28 days was gradually increased from 55.58 to 71.42 N/mm^2 for the cement replacement values of 5+10% to 7.5+12.5%(M1and M5) and reducing gradually from 66.50 to 61.18 N/mm^2 for 10+12.5% to 10+15% cement replacement levels, From the table 4, it was noted that all the ages the compressive strength was increased for mixes M1, to M5 and reducing for mixes M6 to M9.

From the above results it has been noted that the maximum compressive strength were attained for 7.5%+12.5% replacement of cement by MK and RHA for M60 grade concrete. It is clear that the MK and RHA content in concrete increases from zero percent, the compressive strength gradually increases up to 7.5% MK and 12.5% RHA content and thereafter it gradually decreases. It is due to the reason that the increase in compressive strength was due to the pozzolanic reaction and filler effect of MK and RHA.

Study on optimum usage of SF and MK in combination is 6% and 15%, by weight respectively at 7, 14 and 28 days compressive strength, [5] The compressive strength results agree with the reported by [6], who said that an increase in MK content in concrete up to 20% as partial substitution of OPC increases the strength particularly during early age of hydration.

The compressive strength at different ages of MK and RHA combinations are given in Table 5.

Table 5 Compressive strength

Mix Designation	Percentage Replacement		W/C	Compressive strength in N/MM^2		
	MK	RHA		7 days	14 days	28 days
Mc	0	0	0.31	40.98	48.87	52.31
M1	5	10	0.31	45.54	50.71	55.58
M2	7.5	10	0.31	47.65	53.89	59.10
M3	10	10	0.31	46.58	52.00	59.91
M4	5	12.5	0.31	49.44	57.59	69.88
M5	7.5	12.5	0.31	56.44	63.44	71.42
M6	10	12.5	0.31	51.28	59.42	66.50
M7	5	15	0.31	54.37	56.87	63.16
M8	7.5	15	0.31	53.79	58.56	62.16
M9	10	15	0.31	44.34	55.23	61.16

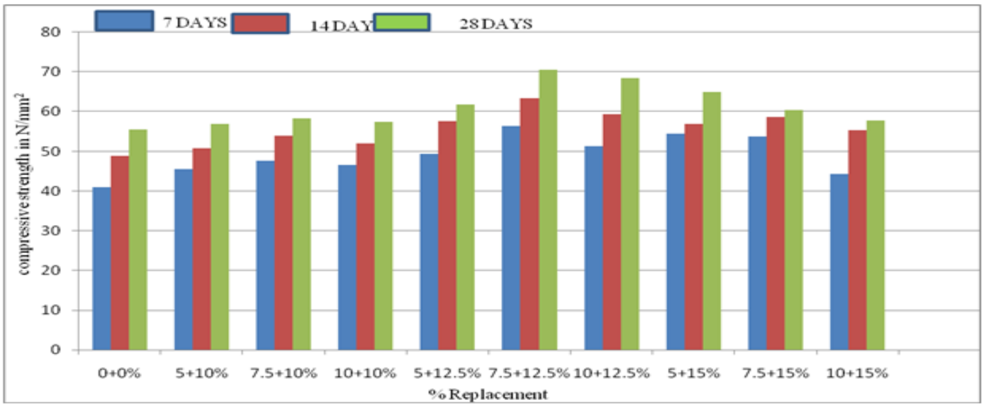

Figure 8 compresive strength

6:Compressive strength development of M60 grade concrete

Mix	% Replacement		Strength gain in %		
	MK	RHA	7 days	14 days	28 days
Mc	0	0	74.38	89.83	100
M1	5	5	75.93	89.62	100
M2	7.5	7.5	77.45	90.20	100
M3	10	10	82.31	91.57	100
M4	5	5	75.67	88.71	100
M5	7.5	7.5	78.99	91.11	100
M6	10	10	80.16	93.97	100
M7	5	5	80.67	94.02	100
M8	7.5	7.5	78.17	90.29	100
M9	10	10	74.78	85.95	100

