EXPLIOTING HUGE NATURAL RESOURCES OF LIME IN PAKISTAN FOR CONSTRUCTION INDUSTRY

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ABSTRACT

Naturally occurring lime in form of calcium carbonate is abundantly available in our country and elsewhere in the world. Its use has not been efficiently made locally in construction perhaps due to lack of understanding of its properties in its different forms. A locally available finely divided hydrated powdered lime of type-S has been studied for its use in concrete. In this paper, behavior of lime modified concrete in comparison to normal concrete having same mix proportions, aggregates, net water-cement ratio and similar curing conditions has been studied in short term upto the age of 56 days during which the specimens were subjected to normal water curing method. Tests were carried out for compressive strength at 3, 7, 14, 28 and 56 days, 24 hours %age water absorption at the age of 56 days and durability (resistance of concrete against N/2 solutions of both nitric acid and hydrochloric acid for 28 days) of concrete were carried out at the age of 56 days.

It was seen that the compressive strength of concrete modified with lime was less than the normal concrete. But so far as the durability and %age water absorption are concerned, Lime played an important role and 24 hours %age water absorption decreases with increase in lime as a cement replacement in concrete. It is recommended for durability purposes that 20% replacement of lime with cement was more effective in concrete than with 40% for the mixes investigated. The purpose of this investigation was to apprise the Engineers and the Architects of Pakistan of the potential and economy of this type of lime when used in mortars and concretes.

Keywords: Lime, Modified concrete, Curing method, Compressive Strength Durability of concrete, Acid resistance, Chemical resistance, %age water absorption.

INTRODUCTION

It is well known that modification of construction materials always aims at some predetermined and carefully selected objective/(s). The choice of admixtures to be used also depends upon the objective/(s) of modification which may either be for strength, architectural finishes, concrete conveyance, placing, permeability, durability or a combination of these.

As reported by ACI committee 212 in its report on “Guide for use of Admixtures in Concrete”, finely divided mineral admixtures include hydrated powdered lime, ground quartz, ground lime stone, betonite and talc. If concrete aggregates are deficient in fine particle sizes particularly those passing sieve 200, the use of finely divided mineral admixtures can reduce

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bleeding and segregation and increase in strength while reverse may also be true if these are used for concrete aggregate not deficient in fine aggregates in said range suggesting that its use should be made under supervision of a good material engineer.

Choosing reduction in permeability of concrete, lime has been used for the purpose as well as for cement replacement. There are many misconceptions about form of lime to be used in construction. For use in mortar/concrete, lime was produced by heating calcium carbonate (lime stone, chalk, shells and corals etc) in kiln to a temperature of approximately 900ºC.At this temperature, CO_2 is driven off and calcium carbonate changes to calcium oxide (quick lime) due to calcinations process. Lime can be used in different forms all originating from quick lime (CaO).Water and quick lime are combined to get hydrated lime which is then ground. If excess water is used, a colloidal gel is formed called “lime putty” and it does not set under water. There are four types of hydrated lime according to ASTM C-207,viz, type-S, type-SA, type-N and type-NA. In this study, type-S hydrated powdered lime has been used.

Hydrated lime in concrete is basically used to reduce the permeability of concrete by filling the pores in concrete. It improves cohesion and achieves economy through cement replacements. It can also be used in hot weather concreting. Its possible uses in mortar may include canal lining, slab screeds and mortars plasters to achieve economy and energy efficiency and in concrete subjected to chemicals with pH value in acidic range. Calculations of mix proportions for mineral lime modified concrete were carried out in accordance with ACI 211 [4]. Its use is basically recommended in mortars where its performance is excellent.

USES OF LIME

Different forms of lime find a variety of applications. There are many misconceptions about uses of hydrated lime in construction industry and valuable research works all over the world on hydrated lime have proved it to be an important admixture in the construction industry. Lime can be used both in mortars and concretes for a number of useful purposes. Lime imparts a high water retentivity to concrete. Some researchers have stated that bond strength also increases by using hydrated lime in concrete. Use of lime in mortars is highly desirable as it increases the strength significantly. Hydrated lime slightly decreases plasticity and workability of concrete. It imparts ease of retempering, high water retentivity, resistance against efflorescence, high sand carrying capacity and more flexibility under stress, more bond strength and autogenous healing to the mortars. Also lighter and colored mortars can be made by using hydrated lime alongwith a suitable pigment.

