MECHANICAL PROPERTIES OF CEMENTITIOUS MATERIALS MADE FROM LIME AND RICE HUSK ASH

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Key Words Cementitious material, Agricultural Waste, Industrial Waste, rice husk ash, lime, compressive strength.

Abstract

The objective of the paper is to develop, through experiments, a cementitious material based on the proper combination of lime and rice husk ash. For rice husk ash, a simple and efficient method has already been developed for its economical production (Ref.1). Requiring no high technology or sophisticated hardware, the manufacturing process is well suited for introduction to the rural areas of the developing countries. For lime, various types of lime available either commercially or locally are investigated. The parameters considered in the testing program include the mixing methods and lime-RHA ratios. The consistency and mix proportion of the cementitious material and sand by weight are kept constant throughout. The mechanical properties of mortar and concrete investigated in this study are the compressive and tensile strength at various ages, modulus of elasticity and saturated density.

Test results indicated that intergrinding of lime and RHA produces better quality mortar than blending and a mix proportion of 1:2 for lime:RHA yields the highest strength for mortar. Among the various types of lime investigated, it was found that lime which was produced by burning limestone in a brick furnace for 7 days and allowed to cool by itself gave the best results. The results showed further that the cementitious material obtained satisfied the minimum requirements of strengths of Portland Cement Specified by ASTM standards and hence can be readily used for masonry work.

1. INTRODUCTION

1.1 General

Nowadays, as conventional construction materials are growing more and more costly due to increased construction activities and world inflation, it becomes essential for the developing countries to look into the development of alternative building materials based on indigenous materials. Many developing countries are attempting to develop new materials from the locally available raw materials like agricultural and industrial wastes. Rice husk is among one of the waste materials in the rice growing countries. This agro waste material weighs about one fifth of paddy. The annual production of paddy is around 341 million tons. From this amount, 68 million tons of rice husk are produced annually after milling. This requires a storage space of over 600 million cubic meters. The production of rice husk ash, (here after, referred to as RHA) is simple but requires special care in the burning and grinding processes. The reactive amorphous type of ash could be obtained by burning under sufficient air supply conditions within a middle range of burning temperature, preferably around 400^{o}C.

Rice husk ash containing silica in a highly reactive form is found to be an excellent ingredient for making either lime-RHA or portland-RHA cements.

1.2 Objectives and Scope

In this paper, the development of a cementitious material based on the proper combination of reactive RHA and lime is presented. For RHA and lime, the simple and efficient processes have been developed for its economical production. Requiring no high technology or sophisticated hardware, the procedures are well suited for adoption in the rural areas of developing countries. This type of material (lime-RHA) can be produced locally and through appropriate technology.

Using RHA and different types of lime available either commercially or locally produced by proposed procedure,different lime-RHA mortar mixes have been prepared and test results on strengths and other properties are shown and discussed. The variables considered in this study are the mixing methods, lime-RHA ratios and types of lime. The consistency and mix proportion by weight were kept constant throughout.

2. EXPERIMENTAL PROCEDURES

The rice husk ash used in this study was obtained by burning the rice husk using WE's (Ref.2) proposed ferrocement incinerator and grinding the ash in a grinding machine designed by ISLAM (Ref.3) with AZAM's (Ref.4) grinding method. The degree of fineness was maintained constant throughout the whole testing program. The chemical composition and physical properties of RHA are shown in Table 1.

Details of four different types of lime used in the present study are given as under:

Lime Type A

Commercially available reagent grade calcium hydro oxide commonly known as pure lime having 98 percent purety was used. Its chemical composition and physical properties are shown in Table 1.

Lime Type B

Commercially available cheap lime was used. Its chemical composition and physical properties are shown in Table 1.

Lime Type C

Cooked (burnt) lime obtained from lime factory was used. This type of lime was produced by using the concept of appropriate technology. It was essentially prepared by burning limestone using wood as a fuel for approximately one week. Its chemical composition and physical properties are shown in Table 1.