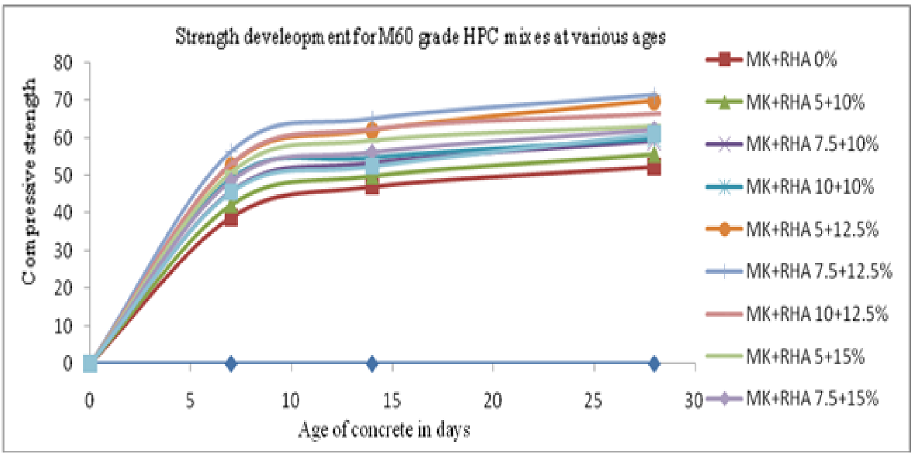

Figure 9 Strength development

5.3 Cylinder compressive strength

The graph showing the difference of cylinder compressive strength of concrete, made using MK and RHA combination, With various MK and RHA content are given in Fig 10, the cylinder compressive strength of the HPC trial mixes Mc to M9 at the age of 28 days were 47.72, 50.95, 52.66, 54.85, 57.76, 64.15, 60.45, 57.70, 54.80 and 51.90 N/mm^2 respectively. From the table 7 it is noted that the compressive strength was gradually increased from 50.95 to 64.15 N/mm^2 for the cement replacement level values of 5%+10% to 7.5%+12.5% (M1 to M5) and reducing to 60.45, 57.70, 54.8 and 51.90 N/mm^2 for 10%+12.5%, 5%+15%, 7.5%+15% and 10%+15% cement replacement level values. From the above result it is concluded that the maximum cylinder compressive strength were attained for mixes with 7.5% and 12.5% replacement by Metakaolin and Rice Hush Ash. It is clear that the MK and RHA content in concrete increases from zero percent, the compressive strength increased up to 7.5%MK and 12.5%RHA content, after that it gradually decreases. It is due to the pozzolanic reaction and filler effect of MK and RHA. The ratio between cube compressive strength and cylinder compressive strength was found as 0.88. The cylinder compressive strength at various Mk and RHA combinations are given in table 7.

Table 7 Cylinder compressive strength

Mix designation	% Replacement		Average cylinder compressive strength in N/mm^2 (28 days)	Cylinder compressive strength activity index at 28 days
	MK	RHA		
Mc	0	0	47.72	1
M1	5	10	50.95	1.068
M2	7.5	10	52.66	1.10
M3	10	10	54.85	1.15
M4	5	12.5	57.76	1.21
M5	7.5	12.5	64.15	1.34
M6	10	12.5	60.45	1.26
M7	5	15	57.7	1.21
M8	7.5	15	54.8	1.15
M9	10	15	51.9	1.09

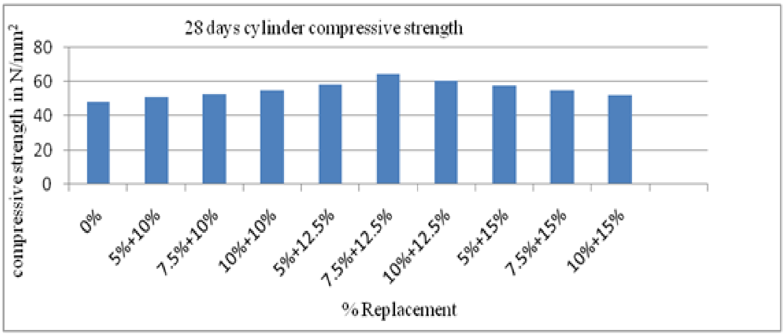

Figure 10 Cylinder compressive strength

5.4 Split tensile strength

Table 8 Split tensile strength

Mix Designation	% Replacement		Split tensile strength in N/mm^2
	MK	RHA	
MC	0	0	4.32
MC1	5	10	4.82
MC2	7.5	10	5.07
MC3	10	10	5.42
MC4	5	12.5	5.77
MC5	7.5	12.5	6.30
MC6	10	12.5	5.82
MC7	5	15	5.47
MC8	7.5	15	5.32
MC9	10	15	5.17