The other uses of lime [1,2,3] include soil modification and stabilization, specially in pavements, environmentally friendly construction, papermaking, production of chemicals (sodium alkalis, calcium carbide, calcium hypochlorites, citric acid, petro-chemicals, refractories, sugar refining, glass making, softening of drinking water, sewage treatment, agricultural fertilizers, fungicidal and insecticidal action, steel fluxing, bleaches, separation of cream from whole milk and in handling chicken litter etc.

In construction industry, use of hydrated lime alongwith fly ash is beneficial in terms of higher strengths and modulus of resilience.

CASTINGS

In order to study the parameters mentioned above for both normal (control) and lime modified concretes, the castings were made using both conventional 1:1.5:3 and 1:2:4 concrete mix proportions by weight having net water-cement ratio (W/C) of 0.6 at a room temperature of 34^0C and relative humidity of 55 %. Locally available Haro sand with a fineness modulus of 2.60 on ASTM Sieve 100 (BS sieve 100) and Margallah crushed stone (3/4"(19.5mm) down lime stone or calcium carbonate) having a fineness modulus of 6.6 on sieve 100 were used. Lime was added to the mixes of concrete at cement replacement doses of 20% and 40% in the light of ACI-211 [4]. Details of various types of modified concretes can be seen elsewhere [6,7,8)

The castings included 100x100x100 mm (4"x 4"x 4") cubes for compression testing and 50x50x50 mm (2"x 2"x 2") cubes for %age water absorption and durability tests. The coarse aggregates had an apparent specific gravity of 2.63. Coarse aggregates comprised crushed stone (3/4" or 19.5mm down). Fine aggregates consisted of Haro sand having a fineness modulus of 2.6.Cement, lime and sand were mixed in the presence of 50% water content then coarse aggregates and remaining water content was added. Total mixing time was about 4 minutes. Table 1 and 2 give the bulk densities of constituent materials and workability test results respectively.

Table-1: Bulk Densities of Constituent Materials

Material	Loose State (Kg/m^3) / (lb/ft^3)	Rodded State (Kg/m^3) / (lb/ft^3)
Haro Sand	1433.8 / 89.61	1586.0 / 99.12
Coarse aggregate (19 mm down)	1418.3 / 88.64	1595.6 / 99.72
Cement	1435.4 / 89.71	--
Lime	649.8 / 40.61	--

Table-2: Results of Workability Test.

Type of test	Type of mix	W/ C ratio	Normal concrete	20% modified concrete	40% modified concrete
Slump test (mm) / (in)	1:1.5:3	0.6	178/7	178/7	152/6
	1:2:4	0.6	32/1.25	6.4/0.25	0
Compacting factor test	1:1.5:3*	0.6	1.0	1.0	0.97
	1:2:4	0.6	0.9	0.856	0.85

* The slump of mix is so high that its compacting factor is almost equal to 1.

CURING OF SPECIMENS

For curing, all the specimens were kept in water for 28 days after demoulding at the age of 24 hours. After that, they were taken out of water and kept at normal laboratory conditions and tested at specified ages. Table 3 gives the results of compressive strength of cubes at different ages.

