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MULTIPLE USES OF LIME IN MEXICAN PUBLIC HOUSING: MORTAR, BLOCK, PLASTER, PAINT AND SOILS*

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Abstract

During the past few years, the Mexican government has increased the quantity of low interest loans available to low-income workers to purchase decent housing.

In the construction of this type of dwelling, special efforts are made to maintain low material costs without affecting the quality of the dwelling. As construction costs continue to rise, companies are looking for more creative ways to use building materials in order to be profitable in this market.

Lime plays an important role in this market. It can be used in the construction of these dwellings in soil stabilization, mortar for union bricks, production of block, renders, and lime paints.

Keywords

Mexico, limewash, stabilization, mortar, block, render, lime

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1 Introduction

Mexico is known for extensive use of lime in the construction of homes. Traditionally, home owners have built their own houses (self construction). Bagged hydrated lime has been used for a variety of applications when building these homes. Throughout the country, this product is sold by a wide range of building product distributors directly to the home owner.

In the past few years, the Mexican government has increased the quantity of loans available through the INFONAVIT* program for workers. These loans can be used to purchase low-income housing being constructed in new developments. The availability of these loans is changing the residential construction market. Instead of constructing their own home (self construction), low-income workers now prefer to borrow money to purchase low-income housing units that are better built and more attractive than traditional housing.

In construction of this type of dwelling, special care is placed in maintaining low costs of the materials used without affecting the quality of the dwelling. Due to the size of these projects, contractors are more sensitive about the types of materials used. Though the cost of the material remains important, the ability of the product to speed production is also considered. The following chart describes the principal differences between the traditional way of building and current low-income housing construction in Mexico.

Table 1 Characteristics of Home Construction Methods in Mexico

Self Construction	Low income housing
40 to 120 m^2	64 to 140 m^2
3 to 10 year building time	1 to 2 year building time
Room by room building	200 to 7000 homes
Family built homes	Large contractor built homes
No architectural involvement	Architect designed
Cheap and traditional materials	New and high-quality materials
Market decreasing	Market growing

With its low cost when compared against other construction materials and multiple beneficial applications, hydrated lime can play an important role in the construction of these low-income housing units. Lime is used in the construction of these dwellings as a raw material for soil stabilization, mortar for union bricks, production of block, exterior or interior renders, and lime paints.

This document examines current beneficial applications for the use of lime in Mexican housing construction.

2 Why is the Mexican residential market changing?

In Mexico, self construction has been the traditional way of building homes for many years. The absence of building regulations and urban programs have allowed people to construct homes without concern about the effect on the infrastructure of the community. See Figure 1. This caused a variety of problems in providing community utilities and services such as electricity, drinking water, roads, waste water collection and trash pick up.

The Mexican government benefits from the construction of planned low-income housing communities. These projects permit planning of efficient ways to deliver services to the residents. See Figure 2. In

some cases, communities can be constructed with commercial areas, schools and hospitals. This results in lower cost for government services, which has justified government financial support.

Figure 1 Self construction is not regulated

Figure 2 Example of a low-income housing unit development

3 Use of lime stabilization

Commonly, 200 to 7,000 low income housing units are built in each community. Where clay soils are present, the plasticity index (PI) must be measured. When the plasticity index is at least 10, according to the Atterberg limits; the soil can be stabilized with lime. This limit expresses the difference between the liquid limit and plastic limit in soils. In general, a PI less than12 means a low plastic soil, and a PI greater than 40 means a very highly-plastic soil (almost liquid). To determine lime demand, soil tests must be run at the site, such as the Proctor test to evaluate lineal contraction and the CBR test to evaluate compressive strength.

For soil stabilization in México, 3% to 6% by weight of lime is commonly added to the soil. The percentage of lime varies according to the strength required and the original characteristics of the soil. The exact percentage of lime is determined after testing with several percentages of lime added until the optimum characteristics are obtained.

All areas where low-income housing is going to be built are stabilized with lime. This includes land for roads, houses, common areas and commercial areas.

Lime stabilization is performed in two steps. The base and sub-base are each stabilized to a depth of 20 cm to form a final platform of 40 cm.

Once the appropriate proportion of lime is determined, there are two ways to perform the stabilization. The first option is to use bagged product. The number of bags and the distance required between bags is calculated to cover the area to be stabilized. The bags are placed on the ground and then opened by hand, as shown in Figure 3. The lime is then mixed into the soil with mechanical equipment.

Figure 3 Example of bag use in lime stabilization

The second option is to use a bulk lime product that requires less hand work. Bulk lime is typically used when the area to be stabilized is large.

The bulk lime is charged into the truck, which is equipped with two or three rubber flaps in the discharge area to help distribute the material across the land. See Figure 4. The lime is then mixed into the soil by a mechanical system.

Figure 4 Soil stabilization using bulk lime

Contractors may use either of these options, depending on the size of the project, cost, resources, expertise, etc. In both approaches, hydrated lime is commonly used, but quicklime is used during the rainy seasons.