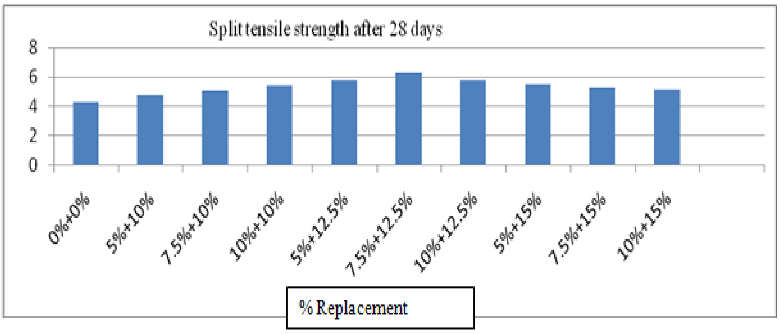

Figure 11 split tensile strength

The graph showing the difference of split tensile strength of concrete containing MK and RHA combinations, with various MK and RHA content are given in fig 11

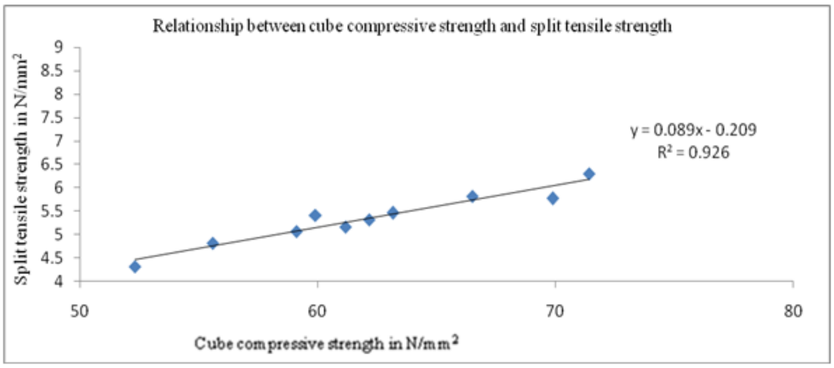

Figure 12 Relationship between cube compressive strength and split tensile strength

5.5. Flexural Strength

The flexural strength of prism at 28 days of different MK and RHA combinations are given in table 9

Table 9 Flextural strength

Mix Designation	% Replacement		Average flexural strength at 28 days In N/mm²
	MK	RHA	
Mc	0	0	6.4
M1	5	10	6.7
M2	7.5	10	6.9
M3	10	10	7.2
M4	5	12.5	7.9
M5	7.5	12.5	8.4
M6	10	12.5	8.10
M7	5	15	7.7
M8	7.5	15	7.5
M9	10	15	7.2