Table-3: Compressive Strength Results on 4”x4”x4”Cubes at age of 28 Days

Type of Mix	Time (Days)	Normal Concrete (MPa) / (psi)	20% Modified Concrete (MPa) / (psi)	40% Modified Concrete (MPa) / (psi)
(1:1.5:3)	3	14.22 / 2065	9.64 / 1400	7.95 / 1155
	7	17.60 / 2555	14.46 / 2100	11.57 / 1680
	14	21.46 / 3115	17.36 / 2520	13.50 / 1960
	28	25.56 / 3710	18.80 / 2730	15.91 / 2310
	56	31.83 / 4620	26.52 / 3850	23.15 / 3360
(1:2:4)	3	18.34 / 2660	13.26 / 1925	10.61 / 1540
	7	21.46 / 3115	15.19 / 2204	13.02 / 1890
	14	23.39 / 3395	16.15 / 2345	14.95 / 2170
	28	27.92 / 4050	19.77 / 2870	16.88 / 2450
	56	31.83 / 4620	27.00 / 3920	25.56 / 3710

Table-4: Results of 24 Hour % Water Absorption Test at Age of 56 Days

Type of mix	24 hours %age water absorption		
	Normal concrete	20% modified concrete	40% modified concrete
1:1.5:3	4.89	3.92	3.05
1:2:4	3.98	3.41	2.96

These Strength ~ Age relationships are shown in figures 1 and 2

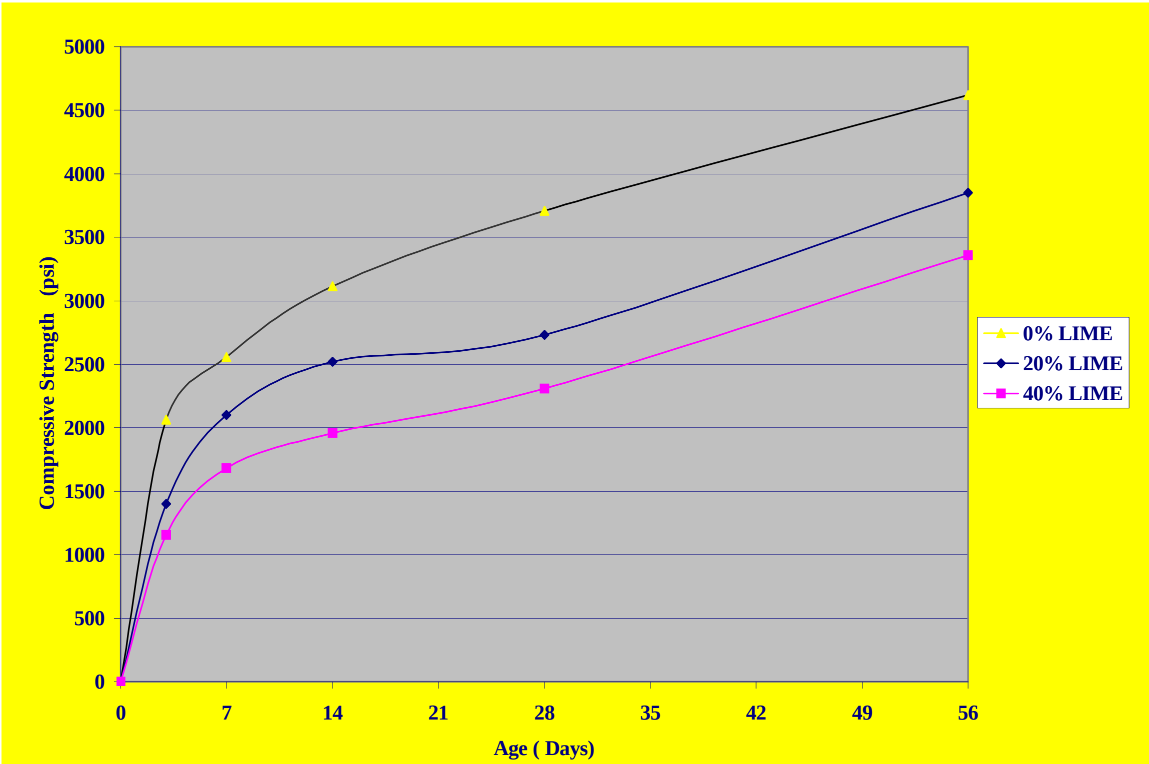

Fig. 1 Age ~ Strength Relatiomship [1:1.5:3 Mix]