Lime Type D

This type of lime was totally prepared in the laboratory. Limestone was burnt in an electric furnace. To obtain cooked lime, limestone was burnt at a temperature of 800^{o}C for 96 hours. Powder Form of lime is obtained by pouring water on it.

Different mixes were cast using two mixing methods, namely, blending and intergrinding. The proportions of lime-RHA by weight were 25:75, 33:67, 50:50, 67:33 and 75:25. The normal consistency of mortar was maintained to have a flow of 110∓5 percent in accordance with ASTM C230-80. Twelve samples from each batch were cast and tested for their mechanical properties. The mechanical properties included compressive strengths at 3,7,28 and 90 days; saturated density and setting times.

3. DISCUSSION

3.1 Setting Time of Lime-RHA Paste Mixture

The initial and final setting times of lime-RHA paste mixture with lime type C, having proportion of lime: RHA equal to 0.33:0.67 and a water/(lime+RHA) ratio of 0.625 were found to be 10½ and 17 hours respectively. The test was carried out in accordance with ASTM C-266-71 test for time of setting of hydraulic cement by vicat needle.

3.2 Properties of lime-RHA Mortars

3.2.1 Compressive strength of lime-RHA mortars with different types of lime.

a) Type A

The compressive strength of lime-RHA mortar of different mix proportions and mixing methods are shown in Table 2 and Fig.1. The

results showed that the highest strength developed at ages of 3,7 28 and 90 days occurred when a lime:RHA ratio of 1:2 was used and the mixing was made by intergrinding. It was observed that as the percentage of RHA increases, the water requirement of lime-RHA mortars also increases. This is due to the higher water requirement of RHA. The saturated density decrease with an increase in RHA content. This is due to the lower specific gravity of RHA as compared to lime. Moreover mixing by blending requires higher water/(lime+RHA) ratios and results in a lower compressive strength and saturated density as compared to mixing by intergrinding.

b) Type B

The compressive strength of lime-RHA mortar of different mix proportions and mixing methods are shown in Table 3 and Fig.2. The results showed that the highest strength developed at ages of 3,7 28 and 90 days occurred when a lime:RHA ratio of 1:2 was used and the mixing was made by intergrinding. It was observed that as the percentage of RHA increases, the water requirement of lime-RHA mortars also increases. This is due to the higher water requirement of RHA. The saturated density decrease with an increase in RHA content. This is due to the lower specific gravity of RHA as compared to lime. Moreover mixing by blending requires higher water/(lime+RHA) ratios and results in a lower compressive strength and saturated density as compared to mixing by intergrinding.

It can be seen from the results that the compressive strength of lime-RHA mortars for lime type B are lower than lime type A. This is due to the fact that lime type B was not good and contained quite high percentage of carbon and impurities as shown in Table 1.

c) Type C

The compressive strength of lime-RHA mortar of different mix proportions and mixing methods are shown in Table 4 and Fig.3. The results showed that the highest strength developed at ages of 3,7 28 and 90 days occurred when a lime:RHA ratio of 1:2 was used and the mixing was made by intergrinding. It was observed that as the percentage of RHA increases, the water requirement of lime-RHA mortars also increases. This is due to the higher water requirement of RHA. The saturated density decrease with an increase in RHA content. This is due to the lower specific gravity of RHA as compared to lime. Moreover mixing by blending requires higher water/(lime+RHA) ratios and results in a lower compressive strength and saturated density as compared to mixing by intergrinding.

It can be seen from the results that the compressive strength of lime RHA mortars for lime type C, are very close to the results obtained with lime type A, even the cost of lime type C is lower than the cost of lime type A and it was produced by using the concept of appropriate technology.

Additional test was carried out with lime type C having different water/(lime+RHA) ratios for observing the effect of water/(lime+RHA) ratio on compressive strength. The results are

shown in Table 4 and Fig.4. The results showed that lime-RHA mortar having lower water/(lime+RHA) ratio could not develop high strength. This is due to the high water requirement of RHA. By lowering the Water/(lime+RHA) ratio the mix became very dry and amcunt of water present was not sufficient to provide the necessary reaction between lime and RHA.

d) Type D

The compressive strength of lime-RHA mortar of different mix proportions and mixing methods are shown in Table 5 and Fig.5. The results showed that the highest strength developed at ages of 3,7 28 and 90 days occurred when a lime:RHA ratio of 1:2 was used and the mixing was made by intergrinding. It was observed that as the percentage of RHA increases, the water requirement of lime-RHA mortars also increases. This is due to the higher water requirement of RHA.