Stabilization of soil with lime assures that the base for all construction is sound. At large housing developments, roads are stabilized first and then several platforms are stabilized to serve as the base for construction of groups of houses.

Unsuitable soils may create significant problems for structures and roads. Most of the sites where housing developments are being constructed were once agricultural lands. Use of lime to treat these sites is almost mandatory.

4 Masonry mortar

Most of the Mexican low-income housing units are made with red brick or block (Figure 5). Red brick is made of clay that is baked in hand-made kilns. The block is made with fine gravel and cement, which is vibrantly-compacted and ambient-cured. To construct walls with these bricks or blocks, lime-based mortars are widely used (Figure 6).

Hydrated lime is a low-cost component of mortar in Mexico. The use of hydrated lime also improves many characteristics of the mortar.

The beneficial properties of hydrated lime may be appreciated in both phases of mortar. The first phase begins after the mortar is mixed with water and becomes highly plastic. The second phase is when the mortar hardens after it cures.

Figure 5 Most of houses in Mexico are made of brick or block

Figure 6 - Lime-based mortar is widely used

In the first phase, hydrated lime improves workability and water-retention of the mortar. Mortars containing only cement are difficult to trowel. The enhanced workability of lime-based mortars provides better coverage of the masonry units. A mortar that fills joints completely produces more intimate contact with masonry units and enhances bond strength (Palmer 1935). Lime sticks to and works into the rough masonry surface. The use of lime optimizes mortar curing by providing water for cement hydration (if cement is present) or enhancing carbonation in lime mortars. Water-retentive mortars also provide good board life, which minimizes the need to re-temper the mortar. Mortars made with lime also increase sand yields and cover more area for less cost, as seen in Table 2.

Table 2 Sand carrying capacity -lime vs. cement mortar

PRODUCT	Kg.	SAND BUCKETS		RESULTS	
		Union Bricks	Interior Finishes	Union Bricks	Interior Finishes
CALIDRA 80% $Ca(OH)_2$	25	5.5	3.75	123.5 BRICKS	3.31 m^2
MASONARY CEMENT	25	2.5	2.5	59 BRICKS	1.80 m^2

In the hardened state, lime-based mortars have several benefits. Lime-based mortars have excellent bond strength (Matthys 1988, 1989). This is beneficial to resistance to water penetration through a masonry wall (Brown 1978). The strength of lime-based mortars is adjusted with portland cement. Portland cement offers excellent compressive strength and quick setting. In modern construction, both of these properties are important. By adjusting the amount of portland cement, a very strong or weak mortar can be obtained. A compressive strength of 35-70 kg/cm^2 is considered good**.**

Lime-based mortars gain strength over time by the reaction of hydrated lime with carbon dioxide. This reaction returns hydrated lime to its original limestone form. This reaction also provides the ability for the mortar to seal hairline cracks. This property, called autogenous healing, is created by carbonation of the exposed hydrated lime in the crack (Voss 1938).

5 Concrete block production

The common block used for building is made of fine gravelwhich has a size distribution between 2.0 and 10.0 millimeters, and cement. This mix produces a heavy and expensive block.

Hydrated lime can be a beneficial additive to the block. Dependent on the quality of the aggregate used, hydrated lime has been added to these masonry units up to a level of 30% by weight of the cementitious materials.

As seen in Table 3, substitution of hydrated lime for cement can be beneficial for the development of initial strength in these masonry units. The presence of lime assists in retention of water in the block to optimize development of cement strength.

An additional benefit gained by the inclusion of lime is that blocks containing lime can become stronger as they age, due to the carbonation reaction. Refer to Figure 7.

Table 3 Effect of hydrated lime addition on block compressive strength

Days	Compressive Strength (kg/cm^2)			
	0% lime	15% lime	20% lime	25% lime
3	119	124	167	155
7	148	137	175	171
14	164	164	184	185
21	178	202	201	192
28	195	214	214	215