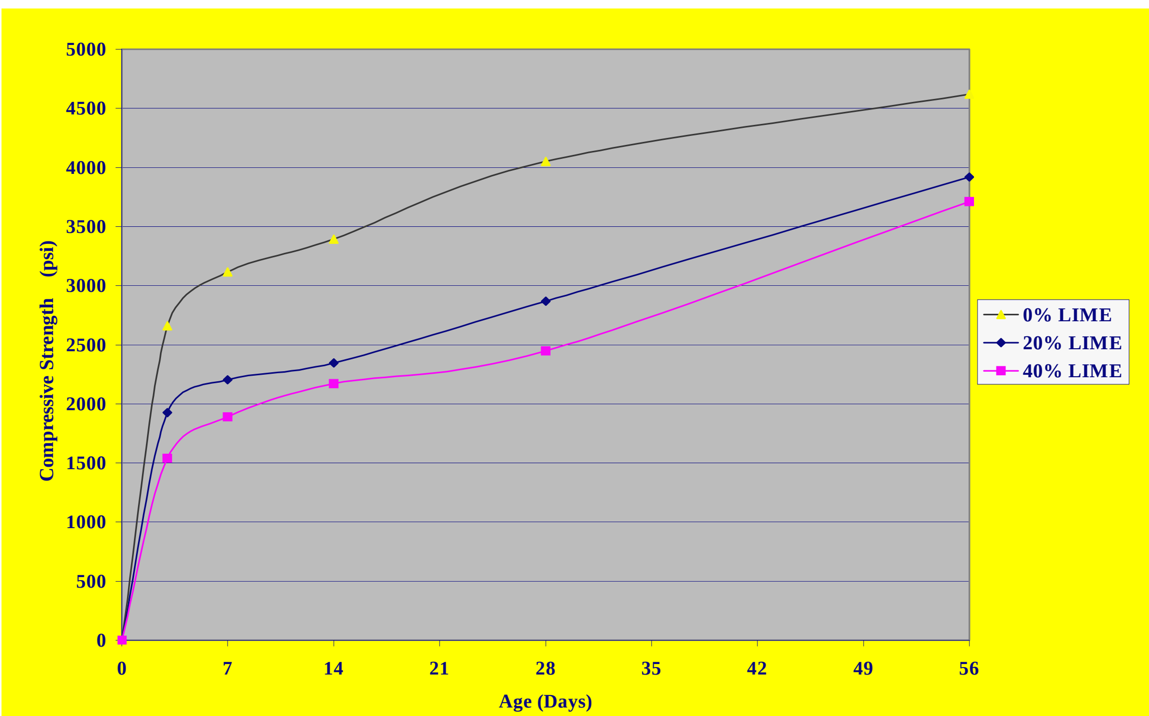

Fig. 2 Age ~ Strength Relatiomship [1:2:4 Mix]

Because concrete has pH values in the alkaline range so it was recommended in literature [9] to test its durability for chemical resistance against acids which were selected considering the results of an earlier investigations by some researchers. The reagents were HCL and HNO_3. Table 5 gives the details of commercially available acids used in the investigation.

Table-5: Properties of Commercially Available Acids used in Investigation

Type of test solution	Density (g/cc)	Purity (%)	1 N Solution of 100% strength (g/l)	1 N Solution of given purity (g/l)	N/2 Solution of given purity (g/l)
HCl	1.14	28.61	36.5	127.58	63.79
HNO_3	1.39	67.18	63	93.78	46.89

In chemical resistance tests specimens of the normal and modified concretes discussed in earlier investigation [ ] were treated by N/20 and N/10 acid solutions first which resulted in no appreciable weight and volume losses. Therefore it was decided to test them for N/2 acid normality. It was observed that a strong chemical reaction took place immediately after acid solutions came `into contact with two different types of concrete specimens and CO_2 was liberated after observing severe efflorescence for N/2 Normality of acids only. Tables 6 gives the weight loss after 28 days treatment with the above mentioned reagents when the age of specimen was 56 days.

Table-6: Weight Loss of Specimens after 28 Days Immersion in various Reagents at the Age of 56 Days.

