International Journal of Emerging Technology and Advanced Engineering
Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 583-590
An ISO 9001:2008 certified Int. Journal, ISSN 2250-2459, available online at www.ijetae.com

REPLACEMENT OF ORDINARY PORTLAND CEMENT BY RICE HUSK ASH TO PRODUCE ORDINARY CONCRETE OF GRADE M10, M15 AND M20

Kalyan Kumar Moulick

PhD Scholar, Department of Civil Engineering
Bengal Engineering and Science University (BESU)
West Bengal, India

Corresponding author email : kkmoulick@gmail.com

ABSTRACT
IS 456:2000 (Indian Standard : Plain and Reinforced Concrete – Code of practice) marked M10, M15 and M20 grade of concrete as 'Ordinary concrete'. In this paper the author studied the possibilities of using Rice Husk Ash (RHA) to replace cement partially to produce ordinary concrete of grade M10, M15 and M20. The concrete produced in laboratory by replacing cement by 5%, 10%, 15%, 20%, 25% and 30% RHA. Compressive strength tests carried out to determine the strength of concrete. The results are represented through tables and figures. Detail interpretation given in respect of possibilities of cement replacement by RHA which in turn will definitely reduce the cost of concrete and environmental friendly due to utilization of waste and replacement of cement.

Keywords: Rice Husk Ash, Ordinary concrete, Cement replacement, Compressive Strength.

1. INTRODUCTION
India is the world's second largest producer of rice after China [1]. West Bengal, one of India's rice bowls, has produced about 15-16 percent of the country's 2010-11 paddy crops of 100 million tonnes. Rice milling generates a by product known as rice husk. Controlled incineration of rice husk between 500^0C and 800^0C produces non-crystalline amorphous RHA [1]. 1 MT of rice grain produces 200 KG of Rice Husk i.e., 20% by weight of rice grain. 1 MT of Rice Husk produces 200 KG of Rice Husk Ash i.e., 20% by weight of Rice Husk [1]. RHA is whitish or grey in colour. The particles of RHA occur in cellular structure with a very high surface fineness. They have 90% to 95% amorphous silica. Due to high silica content, RHA possess excellent pozzolanic property [2, 3, 4, 5].

Cement Hydration is the result of a chemical reaction that occurs between water and the chemical compounds present in Portland cement [3]. Portland Cement is predominantly composed of two calcium silicates which account for 70 percent to 80 percent of the cement. The two calcium silicates are dicalcium silicates (C_2S) and tricalcium silicate (C_3S). The reaction of dicalcium silicate and tricalcium silicate with water produces calcium silicate hydrate (C-Si-H) and calcium hydroxide $Ca(OH)_2$ as illustrated below:

Calcium Silicates + Water -> Ca-Si-H Gel + $Ca(OH)_2$

Ca-Si-H Gel contributes to strength & long term durability & it accounts for more than half the volume of the hydrated cement paste. $Ca(OH)_2$ does not contribute to the strength & can potentially lead to reduced strength & lowered durability. It accounts for about 25% of the paste volume. RHA has high Silica content. The pozzolanic reaction of RHA converts the soluble $Ca(OH)_2$ to C-Si-H Gel, increasing the overall strength and durability of the concrete [3].

SiO_2 + $Ca(OH)_2$ -> Ca-Si-H Gel

Additional Ca-Si-H Gel produced by RHA improves the properties of Portland cement concrete.

2. RESEARCH SIGNIFICANCE
The global market for cement and concrete is huge; it is the second biggest traded commodity in the world after water. Cement production now accounts for around 5% of the global CO_2 emission [6]. The production of one ton of cement results in the release of approximately one ton of CO_2 [7,8]. One of the main key levers to reduce carbon emissions is replacing cement with cementitious material while producing concrete [8].

Presented at International Conference on Energy Resources and Technologies for Sustainable Development, 07-09 February 2013, Howrah, India.

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 583-590*

There is not only an environmental imperative to act but also a moral, social and even economic one as the world targets to support around 9 billion people in 2050 [7,8]. Advances in construction design, planning and materials will have a key role to play.