The saturated density decrease with an increase in RHA content. This is due to the lower specific gravity of RHA as compared to lime. Moreover mixing by blending requires higher water/(lime+RHA) ratios and results in a lower compressive strength and saturated density as compared to mixing by intergrinding.

The results obtained with lime type D are close to the results obtained with lime type A and C.

3.3. Comparison of Different Types of Lime

The Compressive strength of lime-RHA mortar with a mix proportion of 1:2 with lime type A,B,C and D are shown in Fig.6. The results showed that the highest strength developed at ages of 3,7,28 and 90 days occurred with lime type A. But because of its high cost, it is not applicable and lime type C is suitable for lime-RHA cements, as it was produced by using the concept of appropriate technology.

3.4 Comparison with other Researchers

Similar investigations were also carried out by MEHTA (Ref.5), PAUL (Ref.6) and MALLA (Ref.7); and the results are summaries in the following table:

By	Type of Lime	Mix Proportions (lime+RHA):Sand	Mixing Method	Water/(lime+RHA)	Compressive strength (MPa) Age at Test			
					3 Days	7 Days	28 Days	90 Days
MEHTA	A	(0.30+0.70):2.75	Interg.	0.57	4.48	16.55	24.48	-
PAUL	A	(0.33+0.67):2.75	Blending	1.176	-	1.08	1.34	1.43
MALLA	A	(0.25+0.75):2.75	Blending	1.16	-	3.53	4.32	4.96
THIS STUDY	A	(0.33+0.67):2.75	Interg.	0.71	7.24	11.51	16.94	18.28
	B	(0.33+0.67):2.75	Interg.	0.675	5.40	7.94	9.78	11.22
	C	(0.33+0.67):2.75	Interg.	0.71	7.01	10.19	15.16	17.71
	D	(0.33+0.67):2.75	Interg.	0.72	5.33	9.90	14.72	17.39

It was noted that the results obtained from this study are still lower than those obtained by METHA but showed a considerable improvement over those by PAUL and MALLA. In the former case a lower water/(lime+RHA) ratio was used and this could result in a higher compressive strength, whereas for the two latter cases the RHA was prepared in a different way and also a very high water/(lime+RHA) ratio was used.

5. CONCLUSIONS

On the basis of the results presented in this paper, the following conclusions can be made:

1. The optimum ratio of lime to RHA to produce the maximum compressive strength of lime-RHA mortar having the same workability is found tobe 1:2. Intergrinding of lime and RHA produces better quality mortar then blending.

2. Among the four types of lime investigated, lime type C which contains 74 percent calcium oxide and can be produced locally and through appropriate technology is found to be most reactive when interground with RHA.

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Table 1. Chemical Composition and Physical Properties of RHA and Three Different Types of Lime used in this study.

Composition	RHA (%)	Lime Types A (%)	B (%)	C (%)
Silicon dioxide (SiO_2)	92.05	0.44	0.56	0.07
Aluminium oxide (Al_2O_3)	0.94	0.09	0.27	0.11
Iron oxide (Fe_2O_3)	0.81	0.06	0.08	0.03
Calcium Oxide (CaO)	0.27	73.10	60.24	73.86
Magnesium Oxide (MgO)	0.27	0.54	1.16	0.48
Sodium Oxide (Na_2O)	0.06	0.05	0.05	0.05
Potassium Oxide (K_2O)	1.72	0.02	0.03	0.02
Sulfite (SO_3)	0.13	0.11	0.03	0.02
Loss	3.19	25.05	37.04	25.00
Total	99.44	99.46	99.46	99.64
Carbon dioxide (CO_2)	0.43	1.22	28.49	0.98
Purity about, %	-	95.90	36.60	97.10
Blaine Fineness, Cm^2/g	14,300	12,670	4,770	14,560
Specific Gravity	2.085	2.226	2.439	2.172

Table 2: Compressive Strength of Lime-RHA Mortars Having Different Mix proportions and Mixing Methods for Lime Type A.