Reagent	Type of mix	Strength of solution	Type of concrete	Initial weight (grams)	Dry weight after 28 days (grams)	Weight Loss (%)
HCl	1:1.5:3	N/2	Normal	304	261	14.27
		N/2	20% modified	274	228	16.71
		N/2	40% modified	350	288	17.63
	1:2:4	N/2	Normal	288	260	9.62
		N/2	20% modified	281	258	8.32
		N/2	40% modified	271	250	7.84
HNO3	1:1.5:3	N/2	Normal	298	266	10.91
		N/2	20% modified	311	281	9.68
		N/2	40% modified	308	270	12.54
	1:2:4	N/2	Normal	301	256	14.85
		N/2	20% modified	289	253	12.32
		N/2	40% modified	285	236	17.33

pH value changes within reagent solutions during a weeks' use in a treatment cycle of 28 days have also been monitored by using pH sticks. No pH changes in salt solutions could be observed during a week. HCL showed low weakness and HNO_3 showed more weakness in terms of an increased pH value. Table 7 shows the corresponding values.

Table No 7 pH Variations for one Weekly Change of Reagent

Reagent	Type of mix	Type of Concrete	Value at Day 1	Value at 28 Days
HCl	1:1.5:3	Normal	1	5
		10 %	1	5
		20%	1	5
HNO_3	1:1.5:3	Normal	1	4
		10%	1	5
		20%	1	5
HCl	1:2:4	Normal	1	4
		10 %	1	5
		20%	1	4
HNO_3	1:2:4	Normal	1	5
		10%	1	4
		20%	1	5

CONCLUDING REMARKS

1. Modification of concrete with lime results in economy and reduced permeability.
2. The compressive strength of concrete decreases with an increase in %age of Lime for the materials and mixes used. But at the age of 56 days and beyond difference between compressive strength of normal and modified concrete is much less than it is at the age of 7 days for both mix proportions which shows that long term strength of such modified concrete may be almost equal to that of control concrete.
3. 24 hours %age water absorption of concrete reduces with increase in %age of Lime in concrete. This trend is same for both mix proportions (1:1.5:3 and 1:2:4) investigated.
4. Full weight loss in acid resistance tests is less for concrete having 20% lime than it is for 40% replacement of lime with cement. This trend is same for both mix proportions investigated.
5. HCl proves to be stronger acid than HNO_3 because it causes more loss in weight than HNO_3. Therefore, concretes/mortars subjected to HCL spills are attacked more.
6. Workability of concrete is reduced to some extent when lime is added to it. It can be compensated by using appropriate plasticizers.
7. Use of this type of lime is more suitable and economical in mortars.

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SELECTED REFERENCES

1. Boynton,R.S "***Chemistry and Technology of Lime and Limestone***". Second Edition 1980, John-Willy and Sons.USA.
2. Cowper,A.D "***Lime and Lime Mortar***", Don Head Publishing Ltd.Jan 1998.
3. R,Klus and Wynne,C "***Building that Changes the World***" Pestel Publishing Sept 1999.
4. ACI Committee-211 "Selecting the normal weight concrete mix proportions"
5. ***ACI Committee-212***, Admixtures in Concrete, Publication SP-40 and SP- 58, American Concrete Institute,Detroit,1973.
6. Rizwan S.A., Ahmad,A and Ahmad,K**" A Comparative study of modified concretes"**. Proc 68th Annual session of Pakistan Engineering Congress, Vo68, Jan 19-21, 2001,Lahore, Pakistan Paper No. 621 pp 313-323
7. ACI Committee 548, "**Polymers in Concrete**", Publication SP-40 and SP-58, American concrete institute, Detroit, 1973.
8. Ohama, Y., **"Polymer-Modified Mortars and Concretes,"** Concrete Admixtures Handbook, Edited by Ramachandran, V.X., Noyes Publications, Park Ridge, NI, 1984, pp.407-410.
9. Ohama, Y., and Miyake, M. :**Resistance of Polymers modified Concrete to Inorganic Acids"** National Symposium on Binder Economy and Alternate Binders in Road and Building Construction,1981, Japan.

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- British Lime Association, http://www.bla.com
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