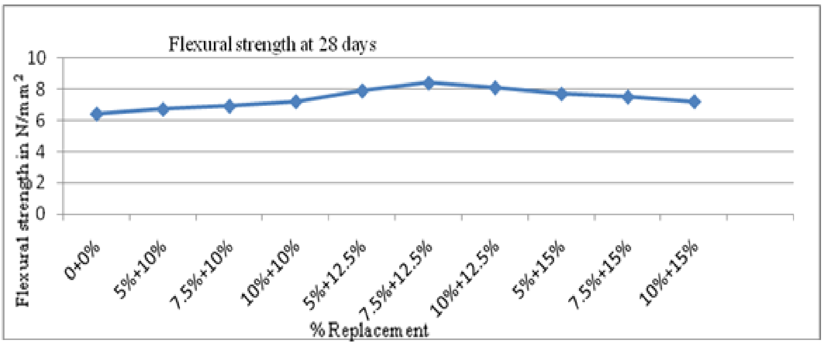

Figure 13 Flexural strength

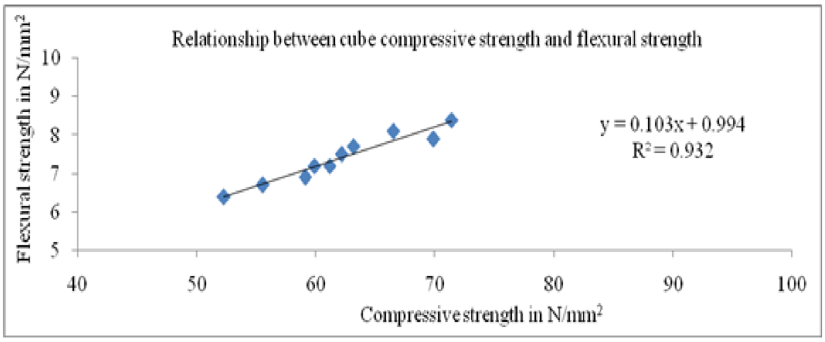

Figure 14 Relationship between cube compressive strength and flexural strength

The graph showing the flexural strength of concrete, made using MK and RHA combination, with various MK and RHA content are given in fig 13. It has been noted that with the inclusion of MK and RHA, flexural strength of concrete at the age of 28 days has increased with different proportion of the mix. The flexural strength at the age of 28 days for M60 grade concrete (Mc to M9) containing 0, 5+10, 7.5+10, 10+10, 5+12.5, 7.5+12.5, 10+12.5, 5+15, 7.5+15 and 10+15 percent of cement replacement by MK and RHA were 6.4, 6.7, 6.9, 7.2, 7.9, 8.4, 8.1, 7.7, 7.5 and 7.20 N/mm2 respectively.

From the table 9, it is clear that the flexural strength was gradually increased from6.7 to 8.4 for the cement replacement values of 5%+10% to 7.5%+12.5%(M1 to M6) and reducing to 8.1, 7.7, 7.5 and 7.2N/mm2 for 10%+12.5% to 10%+15% cement replacement values. So that the flexural strength increases with the increase of MK and RHA up to 7.5%+12.5%, the replacement level beyond this level the flexural strength decreases.

By studying the tested specimen it is noted that the bond between concrete matrixes was appreciable one. The combination of blended mixes of 7.5% MK and 12.5% RHA by partial replacement by weight of cement has exhibited increasing strength by 76% comparing with OPC mix.

5.6 Modulus of elasticity

The modulus of elasticity of cylinder at 28 days are given in Table.10

Table 10 Modulus of Elasticity values

Mix Designation	% Replacement		Cube compressive strength in N/mm^2	Modulus of Elasticity in GPA
	MK	RHA		
Mc	0	0	52.31	31.20
M1	5	10	55.58	32.00
M2	7.5	10	59.10	32.90
M3	10	10	59.91	33.20
M4	5	12.5	69.88	36.20
M5	7.5	12.5	71.42	38.20
M6	10	12.5	66.50	35.00
M7	5	15	63.16	34.40
M8	7.5	15	62.16	34.00
M9	10	15	61.16	33.70

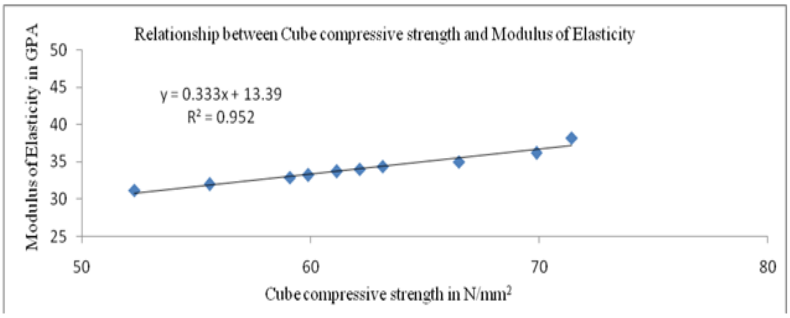

Figure 15 Relationship between cube compressive strength and modulus of elasticity

The graph showing the difference of modulus of elasticity of concrete, made using MK and RHA combination, with various MK and RHA content are given in table 10. Figure 15 and 16 has explained the experimental values of modulus of elasticity at 28 days period for High performance concrete specimens. The values of modulus of elasticity of HPC mixes (Mc to M9) at the age of 28 days were 31.2, 32, 33.2, 36.2, 38.2, 35, 34.4, 34, and 33.7 GPA respectively.