Mix Proportions (Lime+RHA):Sand	Mixing Method	Water/ (Lime+RHA) *	Saturated Density Kg/m3	Compressive Strength (MPa) Age at Test			
				3Days	7Days	28Days	90Days
(0.25+0.75):2.75	Blend.	0.76	1932	6.09	7.63	11.54	13.09
(0.33+0.67):2.75	Blend.	0.74	1963	6.22	0.08	12.37	14.04
(0.33+0.67):2.75	Inter.	0.71	2020	7.24	11.51	16.94	18.28
(0.50+0.50):2.75	Blend.	0.61	1970	4.84	6.09	8.76	9.22
(0.67+0.33):2.75	Blend.	0.56	1978	3.17	4.19	6.23	7.19
(0.75+0.25):2.75	Blend.	0.55	1990	2.52	3.59	5.43	6.19

Table 3: Compressive Strength of Lime-RHA Mortars Having Different Mix proportions and Mixing Methods for Lime Type B.

Mix Proportions (Lime+RHA):Sand	Mixing Method	Water/ (Lime+RHA) *	Saturated Density Kg/m3	Compressive Strength (MPa) Age at Test			
				3Days	7Days	28Days	90Days
(0.25+0.75):2.75	Blend.	0.76	1928	3.77	6.15	7.40	8.49
(0.25+0.75):2.75	Inter.	0.70	1979	4.28	6.81	8.22	9.42
(0.33+0.67):2.75	Blend.	0.72	1971	4.65	7.58	8.66	10.33
(0.33+0.67):2.75	Inter.	0.675	2017	5.40	7.94	9.78	11.22
(0.50+0.50):2.75	Blend.	0.65	1988	3.62	5.71	6.42	6.99
(0.67+0.33):2.75	Blend.	0.60	1995	1.97	3.44	4.82	5.28
(0.75+0.25):2.75	Blend.	0.58	2021	1.38	2.82	4.24	4.52

* Flow is 110 $\pm$ 5%.

Table 4: Compressive Strength of Lime-RHA Mortars Having Different Mix proportions and Mixing Methods for Lime Type C.

Mix Proportions (Lime+RHA):Sand	Mixing Method	Water/ (Lime+RHA) *	Saturated Density Kg/m^3	Compressive Strength (MPa) Age at Test 3Days	7Days	28Days	90Days
(0.25+0.75):2.75	Inter.	0.74	1965	5.37	8.27	12.46	14.26
(0.33+0.67):2.75	Inter.	0.71	2009	7.01	10.19	15.16	17.71
(0.33+0.67):2.75	Blend.	0.74	1983	6.51	9.77	14.13	15.19
(0.33+0.67):2.75	Inter.	0.60 Fixed	1874	4.71	6.28	8.05	8.92
(0.33+0.67):2.75	Inter.	0.50 Fixed	1855	1.38	2.55	3.15	4.68
(0.50+0.50):2.75	Inter.	0.695	1992	4.44	8.00	11.19	13.74

Table 5: Compressive Strength of Lime-RHA Mortars Having Different Mix proportions and Mixing Methods for Lime Type D.

Mix Proportions (Lime+RHA):Sand	Mixing Method	Water/ (Lime+RHA) *	Saturated Density Kg/m^3	Compressive Strength (MPa) Age at Test 3Days	7Days	28Days	90Days
(0.25+0.75):2.75	Inter.	0.73	1967	5.22	9.55	14.50	15.49
(0.33+0.67):2.75	Inter.	0.72	1980	5.33	9.90	14.72	17.39
(0.50+0.50):2.75	Inter.	0.71	1997	4.23	9.08	12.78	14.17

* Flow is 110 ± 5%.

