

The Albuminous Arch: How Ancient Mortars Expose the Hubris of Modern Engineering

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The Albuminous Arch: How Ancient Mortars Expose the Hubris of Modern Engineering We suffer from a chronological hubris



By Frank Dumon

As a civilization that builds with self-healing concrete, carbon-fiber rebar, and algorithmic structural optimization, we look back at our ancestors with a patronizing fondness. We look at medieval cathedrals or colonial fortresses and marvel that they managed to stand at all, assuming their builders were operating on blind luck, superstition, and an abundance of manual labor. But then we look at our own infrastructure. Our modern highway overpasses sprout structural cracks within three decades. Our concrete high-rises are plagued by "concrete cancer" (alkali-silica reaction) and structural degradation before their first major

centennial.

Meanwhile, Roman aqueducts still channel water, Mayan temples endure tropical monsoons, and Spanish colonial churches in the Philippines withstand catastrophic typhoons and seismic upheavals centuries after their foundations were laid. When we dig into why these ancient structures survive, we do not find primitive blunderers. Instead, we discover an astonishingly sophisticated understanding of organic chemistry, materials science, and environmental adaptation—all achieved without a single microscope or computer simulation.

Nowhere is this clearer than in the historic use of eggs in construction.

To the modern mind, throwing thousands of duck eggs into a mortar mixer sounds like an absurd waste of food or a bizarre ritualistic superstition. But the science behind it is impeccably clever. In fact, exploring the history of albuminous mortars reveals a humbling truth: our ancestors were not primitive; they were masters of context-driven engineering. If anything, it is our modern obsession with standardized, rigid materials that proves we are not always as clever as we think.

The Chemistry of the Egg

In the Mortar, Not the Brick To understand why this practice worked, we must first dismantle a common misconception. Historical folklore often suggests that ancient builders mixed eggs into the clay used to form bricks themselves. While organic materials were added to bricks for specific reasons (which we will explore later), eggs were almost exclusively reserved for mortar and plaster—the binding matrices that hold walls together and protect them from the elements.

For most of human history, the standard binding material was lime mortar, a mixture of lime (calcium oxide), sand, and water. Unlike modern Portland cement, which cures through a rapid chemical hydration process, lime mortar hardens through carbonation. It slowly absorbs carbon dioxide (CO₂) from the atmosphere, reverting from calcium hydroxide back into calcium carbonate (calcite)—essentially turning back into stone over decades or even centuries. While pure lime mortar is remarkably flexible and breathable, it has low initial tensile strength and can be highly vulnerable to water erosion before it fully carbonates. This is where the eggs came in. The Role of Albumin as a Natural Polymer An egg white is roughly 90% water and 10% proteins, the most dominant of which is ovalbumin. When egg whites are introduced into a wet mix of slaked lime (Ca(OH)₂), a complex bio-chemical reaction takes place: •

Denaturation: The highly alkaline environment of the lime mortar (often a pH greater than 12) breaks down the folded, three-dimensional structures of the proteins, uncoiling them into long peptide chains. • **Cross-Linking:** These uncoiled protein chains interact with the calcium ions (Ca^{2+}) present in the lime slurry. They form a dense, hydrophobic (water-repelling) organic-inorganic network. • **Micro-Structural Packing:** As the mortar cures, this protein network fills the microscopic voids within the calcite crystal lattice. In modern engineering terminology, egg whites act as a superplasticizer and a biopolymer modifier. They reduce the amount of water needed to make the mortar workable, template the growth of smaller, more uniform calcite crystals, and create a significantly denser material structure. The result is a mortar that is stickier when wet, vastly stronger when cured, and highly resistant to water penetration.

The Philippine Palitada

Architecture of Survival Perhaps the most dramatic and historically documented application of egg-based construction occurred in the Philippines during the Spanish colonial era (16th to 19th centuries). The Spanish friars and local master builders faced a brutal engineering environment characterized by intense tropical heat, torrential monsoon rains, high humidity, and frequent, violent earthquakes. Standard European building techniques failed in this climate. The intense humidity prevented standard lime mortars from drying correctly, and the heavy rains washed away fresh plaster coatings. To protect their stone and brick structures, Filipino builders perfected the palitada—a protective layer of mortar or plaster applied to the exterior of walls.

The construction of the famous Manila Cathedral and the historic churches of Ilocos and Iloilo relied heavily on these mixtures. For the Manila Cathedral, historic accounts detail the consumption of thousands of duck eggs, which were favored over chicken eggs for their larger size and denser protein content. The egg whites were whipped and mixed into a slurry of lime, fine sand, powdered brick, and bamboo sap (which provided additional sticky polysaccharides). In some regions, molasses was added to slow down the setting time, allowing the mortar to be worked smoothly without drying out too fast under the tropical sun. The resulting palitada formed a tough, slightly flexible, and deeply water-resistant skin over the vulnerable coral stone or brick core of the churches. When typhoons threw driving rain against these buildings, the egg-enriched plaster prevented water from soaking into the walls, while still allowing internal moisture to evaporate out—a property modern synthetic sealants frequently fail to replicate, leading to trapped moisture and structural rot.

