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Evaluation of Lime for Use in Mortar

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Abstract
Lime has been used in India as material of construction from very ancient days. The manner in which lime structures about 2000 years old have withstood the ravages of time bear irrefutable evidence to the durability of lime mortars. Lime mortars were the mortars of very recent years – used until the twentieth century. Although they are almost forgotten today, they still remain a viable and important construction method [1]. There is something about this material that remains just as valuable today as it was 150 years ago [2]. The lime belt of Vidarbha area is not of industrial grade. To use for construction purpose it needs some improvement and alteration in the ingredients. This calls the development of an alternative approach to make it suitable for construction in large extent.
Keywords*:* Lime,limestructures,durability,limemortars, construction material.

I. Introduction

Lime

There are two basic types of lime for traditional lime mortars

1). Non hydraulic lime mortars - Those that set and harden by the reaction with air. 2). Hydraulic lime mortars - Those that set and harden by the reaction with water [3]. The non-hydraulic lime mortar sets very slowly through reaction with the carbon dioxide in air. The speed of set can be increased by using impure limestone in the kiln, to form a hydraulic lime that will set on contact with water. Alternatively a pozzolanic material such as Fly Ash, calcined clay or brickdust may be added to the mortar mix. This will have a similar effect of making the mortar set reasonably quickly by reaction with the water in the mortar.

One of the greatest benefits of lime mortar is its recyclability. After a building has served its purpose, lime mortar can easily be removed from brickwork, unlike Portland cement which is extremely difficult to remove. After it has been removed lime is very easy to recycle because the mortar has the same chemical makeup ($CaCO_3$) as the raw materials from which it was derived. The mortar can go straight to the kiln. Lime mixed with cement is much more difficult to recycle. Portland cement is an excellent material for mass concrete and engineering structures but the last 50 years have shown that it is not the greatest for mortars, plasters and renders as it is too hard, too rigid and too permeable. For these reasons, many people think that lime mortar will be a better fit for modern mainstream buildings and structures. The combination of lime with modern technologies and higher demand could cause the market for lime mortar to take off. The future of lime mortar is far better than Portland cements. The introduction of carbon tax, or legislation setting targets for recycling of buildings could make Portland cement impractical and therefore make lime mortar the better choice [4]. "The future is green, lime green" as Prichett would put it. Limes are produced at a temperature of around 900 to 1100 °C, Portland cement is produced at 1200 to 1500 °C. That means that more energy is required to produce a metric ton of Portland cement than a metric ton of hydraulic lime, thereby increasing CO_2 emissions. Portland cement does not just produce a little more CO_2 emissions than lime mortar, but Portland cement production is responsible for 1500 million metric tons of CO_2 each year that is approximately 10 percent of all worldwide CO_2 productions. So with the introduction of carbon tax or legislation setting targets for recycling buildings, lime mortar has a great chance to over take the mortar market in the future if not soon. In addition to the low level of CO_2, emissions by lime mortar compared to Portland cement, buildings constructed with lime mortar can be altered easily and bricks/stones reused. Indeed the building can be reclaimed entirely if a building has completed its useful life. This is why architectural salvage yards have second-hand bricks to sell. Bricks bound together with cement mortars, however can generally never be recycled except as hardcore. This is especially pertinent to modern commercial buildings, which may be demolished after only a few years [4].

Lime mortars are more liable to settlement and movement associated with seasonal changes in ground conditions [5]. Other advantages of using lime mortars are lime binders can be durable and have stood the test of time, limes allow moisture movement and lime also contributes to a healthy environment [6].In many places lime is more environmentally friendly.

Portland cement is a valid choice for certain instances but it requires more energy for production. Lime mortar is fully recyclable and soft which makes it good for restoration. It also requires less energy for production and therefore emits less carbon dioxide [1].

High energy costs and CO_2 emissions associated with OPC production in the last few decades have prompted the use of cement replacement materials. Pozzolanic material, fly ash combined with lime can be used as partial or complete substitutes for OPC [7].