From the table 10, it is observed that the modulus of elasticity was gradually increasing from 32.0 to 38.20 GPA for the cement replacement values of 5%+10% and 7.5% to 12.5 %(M1 to M6) and reducing to 35, 34.4, 34 and 33.70 GPA for 10%+12.5%, 5%+15%, 7.5%+15% and 10%+15% cement replacement values. It is noted that the influence of MK and RHA on the modulus of elasticity is same as that of strength. The increasing trend of compressive strength leading to increase of modulus of elasticity [7]

6 Conclusions

In this research work M60 grade concrete was designed. About 150 cubes, 65 cylinders and 65 prisms were casted with various mix namely Mc, M1, M2, M3, M4, M5, M6, M7.M8 and M9 respectively. On the arrival of results the following conclusions were obtained. Both Metakaolin and Rice Husk Ash is very fine material which requires the addition of super plasticizer to improve the workability of HPC.

1. Metakaolin and Rice husk Ash concrete gains strength over a period of time, the compressive strength of MK and RHA Concrete is more than conventional concrete.
2. The optimum replacement of cement with MK and RHA is 7.5% and 12.5%.
3. The addition of MK and RHA shows an increased water absorption comparing with OPC concrete.
4. The split tensile strength and flexural strength is more when the cement is replaced by 7.5%MK and 12.5%RHA

5. The values of young's modulus increased from 0% to 7.5%Mk and 12.5%RHA, beyond this level young's Modulus

Values reduces

6. As per the experimental results it is concluded that the optimum concrete mixes can be arrived by blending cement With MK and RHA.

Acknowledgement

We express our gratitude to Dr.S.Karthikeyan, Correspondent, and Dr.V.Velmurugan, Principal, Sree Sakthi Engineering College, Coimbatore, for granted the permission to do the experimental work in concrete and high way laboratory of their institution. Also we would like to thank the students for their support.

REFRENCE:

[1] perumal.K, sundararajan.R, Experimental investigation on high performance concrete using silica fume and superplasticizer proceeding of the international conference on technology and structures,Kumara guru college of technology, Coimbatore, vol. II, sep-2003, pp 303-313.

[2] B.B.Patil, P>O>Kumbhar, Strength and durability properties of HPC incorporating high reactive Metakalin international journal of modern engineering research, Vol.2, Issue 3, May june 2012 pp. 1099-1104.

[3] W.Micah Hale, Seamus F, Freyne, Thomas D, Bush Fr, Bruce W, Russell,

Preparation of concrete slag cement and fly ash for use in transportation structures construction and building material 22(2008)

[4] S.Wild, J.M,Khatib, A.Jones, Relative strength pozzzolonic activity and cement hydration in susperplasticizedmetakaolinconcrete. Cement and concrete research, vol.26, No.10, pp., 1537-1544, 1996

[5] Vikash srivastara, Rajakumar, Agarwal V.C., Mehta P.K. Effect of Silica Fume and Metakaolin combination on concrete international journal o civil and structure engineering, volume 2, No3, 2012

[6] Khatib, J.M., &Hhibbert, J.J, Selected engineering properties of concrete incorporating slag and metakolin. Construction and building materials 19(6), pp. 460-472, 2005

[7] Nevil, A.M. properties of concrete four and final edition wiley, Newyork and longman, London, 1995.

[8] ACI committee 363.(1984). State of the art report on high strength concrete, ACI journal proceeding, 81(4)

[9] J.Bai, S.Wild, B.B.Sabir and J.M.Kinuthia in concrete incorporation PFA and Metakaolin Magazine of concrete research, 52, 2000, pp.153-162

[10] IS: 4656-2000, Indian standard for code of practice for plain and reinforced concrete.

[11] IS: 383-1970, Specification for course and fine aggregates from natural sources for concrete. Bureau of Indian standard, New Delhi

[12] IS 383-1970, Specification for course and fine aggregates from natural sources for concrete, ''Bureau of Indian standards, New Delhi

About the authors

Prof.A.N.Swaminathen is a structural engineer involving himself in teaching and research for more than six years currently he is pursuing his doctoral programme in Anna University Chennai. His research interest includes concrete technology, retrofitting of concrete structures and structural behaviour of concrete

S.Robert Ravi graduated (B.E civil) in the year 1990 from Thiagarajar college of Engineering, Madurai. He had industrial experience for 7 years by means of involving various projects in ONGC, Port trust of India etc…. He post graduated (M.E Structural engineering) in the year 2006 & got doctorial degree (Ph.D) in civil Engineering in the year 2011 from Karunya University, Coimbatore. He has teaching experience about 16 years in various educational institutions. He published 35 articles in various journals and conferences. He is an active member in 14 associations including F.I.E & F.I.V.