Global Innovations



The Breadth of Organic Additives

Lest we think this was an isolated phenomenon unique to the South China Sea, history shows that using organic additives to manipulate the chemistry of building materials was a global discipline. Builders throughout antiquity used whatever local biological waste or agricultural products were available to solve specific structural problems. The Indus Valley and India: Casein, Jaggery, and Curd Long before the rise of the Roman Empire, the cities of the Indus Valley Civilization, such as Mohenjo-Daro (dating back to 2500 BCE), were utilizing advanced material formulas.

The exceptional preservation of their brickwork, which has survived millennia of exposure to saline groundwater and intense heat, is partly due to the inclusion of organic binders. In traditional Indian architecture, as codified in ancient Sanskrit treatises like the Shilpa Shastra, mortar recipes reads more like a culinary manual than an industrial spec sheet:

- Jaggery (unrefined cane sugar): The carbohydrates retard the setting time of lime, allowing crystals to grow larger and stronger over time, while also increasing water retention during application.



Bel fruit (Aegle marmelos) pulp: Provides natural mucilage that increases the stickiness and tensile strength of the mortar.



Curd and Casein (milk proteins): Similar to the albumin in eggs, milk proteins react with lime to form calcium caseinate, a highly effective, water-resistant natural adhesive.

The Great Wall of China

Sticky Rice Mortar Perhaps the most famous organic mortar innovation is China's sticky rice mortar, developed during the Northern and Southern dynasties (386–589 CE) and perfected during the Ming Dynasty for use on the Great Wall. Sticky Rice Mortar Reaction: Slaked Lime + Amylopectin (Sticky Rice Polysaccharide) → Highly Compact Calcium Carbonate (Amorphous/Crystalline Matrix) Builders mixed slaked lime with a boiled broth of sticky (glutinous) rice. The secret ingredient here was amylopectin, a complex branched polysaccharide. The amylopectin acted as a template, controlling the growth of the calcium carbonate crystals. The resulting mortar was so compact and chemically stable that it blocked the growth of weeds and moss, prevented water infiltration, and provided incredible seismic resilience. Modern testing has shown that sticky rice mortar remains one of the greatest masonry binders ever invented, displaying mechanical strengths that rival modern cement while maintaining far greater flexibility.

The Engineering Logic of Porosity and Biomimicry

To truly appreciate why these ancient materials are superior in their contexts, we must look at how they handled a building's worst enemy: internal stress. Modern engineering relies heavily on strength and rigidity. We build structures out of high-strength Portland cement and steel. This works exceptionally well under predictable, static loads. However, rigid materials handle environmental changes poorly. When a modern building settles, or when it experiences thermal expansion and contraction (heating up in the sun and cooling at night), rigid concrete cannot move. Instead, it cracks. Once a crack forms, water enters, rusts the internal steel rebar, and the structure begins its inescapable march toward failure.

Ancient builders designed for flexibility and breathability. By using organic additives like eggs, they altered the micro-porosity of their materials. Combustion and Thermal Insulation In traditional brick-making contexts across Europe and Asia, organic materials like sawdust, rice husks, sunflower seeds, or animal manure were mixed into the raw clay before firing. Firing $\sim 900^{\circ}\text{C}$ - Organics combust away. When the bricks were baked in a kiln, these organic components completely burned away,

leaving behind a network of tiny, microscopic air pockets.

This was not a mistake or a shortcut; it was a highly intentional engineering strategy:

1. Weight Reduction: It produced lighter bricks, reducing the dead load on massive foundations.
2. Thermal Insulation: The dead air spaces within the bricks acted as a thermal barrier, keeping the interiors of buildings cooler in the summer and warmer in the winter.
3. Sacrificial Porosity: A porous brick or mortar allows moisture to migrate freely. If water freezes inside a highly rigid, non-porous material, the expansion chips away the surface (spalling). In a micro-porous material, the pores provide microscopic expansion chambers, allowing the material to freeze and thaw without breaking apart.

What Happened to the Yolks?

The Birth of a Culinary Tradition The widespread use of egg whites in construction created a unique secondary problem: an unprecedented surplus of egg yolks. In an era when resources could not be casually thrown away, this structural necessity sparked a culinary revolution, particularly in the Philippines. When Spanish friars ordered the collection of tens of thousands of eggs from local communities to construct churches like those in San Agustin or the churches of Iloilo, the egg whites went straight into the lime pits.

The remaining yolks were handed over to the local population, who had to find creative ways to utilize them before they spoiled. This structural waste stream directly birthed some of the most famous items in traditional Filipino cuisine:

- Leche Flan: A rich, heavy custard made almost entirely from egg yolks and condensed or caramelized sugar.
- Pan de San Nicolas: A traditional pastry stamped with the image of Saint Nicholas, utilizing egg yolks as the primary binding and enriching agent for the dough.
- Yema: A sweet, chewy confection made by cooking egg yolks with sugar until thick and malleable.