Lime mortar is softer than cement mortar, allowing brickwork a certain degree of flexibility to move to adapt to shifting ground or other changing conditions. Cement mortar is harder and allows less flexibility. The contrast can cause brickwork to crack where the two mortars are present in a single wall.

Fly ash

Fly ash is a pozzolanic material containing reactive silica and/ or alumina which on their own have little or no binding property but, when mixed with lime in presence of water, will set and harden like cement. They are important ingredients in the production of an alternative cementing material to ordinary Portland cement (OPC).

Although the chemical content of a raw material will determine whether or not it is pozzolanic and will react when mixed with lime or OPC, the degree of reaction and subsequent strength of the hydrated mixture cannot be accurately deducted from just the chemical composition (except for a small number of known pozzolanas). In most cases no direct correlation can be found between chemical content and reactivity. Other characteristics of the pozzolana also affect its reactivity, such as fineness and crystalline structure.

It is also argued that because pozzolanas are used for a variety of different applications, such as in mortars, concretes, block manufacture, etc, and mixed with

a variety of other materials such as lime, OPC, sand, etc, (which can also radically affect the reaction of the pozzolana), then perhaps it is better to develop a test and procedure to determine the desired properties of the mixture in the context for which it is intended. This may provide valuable information for specific project applications and can also help to determine the general characteristics of a pozzolana for cases where the application of the pozzolana is not specified.

Fly ash is widely available in huge amounts in our country. The reactivity of these ashes depends on the chemical composition and on several factors involved in the burning process. A combination of lime and / or OPC and the above mentioned reactive pozzolan can react as a “blended hydraulic lime” suitable for use as a mortar binder for masonary constructions or as a blended cement for concrete production.

A thoroughly blended lime–pozzolan binder (LPB) is used as an active mineral addition to the binder in concrete. The very fine lime particles having size between 0.1 and 10 µm can fill the gaps between OPC grains, while the larger pozzolan particles having size between 10 and 100 µm can fill the gaps between fine aggregate grains. The result is much denser matrix. The addition of lime [$Ca(OH)_2$] during concrete mixing also increases the Ca^{2+} and OH^- ion concentrations, which results in a better and faster hydration of both OPC and pozzolans. The use of LPB as an active addition in some concretes could contribute to lowered product cost with equivalent strength and durability performance through the use of less cement [7]. The use of less cement and larger amounts of lime- pozzolanic binder combined with highly active dispersing agents seems to be an attractive way to improve the environmental profile of concrete. There are now a wide variety of blended cements available. The inorganic materials that are used to reduce cement quantities can be blended and/or ground intimately with clinker and/or cement during manufacture, or blended while preparing the concrete or mortar. The most commonly used materials are fly ash, granulated slag, micro silica (silica fume), various natural and calcined pozzolans [8,9,10,11]. In concrete, pozzolans are added to reduce cost and to improve long term strength and durability of the hardened mass [12,13]. The properties of concrete with large volumes of pozzolan can be improved by replacing cement with lime–pozzolana blends (LPB) rather than with pozzolan alone. A pozzolan for use in an LPB must be highly reactive and finely ground [14]. Mixing and grinding the pozolan with lime should be done until the fineness of the powder equals that of OPC .Being softer, lime is more finely ground than the pozzolan [15,7].

Lime fly ash mix

For Lime-Pozzolana mix, of Vidarbha area, as a mortar for construction neither the standard test results and references have been produced nor it is available with the Engineers for ready reference. Whereas such material needs actual data of performance, durability and strength of the product as per the requirement of BIS when it is used in construction work. Hence lime-pozzolana mix could not get popularized and could not be accepted by technical persons and mass consumers for the use in construction activity.

The evolved knowledge of this research will be utilized for the creation of awareness amongst consumers and to rely on the test results.

