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Lime Mortar

Humans have utilized various types of construction as long as they have been in existence. Mortars enabled man to expand beyond rudimentary survival spaces. The Ancient Egyptians were the first to use lime mortars. They used them to cover the pyramids. The Romans expanded the idea of lime mortar by creating hydraulic limes, limes that set with water. They were used in everything from the coliseum to aqueducts. The Great Wall of China was also built with lime mortar. Lime mortars were the mortars of very recent yesterday - used until the twentieth century. Although they are almost forgotten today, they still remain a viable and important construction method.

There are two types of lime mortar: non-hydraulic lime, and hydraulic lime. The former is made from pure calcium carbonate (limestone being the most common source, chalk being another). The calcium carbonate ($CaCO_3$) is heated to approximately 900+ degrees Celsius in a kiln to produce calcium oxide (CaO), also known as quicklime. After this, water is added to the quicklime. This is fairly dangerous because calcium oxide has an “avid thirst for water” (Nicholson 2). This process is known as *slaking* and it releases a large amount of heat, causing the water to boil and “spit”. The resulting product is calcium hydroxide ($Ca(OH)_2$), or “slaked lime”, or “lime putty”. This lime putty hardens extremely slowly by drying and by a process known as *carbonation* in which the lime putty reacts with the carbon dioxide in the atmosphere. This eventually forms calcium carbonate, the original component needed to make the lime in the first place.

By adding a hydraulic or "pozzolanic" (substances resembling the volcanic ash used by the Romans to make hydraulic cement) additive, non-hydraulic lime can set much faster. These additives include cement and brick powder. Cement is by far the most common of the two. "These [additives] contain highly reactive silica and/or alumina, which give a rapid chemical set by reaction with water" (Bricks and Brass 1). There are several advantages and disadvantages to doing this. The most substantial advantage results from the reduction in set time. Consequently layers may be built up much faster and they are protected from rain before the carbonation process occurs. Also, there is less risk of cracking because the chemical setting of the cement occurs before the mortar shrinks. Some of the disadvantages of adding cement to lime include: Time to work with the mortar is greatly reduced because of the rapid setting time. Damaging soluble salts (esp. potassium sulphate) have been found in some cements. Also, sometimes "the cement separates from the lime as the mortar dries and hardens, blocking the pores in the mortar, reducing the porosity and weakening the mortar" (Bricks and Brass 2).

Hydraulic lime is made in a very similar process. Quite often the limestone used for the source of calcium carbonate contains impurities, such as small amounts of silt or clay. Along with the calcium oxide formed while being burned in the kiln, the silt and/or clay form calcium silicates and aluminates. These compounds will "react with water to set and harden regardless of the presence of air" (Bricks and Brass 1). Only enough water is added to produce calcium hydroxide in a powder form, not enough is added to set the calcium silicates and aluminates. This dry material is mixed with water to produce a mortar that will set very quickly compared to non-hydraulic lime.

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.

Another problem with Portland cement is that the bricks themselves cannot be reused after deconstruction. "All buildings built with a hard cement cannot currently yield bricks to be recycled" (http://carlos.engi.cf.ac.uk/db/conmas%20index/ Richard%20work.htm). This is a detriment to the building industry as well as the environment because all too often these bricks are put in a dumpster and transported to the nearest landfill. Humans really need to get away from "landfilling" materials and start reusing them.

Besides lime mortar and Portland cement, polymer mortars are also available. These mortars are made largely from recycled plastic bottles, which contain polyethylene terephthalate (PET). The PET "can be chemically modified to produce unsaturated polyester resin. In turn, the polyester resin can be mixed with fly ash to produce polymer mortar (PM)" (Thermal Properties…1). Using polymer mortars can cut down on environmental concerns by reducing the amount of energy needed (and therefore CO_2 emissions) to develop lime mortar or Portland cement. Other advantages to polymer mortar are that they are not affected by freeze-thaw cycles and they harden very quickly, usually between forty-five minutes and two hours.

Cement production has a tremendous multifaceted impact on the environment that sometimes goes by unnoticed by the general public as a result of more obvious and sensationalized pollutant sources such as transportation. The production of cements and mortars includes (no sentence or finish to the paragraph)

Cements impact on the environment is very great for several reasons. Although significant progress has been made to reduce CO_2 emissions in the process of mining and heating limestone, the basic process of calcinating limestone produces CO_2. This calcinating process currently accounts for approximately 50% of total CO_2 produced.("Low Carbon Construction")

The first step for manufacturing Portland cement as well as lime mortar is, of course, obtaining the raw materials. Limestone is a resource of great abundance in the world. In order for a limestone quarry to be economically viable within the current market, the limestone must have less than 100 feet of alluvium or waste rock, called overburden. (Morton 2) There are many locations in the United States in which limestone can be mined with little environmental impact; however, the transport of quarried limestone is costly enough that quarry managers greatly prefer locations that are close to a market. The desire to be close to a market causes limestone to be mined in places such as the Florida everglades.

In 2002 the Army Corps of Engineers Issued permits for the mining of 5,409 acres of everglades wetlands. It was decided that this would be allowed, in part, because the companies will pay 46 million dollars in fees in order to use this area; money that will go towards the purchase and restoration of about 7,500 acres of wetlands near Everglades National Park. The mining of limestone in the everglades since the 1950's has created nearly 5000 acres of lakes which “serve to drain water out of the everglades,” according to Brad Sewell, a senior attorney for the Natural Resources Defense Council (“Army Corps…”).