In a developing country like ours RHA based cement will definitely reduce cost of concrete. In semi-urban and rural areas of India generally 'Ordinary Concrete' is used to construct houses. If the rice producing zones in our country are earmarked and RHA is used to produce concrete in those areas then definitely it will enrich the economic condition of the poor & middle-class Indians.

3. PROCESSING AND PRODUCTION OF RHA

3.1 Combustion

To produce the best pozzolanas, the burning of the husk must be carefully controlled to keep the temperature below 700^0C and to ensure that the creation of carbon is kept to a minimum by supplying an adequate quantity of air. At burning temperatures below 700^0C an ash rich in amorphous silica is formed which is highly reactive. Temperatures above 700^0C produce crystalline silica which is far less reactive [5,8,9].

The presence of large quantities of carbon in the ash will adversely affect the strength of any concrete or mortar produced using RHA cements. Where possible, the carbon content of the ash should be limited to a maximum of 10% [5].

Rice husks which have been burnt in large open heaps to dispose of waste husks or burnt as a fuel in an industrial furnace, are unlikely to produces ashes with the specification described above. In particular, they are likely to be crystalline due to high combustion temperatures. Although this does not rule out their use as a pozzolana, ashes composed of crystalline silica will require a considerable amount of grinding to produce an acceptable reactivity [5].

Rice husk has an energy value about half that of coal and is therefore an important potential energy source. Although rice husk is still burnt as waste, this practice is likely to become less common, as other more traditional fuel sources become less readily available and / or more expensive. Recently attempts have been made to design kilns or furnaces for husks which will utilize the potential energy value of the husk by making it available for useful work and which control the temperature of combustion to below 700^0C [5].

There are several designs of small simple incinerators, normally made of fired clay bricks, which are capable of burning ash at temperatures below 700^0C and without excessive quantities of carbon. The temperature is monitored by a pyrometer (an industrial instrument for measuring high temperatures) and rapid cooling is necessary if the temperature rises above 650^0C. This is normally achieved by removing the ash and spreading it on the ground [5].

3.2 Grinding

The second step in processing is grinding the RHA to a fine powder. Ball or hammer mills are usually used for this purpose. Crystalline ash is harder and will require more grinding in order to achieve the desired fineness [5].

4. MATERIALS USED IN LABORATORY EXPERIMENTS

4.1 Ordinary Portland Cement

Ultratech brand Ordinary Portland Cement (OPC) 43 grade was used in the laboratory experiments. Typical properties and composition of this product are given in Table 1.

4.2 Rice Husk Ash

Rice Husk Ash (RHA) was procured from "Manas Rice Husk Ash Research & Export India Pvt. Ltd., Bardhaman, West Bengal". Typical properties and composition of this product are given in Table 2.

4.3 Coarse Aggregate

Pakur variety 20 mm down was used as coarse aggregate in the laboratory experiments. Grading of this product are given in Table 3. The bulk density obtained in the lab was 1440 kg / cum.

4.4 Fine Aggregate

River sand from rivers at Bardhaman was used as fine aggregate in the laboratory experiments. Grading of this product are given in Table 4. The bulk density obtained in the lab was 1450 kg / cum. The fineness modulus obtained was 2.83.

4.5 Water

The water that is supplied in the Civil Engineering Laboratory was used in the experiments. This water is potable and can be used for making concrete as per laboratory records.

5. TESTS CONDUCTED

5.1 Slump flow test

To determine the workability of concrete, slump flow test conducted with slump cone. The mould was filled in four layers, each roughly one quarter of the height of mould. Each layer tamped uniformly with twenty five strokes of the rounded end of the tamping rod with penetration slightly in to the underlying layer.

5.2 Compressive strength test

Cubes of 150x150x150 mm with OPC and OPC replaced by RHA at 0%, 5%, 10%, 15%, 20%, 25% and 30% replacement levels were cast. After 24 hours of casting, cubes were subjected to water curing for 7 to 28 days. The cubes were tested for compressive strength using compressive testing machine. The tests were carried out on triplicate specimens and the average compressive strength values were recorded.