Lime-pozzolana mixture which essentially, a mixture of lime and pozzolana could be used as an alternative cementing material to ordinary Portland cement for certain categories of work like masonry mortar and plaster, foundation concrete, leveling course under floors, road and airfield bases, pre-cast building blocks (including light weight blocks), paving blocks, soil stabilization and filler in water bound macadam in road construction. Hence the production and marketing of properly mixed, ready to use and properly packaged dry mixtures of lime-pozzolana of specified strength would go long way in making available a standardized product that could be safely used in construction as a substitute for Portland cement in places mentioned above [16].

II.Plan Of Research

A proper study is required to get improved material mix of lime and pozzolana from the locally available raw materials (especially from Vidarbha area) and to get the required test results of the product so that technocrats can use the product with reference to those results. It is to be noted here that the lime, which is available in Vidarbha area, is best suited for construction purpose after some modifications and improvement. It needs some improvement and alternative approach to make it suitable for construction activity.

Potential application of cement-fly ash aggregate, lime-fly ash aggregate and lime-cement-fly ash aggregate mixtures in construction will be reviewed. Engineering properties such as moisture-density relationship, compressive strength, flexural strength, dry shrinkage. and durability will be summarized on the basis of studies. Further research will be conducted to evaluate durability of such materials under regional weather conditions.

III.Method Of Analysis And Tests

The following tests are the example of Standards developed in our country to allow accurate characterization of pozzolanic materials. Other countries published such Standards and these should be referred to wherever applicable.

There are also even more sophisticated procedures used, such as x-ray diffraction or electron microscopy to determine whether the structure of a pozzolana is amorphous(more reactive with lime) or crystalline.

1. Chemical analysis.
2. Fineness
3. Soundness
4. Initial and final setting time
5. Lime reactivity
6. Compressive strength
7. Transverse strength
8. Drying shrinkage
9. Permeability
10. Reduction in alkalinity and silica release Specific gravity

All tests were carried out as per the Bureau of Indian Standards. Relevant Methods and Specifications were referred for each test.

IV.Experimental Results

The local materials from Vidarbha region of Maharashtra state of India, which are lime from lime-belt of Yavatmal district, fly ash from thermal power station of Nagpur district and lime-fly ash mix, were tested for Physical and Chemical properties as per the respective codes of Bureau of Indian Standards Institution.

The test results for Physical and Chemical properties of Lime, fly ash and Lime-fly ash mix are shown in Table-1 to Table-6

SN	Characteristics	Class		Test values	Method of test refer to
		B	C		
1	2	3	4	5	6
1	Calcium and magnesium oxides, percent Min (on ignited basis)	70	85	78.4	IS:6932(Part1)1973
2	Magnesium oxides; percent, (on ignited basis), Max Min	6 -	6 -	4.5	IS:6932(Part1)1973
3	Silica,alumina and ferric oxide percent, Min	10	-	7.24	IS:6932(Part1)1973
4	Insoluble residue in dilute acid and alkali,percent Max	10	2	8.24	IS:6932(Part1)1973
5	Carbondioxide, percent. Max	5	5	3.66	IS:6932(Part2)1973
6	Free moisture content; percent. Max	2	2	1.14	IS:1514-1990
7	Available lime as C_aO, percent. Min	-	75(on ignited basis)	74	IS:1514-1990

Table- 1: Chemical analysis of Hydrated lime sample

V. Conclusion

The result shows that lime-pozzolana cement, where the pozzolana is a fly ash should contain at least 50% hydrated lime (by weight) to get optimum performance. The pozzolanic reaction between $Ca(OH)_2$ and fly ash is a very slow process compared with the hydration of Portland cement. The pozzolanic reaction is much slower than the hydration of Portland cement. The un-reacted fraction acts as fine aggregates.

For any combination of materials, the optimum lime content value may vary with the source of lime and pozzolana to be used. Consider, however, that a rise in lime content higher than a specific optimum amount will increase the water requirement of the lime-pozzolana cement and lower the strength of the hardened paste. According to the experimental results and the theoretical analysis 50% hydrated lime mixed with 50% Fly ash is considered to be chosen as an optimum mixture for lime - fly ash for LP20 grade lime fly ash cement.