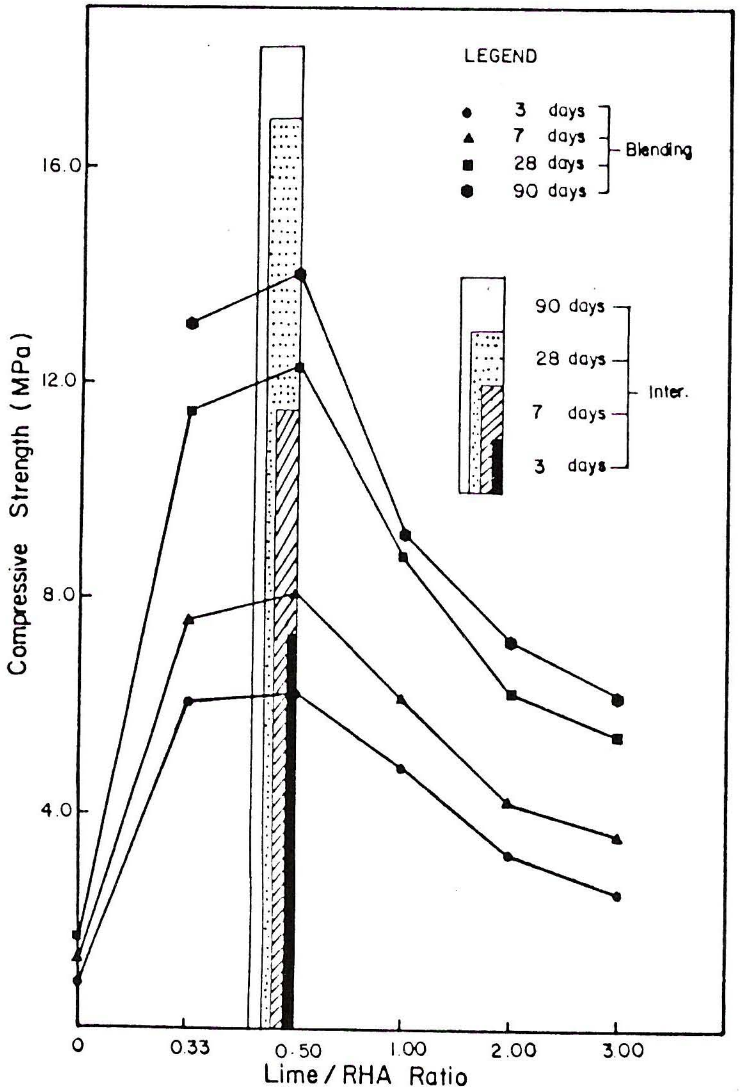

Fig. 1- Variation of Compressive Strength of Lime - RHA Mortars with Lime Type A

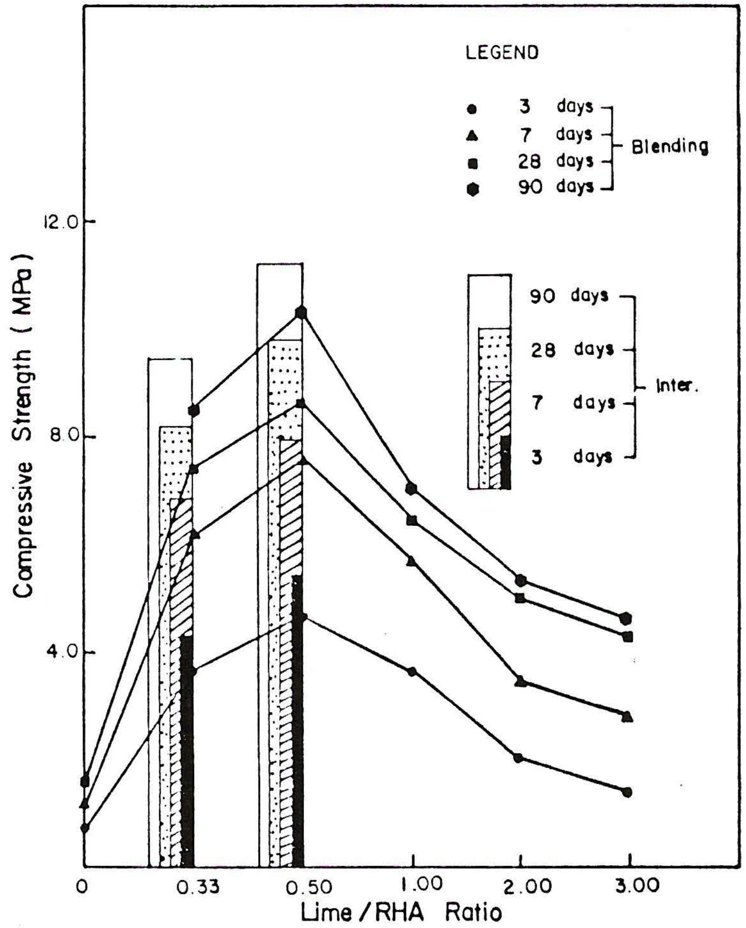