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 583-590*

5.3 Tensile Strength of Concrete

The flexural and splitting tensile strengths may be obtained as per IS 516 and IS 5816 respectively. Here the following formula has been used as per IS 456 : 2000 to determine the tensile strength from the compressive strength:

Flexural strength, $fcr = 0.7 \sqrt{fck}$ N/mm^2

Where fck is the characteristics cube compressive strength of concrete in N/mm^2.

5.4 Modulus of Elasticity of Concrete

The modulus of elasticity is primarily influenced by the elastic properties of the aggregate and to a lesser extent by the conditions of curing and age of the concrete, the mix proportions and the type of cement. The modulus of elasticity is normally related to the compressive strength of concrete. Here the following formula has been used as per IS 456 : 2000 to determine the modulus of elasticity of concrete:

$Ec = 5000 \sqrt{fck}$

Where Ec is the short term static modulus of elasticity in N/mm^2 and fck is the characteristics cube compressive strength of concrete in N/mm^2.

6. COST ANALYSIS AND COMPARISON

A cost analysis and comparison is done in Table 11 between 'no replacement' and '20% replacement'. It is observed that the cost of one cum concrete with '20% replacement' reduces by 7%, 9% & 10% in comparison with 'no replacement' for M10, M15 and M20 respectively.

7. RESULTS AND DISCUSSION

The results of slump flow tests are given in Table 5, 6 & 7. The slump obtained in the range of 30 to 85mm. As per IS 456 : 2000, the workability can be marked as low to medium degree. This type of workability is suitable for Mass concrete; Lightly & heavily reinforced sections in slabs, beams, walls, columns; Floors; Hand placed pavements; Canal lining; Strip footings etc. Slump flow test results show that increase of replacement of cement with RHA & with constant water / binder ratio, the slump decreases. This is because adding RHA by weight results increase of the resulted concrete volume, as the density of RHA is significantly lower than cement, i.e. 2.1 compared to 3.11 of cement.

The results of compressive strength tests are given in Table 8, 9 & 10 and Figure 1, 2 & 3. With replacement of cement upto 30% by RHA, Ordinary Concrete of grade M10, M15 & M20 can be produced. Replacement of cement by 20% RHA gives best results.

The values of Tensile strength and Modulus of Elasticity of concrete based on compressive strength are given in Table 8, 9 & 10. With replacement of cement upto 30% by RHA, the tensile strength and modulus of elasticity got improved and the best results were obtained at 20% replacement level.

8. CONCLUSION

Based on the experimental results, following conclusions can be drawn:

i) 'Ordinary Concrete' of Grade M10, M15 and M20 can be produced by replacing Ordinary Portland Cement with Rice Husk Ash upto 30%. Replacement at the level 20% provides best results.

ii) OPC replacement by RHA results in reduction of cost of production of concrete in the range of 7 to 10%.

iii) OPC replacement by RHA is environmental friendly due to utilization of waste (RHA is basically a waste obtained from Rice Mill) and replacement of cement (Production of 1 MT cement emerges 1 MT Carbon-di-Oxide).

ACKNOWLEDGEMENTS

I gratefully acknowledge the resourceful guidance, active supervision and constant encouragement of Prof. Dr. Saibal Ghosh, Professor – The Department of Civil Engineering, Bengal Engineering and Science University, Shibpur.

I also gratefully acknowledge the resourceful guidance from the faculties and staffs of Civil Engineering Laboratory, Bengal Engineering and Science University, Shibpur.

I also gratefully acknowledge "Manas Rice Husk Ash Research & Export India Pvt. Ltd., Bardhaman, West Bengal" for supplying the RHA for research purpose and also for providing valuable information regarding RHA.