The choice of not mining the everglades could also have negative ramifications. The fact that mining companies find it a good business venture to mine the everglades despite political difficulties, indicates that it would be more profitable than mining opportunities elsewhere. In the case of limestone quarries, it is logical to assume that greater profit for companies is good for the environment as the main points which cause the cost to vary include transportation and how much overburden must be removed. Both of these processes of cost to mining companies are also of cost to the environment as they are highly energy intensive (Morton 2). (Awkward)

Another case study of damage to ecosystems by limestone quarrying and mining is shown by the designation of over 13,000 acres of the San Bernardino Mountains as critical habitat. It has been labeled as such because limestone mining has had a dilapidating effect on the well being of five plant species that grow there. Maintaining the limestone habitat is very important to these plants, known as “carbonate plants”, are restricted to soils derived from limestone, dolomite or other substrates high in calcium carbonate (Critical Habitat Designated… 1).

During manufacture, Portland cement is definitely the more energy intensive process, but the fact that it contains more easily collected shale and clay in addition to limestone means that it requires less energy to gather the raw materials (Morton 3). The use of mineral resources in addition to limestone mean that it would have less of an effect on ecosystems in which calcium carbonate plays a vital role. In the total picture of limestone mining; however, limestone for all construction purposes equals less than 10% of total limestone mined (Morton 1).

Modern society may have exceeded the ability of volcanic activity to provide for the silica or alumina content necessary to create hydraulic cements, but we can turn to a waste product of coal burning that would otherwise be dumped in a landfill. Fly or fuel ash is a waste product of coal burning that has little other purpose and is frequently used as “filler” in landfills. Added to normal Portland Cement, this ash has the same effect as other pozzolans, including an increase in sulfate and chloride resistance; in addition, fly ash contains a highly reactive form of silica which reduces the possibility of an alkali silica reaction which has a negative effect on consistency of cement.

We can probably witness the fast pace of new homes being build right in our own neighborhood each day on our way to work and as we drive home after our day is done. We are now at a crossroads, there are needs to build millions of new homes, but environmental issues are becoming more important to us as we build more. Architects and environmental specialists are working together to find new, efficient and more effective ways to build these new homes and other construction projects. Higher demand and modern technologies has increased the use of lime mortar in mainstream buildings. Lime mortar not only generates major benefits and advantages to modern buildings, but also may be better for the environment at the same time then the traditional Portland cement.

Portland cement was considered as a specialist material 150 years ago and no one thought it would catch on in mainstream buildings, because it required grinding during its manufacturing process. However, advances in industrial processes and the demand for faster building, particularly after the Second World War, changed the market conditions and cement took off. Portland cement is a fantastic 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 impermeable (Pritchett). 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 cement. The introduction of a carbon tax, or legislation setting targets for recycling of buildings, could make Portland cement impractical and therefore make lime mortar the better choice (Pritchett). "The future is green, lime green," as Pritchett would put it.

Furthermore, environmental issues are becoming more important in the process of developing new buildings or structure projects. As a Managing director of lime technology, Pritchett offered some key advantages to the environment when lime mortars are used in mainstream buildings. During the manufacturing process, the firing temperature between Portland cement and lime is significantly different. 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 doesn't 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 world wide 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 mortars 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 hard-core. This is especially pertinent to modern commercial buildings, which may be demolished after only a few years" (Pritchett).

If those reasons are not yet convincing, then the following might be able to help one understand more about the benefits that lime mortar have over Portland cement. Lime mortars are more liable to settlement and movement associated with seasonal changes in ground conditions (buildinglimesforum.org). Other advantages of using lime mortars are; "lime binders can be durable and have stood the test of time, limes allow buildings to breathe, soft limes allow moisture movements and lime also contributes to a healthy environment" (Holmes).

The true "whole picture" impacts on the environment are very difficult to assess. In many places lime is more environmentally friendly. Commercial buildings, with their short average life span, built with lime mortars would allow relatively long-lived masonry to be reused as well as create a directly reusable, high quality calcium carbonate source. The initial production would emit much less CO_2 and the recyclability of masonry and mortar allows for less energy to be expended in the production and mining of these materials.

On the other hand, Portland cement does have higher strength and durability in many applications. Fisher Pavilion in Seattle, Washington is made of concrete created with Portland cement; the project manager of this construction job, Ron Rochon, stated that, "Unless they demolish it, it's a 1,000-year building" ("Concrete Creates…1). This statement leads to the question: is it practical for a building to be around for 1,000 years? In the case of buildings like Fisher Pavilion, it may be. The indoor space is basically open flooring for the purposes of entertainment or events like trade shows. This type of use is one that will undoubtedly be around for a long time, so it is practical to create a structure that will endure for what seems to be a nearly infinite time period compared to the average lifespan of American buildings. Fisher Pavilion can be likened to the Coliseum in Rome in its versatility. Many arena type structures still exist—if the coliseum was in usable condition we would certainly have use for it. The result of creating buildings with very long life spans means that there is reduction of the amount of limestone mined, the CO_2 emissions produced in multiple ways due to the fact calcium carbonate must be heated and calcinate, as well as the environmental impacts of building and tearing down unusable spaces.

Fisher Pavilion
Seattle, WA

Even with its potential long life span, products using Portland cement are not cradle-to-cradle products as pure lime mortar has potential to be. Portland cement must be reused in ways that are different from its original purpose. Reuse of Portland cement includes uses as an aggregate in new Portland cement and as bedding for new roads and other purposes that gravel fulfills. (“Recycling of Portland Cement Concrete” 2).

Ultimately, the choice of construction materials invariably depends on the purpose and location. 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. Both Portland cement and lime have their strengths and weaknesses. It’s important for individuals in the building industry to carefully judge what they need and make an informed decision.

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