Fig. 2- Variation of Compressive Strength of Lime - RHA Mortars with Lime Type B

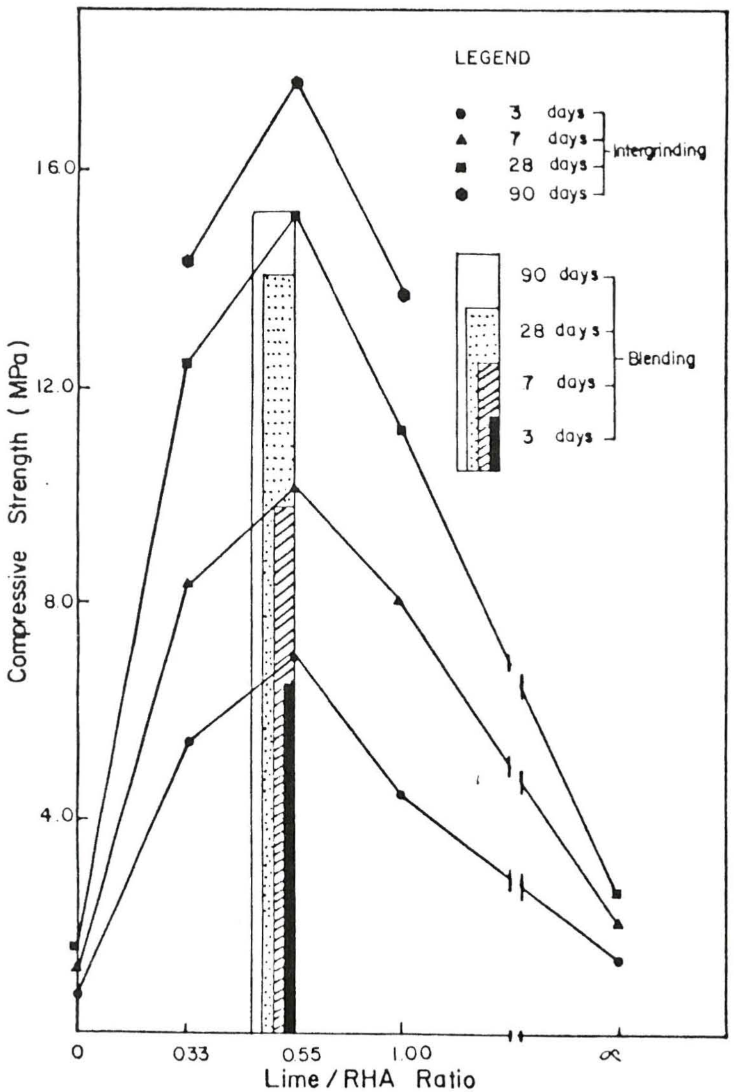

Fig. 3 - Variation of Compressive Strength of Lime - RHA Mortars with Lime Type C