REFERENCES

[1] Rice Husk Ash market study – Bronzeoak Ltd. , 2003. [5]

[2] Pozzolanas: Rice Husk Ash (RHA) & Pulverised Fuel Ash (PFA) – Practical Action – The Schumacher Centre for Technology & Development, Bourton on Dunsmore, Warwickshire, UK. [5]

[3] The possibility of adding the Rice Husk Ash to the concrete – Mauro M.Tashima, Carlos A.R. da Silva, Jorge L.Akasaki, Michele Beniti Barbosa – FEIS/UNESP, Brazil. [4]

[4] Rice Husk Ash– Nick Zemke, Emmet Woods— California Polytechnic State University, 2009. [5]

[5] Supplementary cementitious materials: Part I: Pozzolanic SCM—Adam.D.Neuwald—MC Magazine, Sept-Oct, 2004. [5]

[6] A Sustainability Framework for Concrete Construction -- P Chana -- Proceedings of the

International UKIERI Concrete Congress held at Indian Institute of Technology, New Delhi, India, 8th to 10th March, 2011. [4]
[7] Green materials for sustainable housing development: Agro waste ashes as a cement replacement for concrete structures in hot arid climates. – Shahid Kabir, Universiti Sains, Malaysia. – The first built environmental development symposium: Sustainable real estate & housing development. [4]
[8] Necessity and opportunity of sustainable concrete from Malaysia's waste materials – M.R.Karim, M.F.M.Zain, M.Jamil, F.C.Lai, M.N.Islam – Australian Journal of Basic and Applied Sciences, 5(5): 998-1006, 2011. [1]
[9] Durability of conventional concretes containing black Rise Husk Ash – B.Chatveera, P.Lertwattanaruk – Journal of Environmental Management 92 (2011) 59-66. [1]

AUTHOR BIOGRAPHY

Mr. Kalyan Kumar Moulick is a PhD Scholar at Department of Civil Engineering at Bengal Engineering and Science University, Shibpur, India. He has 14 years of construction industry experience. He has research interst in Concrete Technology.

Table 1: Properties and composition of Ordinary Portland Cement

Ultratech brand OPC 43 grade was used in the laboratory experiments. Typical properties and composition of this product are obtained from their data sheet.

Type of cement	**IS Code**	**Fineness m2/kg (min)**	**Setting Time in minutes**		**Soundness**		**Compressive Strength in MPa**		
			Initial (min.)	**Final (max.)**	**Le Chatelier (mm)**	**Auto Clave (%)**	**3 days**	**7 days**	**28 days**
OPC 43	8112 : 1989	225	30	600	10	0.8	23	33	43

Chemical composition			
Constituents	**% Weight**	**Constituents**	**% Weight**
SiO_2	17-25	SO_3	1.3-3.0
Al_2O_3	4-8	$Na_2O + K_2O$	0.4-1.3
Fe_2O_3	0.5-0.6	Cl	0.01-0.1
CaO	61-63	IR	0.6-1.75
MgO	0.1-4.0		

Table 2: Chemical and Physical properties of RHA

RHA was procured from "Manas Rice Husk Ash Research & Export India Pvt. Ltd., Bardhaman, West Bengal". The properties are provided by them.

Chemical composition					
Constituents	**% Weight**	**Constituents**	**% Weight**	**Constituents**	**% Weight**
SiO_2	90	CaO	0.46	Na_2O	0.07
Al_2O_3	0.39	MgO	0.88	P_2O_5	1.60
Fe_2O_3	0.37	K_2O	3.10	MnO	0.039
				L.O.I (Loss of Ignition)	3.091
Physical Property					
Colour			Light Grey		
Specific Gravity			2.1		

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 583-590*

Table 3: Grading of Coarse Aggregate

I.S. Sieve (mm)	% Retained	Cumulative % Retained	Cum. % Passing	Requirement of Cum. % passing for 20 mm graded coarse agg. as per I.S. 383
40	0	0	100	100
20	4	4	96	95-100
16	36	40	60	-
12.5	24	64	36	-
10	10	74	26	25-55
4.75	22	96	4	0-10

Table 4: Grading of Fine Aggregate

I.S. Sieve (mm)	% Retained	Cum. % Retained	Cum. % Passing	Requirement of Cum. % passing for zone II sand as per I.S. 383
10	0	0	100	100
4.75	2	2	98	90-100
2.36	13	15	85	75-100
1.18	20	35	65	55-90
600 micron	20	55	45	35-59
300 micron	24	79	21	8-30
150 micron	18	97	3	0-10
Residual	3	100	0	