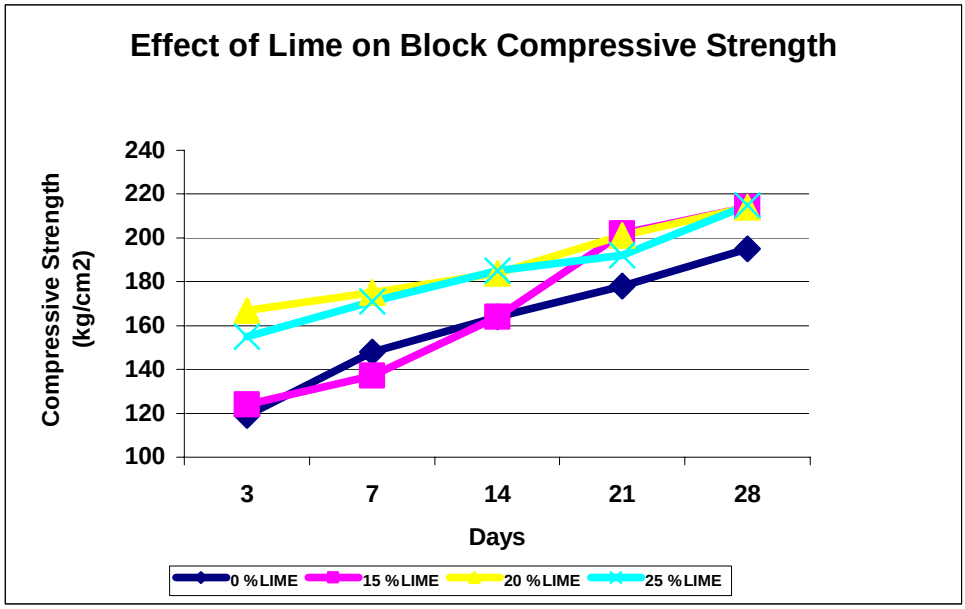

Figure 7 Block compressive strength

The addition of hydrated lime can potentially lower the weight of the block. Common concrete block measures 20 X 20 X 40 cm and weights 4.5 kg. The reduction in weight may be up to 10%, depending on the percent lime substitution.

6 Interior and exterior renders

Lime-based renders can be used on the interior and exterior of the building. See Figure 8. These renders are typically applied to either block, brick or poured concrete surfaces. The mix designs for interior work can range from lime and sand to lime with either gypsum or cement. Lower strength mixes often include fibers.

The most common mix design for interior render is one part cement to two parts lime to six parts sand. Application is generally in two coats.

Mix designs for exterior renders range from lime/sand mixes to blends of cement and lime. A common mix for exterior applications is 1 volume of cement, 1 volume of lime and 4 volumes of sand.

Renders made with only gypsum or only cement are expensive and have poor workability. Because neither product has good water retention, strength development can be erratic. Because of their initial strength development, however, both of these materials are useful additives to mixes containing lime. Many of the advantages of the use of lime in mortars are also seen with renders. The water retention of lime enhances workability and initial strength development of the render. The ability of hydrated lime to react with carbon dioxide also provides long-term strength development and the ability to heal hairline cracks through autogenous healing. The addition of lime to cement has also been shown to increase the vapor permeability of the wall (Jacob et. al., 1989).

Figure 8 – Lime Render

7 Lime paints

Paint made with hydrated lime offers several advantages:

- It is an environmentally safe product.
- It is an economical option and provides many possibilities of color and texture.
- Lime paints have good vapor permeability.
- As the hydrated lime carbonates, the paint forms a thin surface of limestone that protects the whole structure.
- Lime paint provides a disinfecting property due to its high pH.

These are just some reasons why lime is a very good option in wall painting**.** The formulation for a typical lime paint in Mexico is provided in Table 4. The sealant and sodium chloride are added to enhance durability of the paint.

The paint is prepared by first adding hydrated lime into a bucket containing water. The sodium chloride is then added and mixed well. The sealant is then added and mixed until a homogenous mix is achieved. Finally, the pigment is added and mixed to achieve consistent color.

The paint is applied with a 12 cm square head brush in three layers. This type of painting typically lasts about two years.

Table 4 – Lime Paint Formulation

Component	Amount
Hydrated Lime	9 Kg
Sealant	1 Liter
Sodium Chloride	200 g.
Mineral Pigment	100 g.
Water	19 Liters

8 Conclusions

Lime has historically been an important component of the Mexican residential construction market. Despite the shift to a different type of construction, lime will continue to play an important role in the construction of low-income residences in Mexico. The following conclusions can be made:

- There has been a shift in the residential construction market from self-construction of homes to the purchase of low-income housing. Government loans for these purchases are assisting this change.
- The actual demand and deficit in this sector promote the development of new technologies that are able to use lime in several steps of construction. Lime is used in soil stabilization, concrete block production, mortars, renders and painting in Mexican residential construction.
- The most important advantage of the use of lime is the lower total cost of each housing unit. For example, contractors can lower their mortar costs between 5% and 8% by using lime-based mortars.
- Hydrated lime enhances the workability of mortars and renders through its ability to retain water. Water-retention is also important for development of strength of the cement- based mixes.
- Carbonation of hydrated lime provides long-term strength development through the generation of limestone. This chemical reaction also provides the ability for lime-based mixtures to "heal" through a process called autogenous healing.
- Lime-based mixes have the ability to provide excellent bond strength to masonry surfaces. Enhanced bond strength minimizes water penetration into these structures.
- People prefer the use of traditional materials in their buildings. Lime-based systems are environmentally-friendly.

Though the traditional method of constructing homes in Mexico is changing, the use of lime continues to be beneficial. Lime is used in a wide range of applications in construction of low-income housing in Mexico.

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