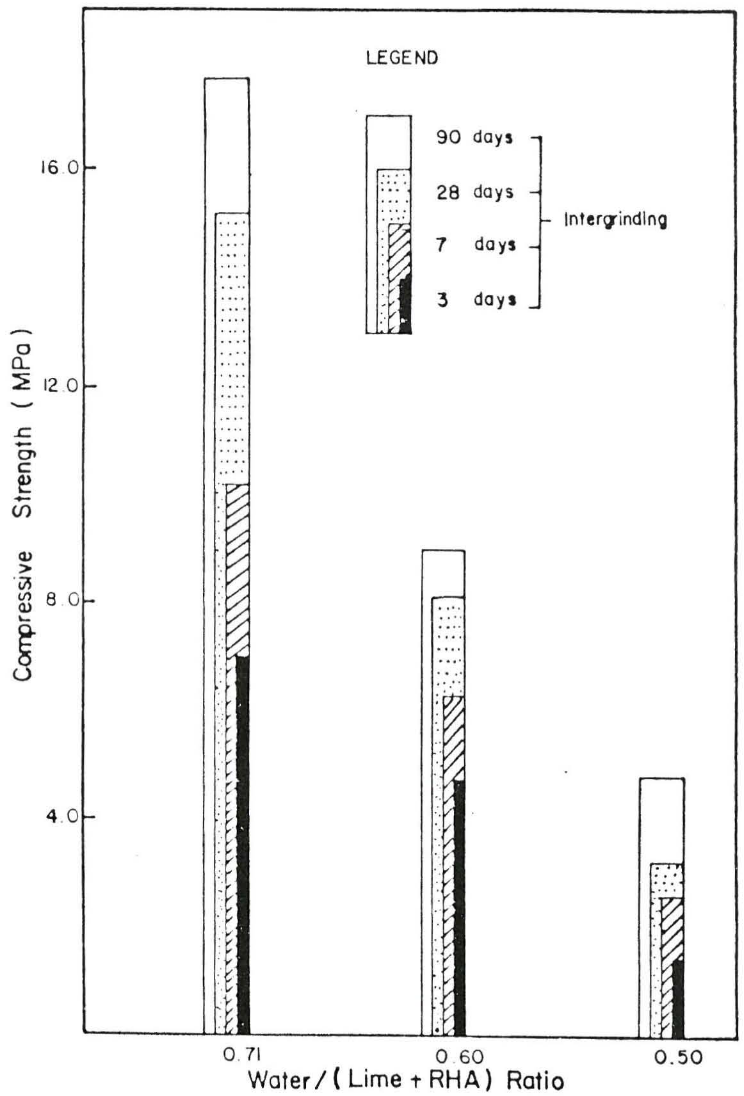

Fig. 4 - Variation of Compressive Strength of Lime-RHA Mortars (1:2) with Lime Type C Having Different Water / (Lime + RHA) Ratios