Table 5: Mixture Proportion for M10 concrete

Sample	Cement	RHA	Water	Coarse Agg.	Fine Agg.	W/B Ratio	Slump
	Kg / Cum	Kg / Cum	Kg / Cum	Kg / Cum	Kg / Cum		mm
C10	220	-	149.6	1340	770	0.68	60
C10-R5	209	11	149.6	1340	770	0.68	55
C10-R10	198	22	149.6	1340	770	0.68	45
C10-R15	187	33	149.6	1340	770	0.68	40
C10-R20	176	44	149.6	1340	770	0.68	37
C10-R25	165	55	149.6	1340	770	0.68	33
C10-R30	154	66	149.6	1340	770	0.68	30

Table 6: Mixture Proportion for M15 concrete

Sample	Cement	RHA	Water	Coarse Agg.	Fine Agg.	W/B Ratio	Slump
	Kg / Cum	Kg / Cum	Kg / Cum	Kg / Cum	Kg / Cum		mm
C15	320	-	204.8	1333	711	0.64	80
C15-R5	304	16	204.8	1333	711	0.64	74
C15-R10	288	32	204.8	1333	711	0.64	68
C15-R15	272	48	204.8	1333	711	0.64	60
C15-R20	256	64	204.8	1333	711	0.64	52
C15-R25	240	80	204.8	1333	711	0.64	46
C15-R30	224	96	204.8	1333	711	0.64	40

Table 7: Mixture Proportion for M20 concrete

Sample	Cement Kg / Cum	RHA Kg / Cum	Water Kg / Cum	Coarse Agg. Kg / Cum	Fine Agg. Kg / Cum	W/B Ratio	Slump mm
C20	400	-	240	1333	652	0.60	85
C20-R5	380	20	240	1333	652	0.60	80
C20-R10	360	40	240	1333	652	0.60	75
C20-R15	340	60	240	1333	652	0.60	70
C20-R20	320	80	240	1333	652	0.60	63
C20-R25	300	100	240	1333	652	0.60	55
C20-R30	280	120	240	1333	652	0.60	45

Table 8: Results of compressive strength test for M10 concrete. Tensile strength & Modulus of elasticity also calculated based on compressive strength value.

Sample	7 days strength (MPa)	28 days strength / fck (MPa)	Tensile strength fcr = 0.7 √fck (N/mm^2)	Modulus of elasticity Ec = 5000 √fck (N/mm^2)
C10	14.1	17.8	2.95	21095
C10-R5	13	18.5	3.01	21506
C10-R10	13	18.5	3.01	21506
C10-R15	11.9	19.1	3.06	21852
C10-R20	11.9	19.3	3.08	21966
C10-R25	10.4	17.1	2.89	20676
C10-R30	8.9	16.3	2.83	20187