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S N	Characteristics	Class		Test values	Method of test refer to
		B	C		
1	2	3	4	5	
1	**Fineness** a)Residue on 2.36 mm IS Sieve,percent Max b)Residue on 300 micron IS Sieve,percent, Max c)Residue on 212 micron IS Sieve,percent, Max	Nil 5 -	Nil Nil 10	Nil 4 --	IS:6932(Part4) 1973
2	**Setting time** a) Initial set,Min, h b)Finalset,Max, h	- -	- -	4 hr 2 min 24 hr 10 min	IS:6932(Part11)1973
3	**Compressive strength** Min, N/mm^2 a) at 14 days b)at 28 days	1.25 1.75	- -	1.28 1.78	IS:6932(Part7) 1973
4	**Transverse strength** at 28 days.N/mm^2,Min	0.7	-	0.85	IS:6932(Part7) 1973
5	**Workability** bumps, Max	-	10	10	IS:6932(Part8) 1973
6	**Soundness**, Le Chaterlier expansion, in mm, Max	5	-	Nil	IS:6932(Part9) 1973
7	Popping and pitting	Free from pop and pits	Free from pop and pits	Free from pop and pits	IS:6932(Part10)1973

Table- 2 : Physical analysis of Hydrated lime sample

Table 3 : Chemical analysis of fly ash sample

Sr. No.	Characteristic	Requirement for grade 1 pulverized fuel ash	Test Values
i)	Silicon dioxide (SiO_2) plus aluminium oxide (Al_2O_3) plus iron oxide (Fe_2O_3) percent by Mass, Min	70.00	90.07
ii)	Silicon dioxide (SiO_2), percent by mass, Min	35.00	53.38
iii)	Magnesium oxide (MgO), percent by mass, Max	5.0	1.53
iv)	Total sulphur as sulphur trioxide (SO_3), mass, Max	5.0	0.73

v)	Loss on ignition, percent by mass, Max	5.0	0.22

Table 4 : Physical analysis of fly ash sample

Sr. No.	Characteristic	Requirement for grade 1 pulverized fuel ash	Test Values
i)	Fineness- specific surface by Blaine`s Permeability method in m^2/kg, Min	250	260
ii)	Particles retained on 45 micron IS sieve (wet sieving) in percent, Max	40	12
iii)	Lime reactivity- average compressive strength in N/mm^2, Min	3.5	6.55

TABLE 5: Chemical analysis of lime-Pozolana mix Sample

S N	Characteristic	Requir-ements	Test Value	Reference to method of test
i	Free moisture content, percent, Max	5	2.5	IS:4098-1983 Appendix A
ii	Free lime, percent, Min	22	34	IS 1514-1990
iii	Carbon dioxide, percent Max	5	4.85	IS:6932-1973 (Part 2)
iv	Sulphate content, percent, Max	3	0.5	I S:1727 – 1967
v	Magnesium oxide, percent, Max	8	1.7	I S:1727 – 1967

Table-6: Physical analysis of lime- Pozzolana mix sample

S N	Characteristic	Requirements types of mixtures		Test values for 50:50 lime pozolana mix	Reference to method of Test
		LP 20	LP 7		
i	Fineness, percent retained on 150 micron IS Sieve	15	--	14	IS:4031-1988 Part 1
ii	Setting Time Hours a)Initial, Min b)Final, Max	 2 36	 2 48	4Hr20 Min 24Hr35 Min	IS:4031-1988 Part 5
iii	Compressive strength, average compressive strength of not less than 3 mortar cubes of size 50 mm composed of one part of lime-pozzolana Mixture and 3 parts of standard sand by weight, N/mm^2 a) At 7 days, Min b) At 28 days, Min.	 1 2	 0.3 0.7	 0.67 1.71	IS:4031-1988 Part 7
iv	Soundness, mm, Max	10	10	1	IS:4031-1988 Part 3

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