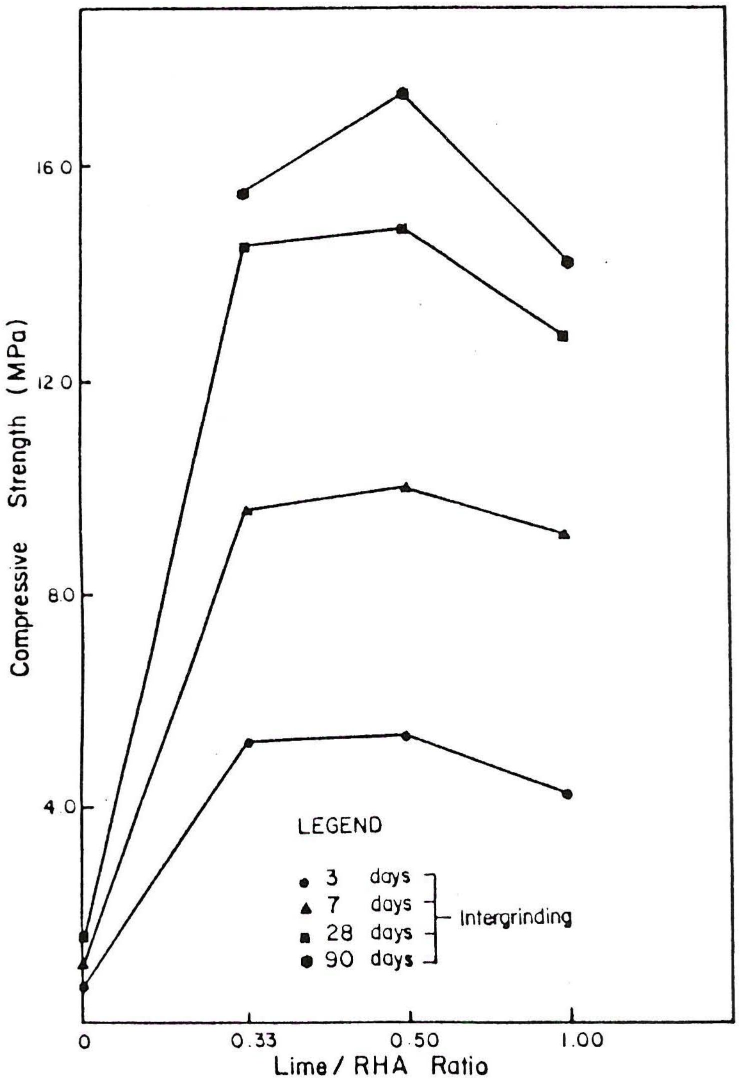

Fig. 5 - Variation of Compressive Strength of Lime - RHA Mortars with Lime Type D

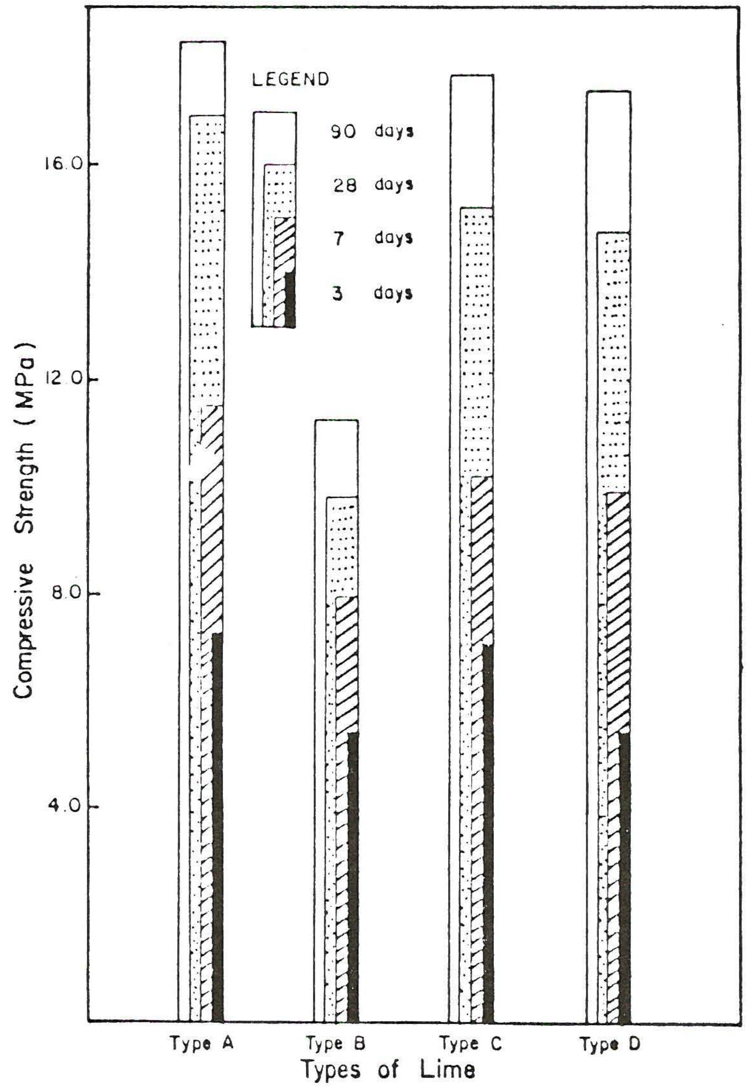

Fig. 6 - Variation of Compressive Strength of Lime - RHA Mortars (1:2) Containing Different Types of Lime