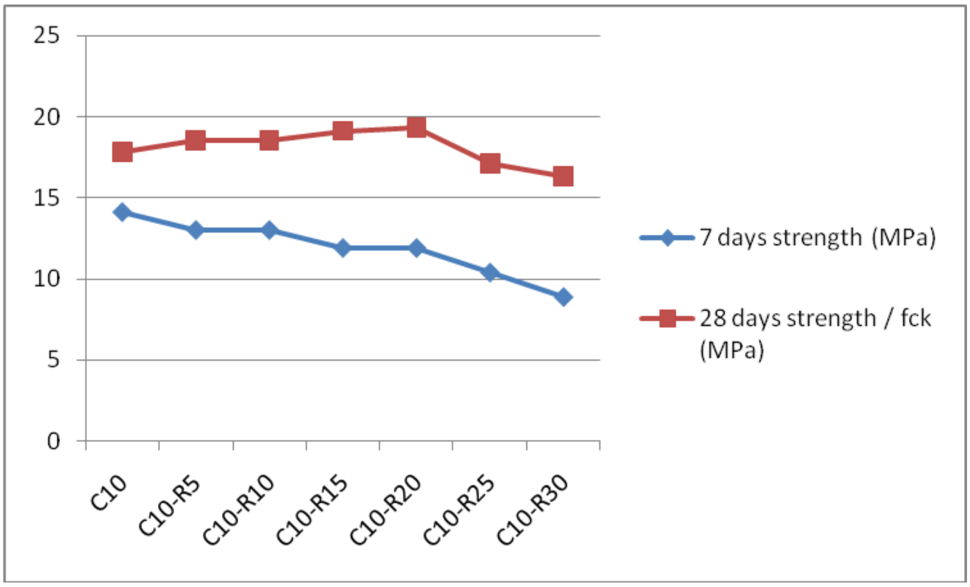

Figure 1: Results of compressive strength test for M10 concrete

Table 9: Results of compressive strength test for M15 concrete. Tensile strength & Modulus of elasticity also calculated based on compressive strength value.

Sample	7 days strength (MPa)	28 days strength / fck (MPa)	Tensile strength fcr = 0.7 √fck (N/mm^2)	Modulus of elasticity Ec = 5000 √fck (N/mm^2)
C15	15.6	20.7	3.18	22749
C15-R5	15.6	21.5	3.25	23184
C15-R10	14.8	20.7	3.18	22749
C15-R15	14.8	21.5	3.25	23184
C15-R20	14.1	22.3	3.31	23611
C15-R25	11.9	19.5	3.09	22079

C15-R30	11.1	18.5	3.01	21506

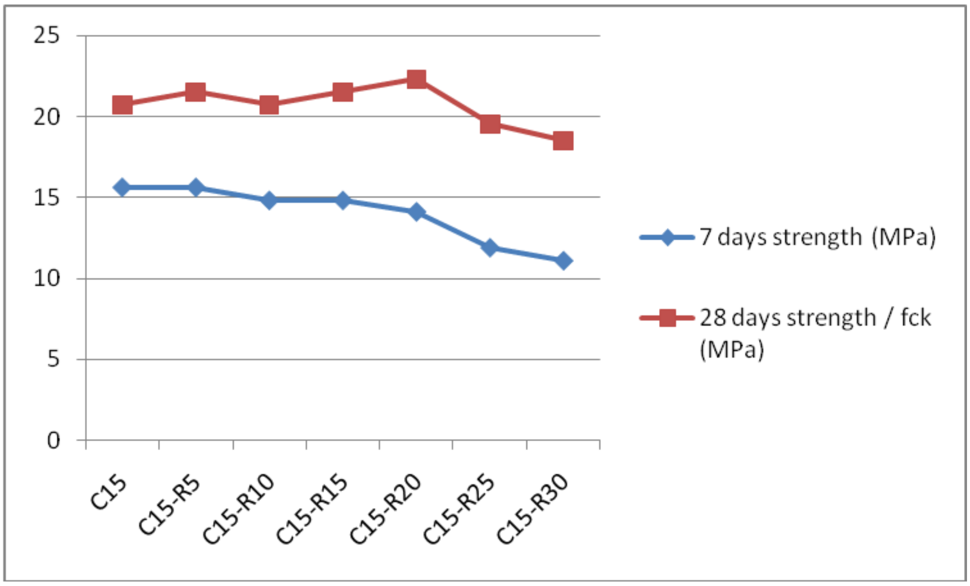

Figure 2: Results of compressive strength test for M15 concrete.

Table 10: Results of compressive strength test for M20 concrete. Tensile strength & Modulus of elasticity also calculated based on compressive strength value.