This historical link reminds us that human systems used to be deeply interconnected. A choice made in structural engineering directly dictated the local diet, creating a culture of total resource utilization that contrasts sharply with our modern, siloed industrial manufacturing pipelines.

The Proof is in the Preservation

Archaeological Evidence If the use of eggs, rice, and sugar in buildings was merely folk superstition, modern chemical analysis would easily expose it. Instead, contemporary archaeological science is validating these ancient methodologies with rigorous empirical data. The Delhi Stepwell Plasters (12th Century) A comprehensive study conducted on 12th-century brick-lime plasters taken from a historic baoli (stepwell) in Delhi, India, revealed fascinating chemical interactions at the microscopic level. Stepwells are highly demanding structural environments; they are constantly subjected to alternating wet and dry cycles as water levels rise and fall, alongside high hydrostatic pressure from the surrounding soil.

Using Scanning Electron Microscopy (SEM) and Fourier-Transform Infrared Spectroscopy (FTIR), researchers found that the organic additives mixed into the mortar had triggered a long-term chemical reaction at the boundary where the brick met the mortar. Over centuries, the organic compounds facilitated a continuous, slow migration of silica from the bricks into the lime mortar, forming a highly stable compound known as Calcium Silicate Hydrate (C-S-H)—the exact same compound that gives modern concrete its strength. The ancient mortar was literally growing stronger over time, adapting to its environmental stresses rather than breaking down.

Similarly, research performed on medieval bricks from Ventspils Castle in Latvia confirmed the presence of organic additives used to induce controlled micro-porosity. Despite centuries of exposure to harsh Baltic winters, freezing salt spray, and high winds, the bricks showed almost zero internal structural degradation. The micro-pores created by long-gone organic fillers provided the exact physical safety valves needed to survive hundreds of freeze-thaw cycles.

The Illusion of Modern Progress

Why We Aren't as Clever as We Think Looking closely at these historical techniques forces us to reevaluate our definition of progress. Modern construction materials are undeniably impressive in terms of sheer throughput and initial performance. We can mix, pour, and set thousands of tons of concrete in days, throwing up massive structures at a speed our ancestors could never dream of. But our system has a fatal flaw: it is unsustainable, brittle, and short-sighted. The Vulnerability of Portland Cement Modern Portland cement is an environmental and structural compromise. Its production accounts for roughly 8% of global carbon dioxide emissions. Furthermore, it is designed for a fundamentally limited lifespan.

Comparing Structural Philosophies

Primary Metric Peak Initial Strength Long-term Durability Material Philosophy Rigid & Impermeable Flexible & Breathable Failure Mode Catastrophic Cracking Self-Healing / Plastic Lifespan Expected 50 - 100 Years 500 - 2000+ Years Eco-Footprint High Carbon (\$CO₂) Output Carbon Sequestering (Lime) Because modern structures rely on steel rebar to handle tensile loads, and because Portland cement is highly rigid, cracking is inevitable. When a modern building cracks, its structural integrity drops immediately. It requires constant, expensive maintenance to survive past a few decades. In contrast, the lime-and-egg mortars of the past offer a properties package that modern materials science is only now trying to replicate through expensive synthetic means:

1. Self-Healing Capabilities: When a lime-mortar wall undergoes stress and forms a micro-crack, water seeping into the crack dissolves unreacted calcium hydroxide within the matrix. As this solution reaches the air inside the crack, it absorbs carbon dioxide and recrystallizes as calcite, effectively sealing the crack itself.

2. True Carbon Sequestration: Over its lifespan, lime mortar re-absorbs nearly all the carbon dioxide driven off during its initial manufacturing process, making it a far more ecologically balanced material than modern concrete. 3. True Lifecycle Sustainability: When an ancient brick-and-mortar building finally collapses, the materials return harmlessly to the earth. Bricks dissolve back into clay; lime mortar returns as calcium carbonate. A demolished modern concrete building, however, leaves behind millions of tons of unrecyclable, chemically contaminated rubble.

Conclusion

The Path Forward is Bio-Chemical. The realization that ancient builders used egg whites, sticky rice, and molasses to build enduring monuments is not a quaint historical footnote. It is a profound critique of modern industrial design. We have spent the last 150 years believing that we could conquer nature through brute force—by engineering materials that are completely rigid, completely impermeable, and completely detached from local biological systems.



The cracked highways, crumbling bridges, and massive carbon footprint of our current infrastructure show the limits of this approach. True engineering cleverness does not lie in creating a single, standardized material that can be dumped anywhere on earth regardless of context.

True cleverness—the kind possessed by the Filipino builders of the palitada churches or the Ming dynasty engineers of the Great Wall lies in understanding the delicate chemical interplay between local inorganic elements and natural organic polymers.

As modern materials science begins to explore bio-concrete (concrete mixed with bacteria that heal cracks) and green polymers, we are not discovering something completely new. We are simply catching up to the wisdom of the past. We are finally realizing that centuries ago, our ancestors looked at an egg, looked at a pile of burnt limestone, and understood the universe far better than we give them credit for.