Sample	7 days strength (MPa)	28 days strength / fck (MPa)	Tensile strength fcr = 0.7 √fck (N/mm^2)	Modulus of elasticity Ec = 5000 √fck (N/mm^2)
C20	21.8	28.8	3.76	26833
C20-R5	21.8	28.8	3.76	26833
C20-R10	20.5	30.5	3.87	27613
C20-R15	20.1	31.4	3.92	28018
C20-R20	20.1	32.3	3.98	28417
C20-R25	16.6	26.2	3.58	25593
C20-R30	13.5	21.8	3.27	23345

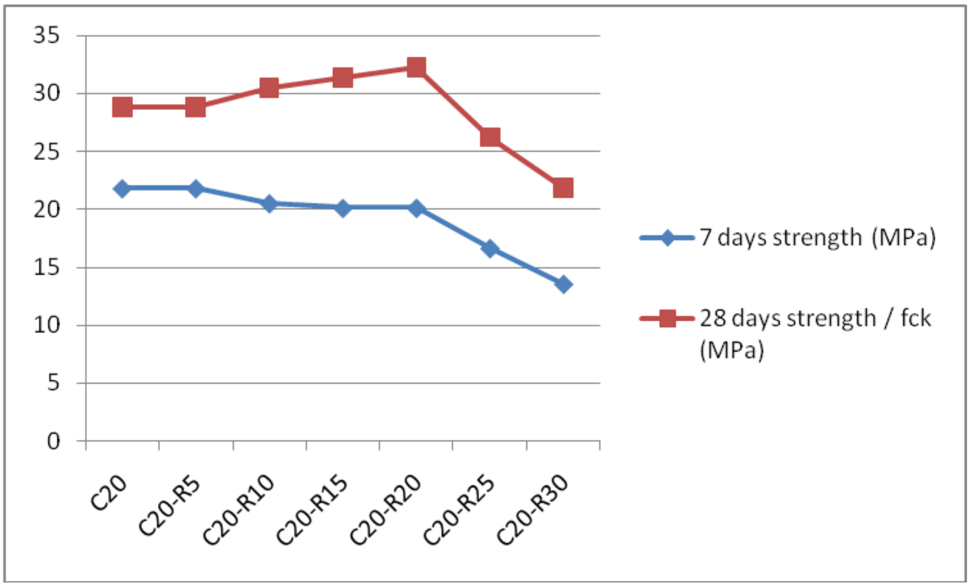

Figure 3: Results of compressive strength test for M20 concrete.

ISSN 2250-2459, *Volume 3, Special Issue 3: ICERTSD 2013, Feb 2013, pages 583-590*

Table 11: Cost Analysis and Comparison

Considering place of construction is within Bardhaman District, West Bengal, India and date of construction is Oct, 2012.

Grade of Conc.	Cement Replacement	Cement (Kg)	Price per Kg (Rs.)	RHA (Kg)	Price per Kg (Rs.)	Coarse Agg. (Kg)	Price per Kg (Rs.)	Fine Agg. (Kg)	Price per Kg (Rs.)	Mixing & placing cost per cum (Rs.)	Total Cost per cum of concrete (Rs.)
M10	Nil	220	7	-	0.50	1340	1.20	770	0.35	600	4018/-
	20%	176	7	44	0.50	1340	1.20	770	0.35	600	3732/-
M15	Nil	320	7	-	0.50	1333	1.20	711	0.35	600	4688/-
	20%	256	7	64	0.50	1333	1.20	711	0.35	600	4272/-
M20	Nil	400	7	-	0.50	1333	1.20	652	0.35	600	5228/-
	20%	320	7	80	0.50	1333	1.20	652	0.35	600	4708/-

NOMENCLATURE

Symbol	Meaning	Symbol	Meaning	Symbol	Meaning
	M10 grade of concrete with		M15 grade of concrete with		M20 grade of concrete with
C10	No replacement	C15	No replacement	C20	No replacement
C10-R5	5% replacement	C15-R5	5% replacement	C20-R5	5% replacement
C10-R10	10% replacement	C15-R10	10% replacement	C20-R10	10% replacement
C10-R15	15% replacement	C15-R15	15% replacement	C20-R15	15% replacement
C10-R20	20% replacement	C15-R20	20% replacement	C20-R20	20% replacement
C10-R25	25% replacement	C15-R25	25% replacement	C20-R25	25% replacement
C10-R30	30% replacement	C15-R30	30% replacement	C20-R30	30% replacement