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A study of the use of natural biopolymers in traditional earthen dwellings in Kerala, India

Introduction

This research will focus on the natural stabilisers traditionally added to earthen plasters in the region of Kerala. Additives of plant and animal base were added into earthen plasters to improve the qualities of the plaster – hardness, workability and water resistance. Often, the efficiency of these additives is largely based on traditional skill as some of these additives prove to be effective only in specific conditions of preparation and environment. The most common natural additives are manure from cows/horses, cooked flour paste, cactus juice, casein (milk protein), the leaves and bark of certain trees, natural oils, tannins etc. [1]

The stabilisers of animal and plant origin can be broadly classified based on their molecular nature into polysaccharides, lipids, proteins and others. The polysaccharide family groups together macromolecules from the family of complex sugars. Cellulose, starch, the main molecules of natural gums and vegetable juices are polysaccharides. Lipids are the fats of living beings. They are hydrophobic, insoluble molecules in water due to the presence of long chains of fatty acids. Proteins are living macromolecules, composed of one or more amino acid chains. They have both hydrophobic and hydrophilic parts. Milk casein, albumin from blood or egg, collagen from skin and bones, are proteins of animal origin. The final category group covers the other living molecules that do not fit into the big three families previously mentioned. These are mainly phenolic compounds: tannins, resins etc. [2 p.13]

Natural additives and their biopolymers

Derivatives from cows

Curd, dung, and urine have been used as natural stabilisers for mud constructions in different parts of the world. In India, the use of dung and urine is most common. These have been added to traditional mud constructions for centuries, both in Kerala and India at large.

01 Cow dung in use

Chanakam

Chanakam is the common term used for cow dung in the region where the study was conducted. Mud plasters with cow dung as an additive is a common mix and examples can be found from the hilly western Ghats of Wayanad to the flat plains of Palakkad and Thrissur.

Usage & benefits

Chanakam is used in mud plasters either directly or after dilution in water. In Kerala, the cow was traditionally fed only grass for a week before collecting the dung to ensure the size of the fibres in the mix. Chanakam contains cellulose which is a polysaccharide. The partial decomposition of the fibres of cellulose and other plant tissues allows a continuous distribution of fibre size in the mixture. The cellulose macro molecule is long enough to attach to several clay platelets at a time and link them between them. When the mix is homogeneous and well proportioned, it contributes to the cohesion of a mortar and increases the strength of the plaster [2 p.16]. The cow dung also adds fibre content to the mud mix resulting in a stronger plaster, improved water resistance and reduced cracking [3]. It is also a good insecticide and prevents insects from laying eggs inside the mud plaster.

Gau Muthram

Gau Muthram is the common term used for cow urine in the region where the study was conducted. Mud plasters that include urine have been found in Thrissur, and many contemporary mud structures have also used this as an additive in Kerala and other states in India. In Hinduism, cow urine has a special significance as a medicinal drink and the sprinkling of cow urine is considered to have a spiritual cleansing effect.

Usage & benefits

Cow urine is added to mud plaster while mixing all the ingredients – normally along with water until the right consistency is achieved. It is generally advised to collect the first urine of the morning. The urea acts

02 Process of extracting starch after boiling rice

04 The snakehead murrel and the slime it secretes into the water

as a binding material and can be used to reduce soil shrinkage, eliminating cracking and improving the ability of the soil to withstand erosion [4].

Rice and its derivates

Rice is a staple crop grown in Kerala, and rice paddy fields are found throughout Kerala in the plains. It is therefore natural that rice has traditionally played an important role, also for natural building. While the grains are de-skinned and used for cooking, the husk, the straw and also the water from cooking are added to mud for construction. The straw is added as a mineral like sand to obtain a more stable mix and avoid cracking while the husks and rice water (kanjivellam) are added as an additive to improve the performance of the mud plaster.

Rice starch

Kanjivellam – i.e. Kanji (boiled rice) vellam (water) – is the Malayalam term given to the water the rice is boiled in.

03 Rice husks

Usage & benefits

The water produced as a residue of boiling brown rice was mainly used as an additive for mud walls and mud plasters. Adding kanjivellam to an earth mix makes it more workable at the time of plastering. After drying, the starch helps to glue the particles of clay together making it harder. Plasters that use starch as a stabiliser also counteract dusting or flakiness of the plaster [3]. The component present in the boiled rice water is starch, which also belongs to the family of polysaccharides. The starch gel is shear-thinning, that is the more it is agitated, the more fluid it becomes. As it dries, the polysaccharide gels stick more to the clays in the mud, reinforcing the properties of the coating [5].

Rice husk

Ummi or rice husk is the hard, protective covering of the grains of rice. Although ummi is a by-product of agricultural production, it has acquired an importance of its own and has been used traditionally for various purposes. The indigenous houses of the Wayanad area make widespread use of ummi as an additive for their mud walls, mortars, and plasters.

Usage & benefits

Ummi is a common additive for earth plasters and mortars. The husk can be added directly to the mud mix and left to ferment while the mix rests a day or two before application. The rice husks strengthen the plaster, reducing cracking, and making it more durable. As the ummi decomposes/ferments it releases cellulose, a polysaccharide. Fermentation enables the cellulose molecules and other microscopic fibres to separate so that the contact surface between the clays and these microscopic plant fibres multiplies.

Some bacteria also produce exopolysaccharides that bind the particles and are real glues that make the plasters more viscous and easier to apply [2 p.18].

Ash

Kari is the term given to ash in Malayalam. Kari from burning both rice husk and rice straw is used as an additive. The mud houses in the Thirunelly region of Wayanad also used kari as a coating to protect the mud walls from backsplash when it rains.

Usage & benefits

Kari is used as a coating for a mud plaster or added to the mix of the topcoat of mud plaster. The rice straw/husk is burnt, and the residue ash is collected and used for mud plastering. The rice husk ash has been proven to increase resistance to water and acid [6]. Kari is known to have puzzolonic properties. The kari contains the mineral silica, and as it mixes with the clay particles it enhances the performance of the mix.

Fresh water fish – Snakehead murrel

Varaal or snakehead murrel is a freshwater fish found mainly in in ponds, paddy fields and in rivers in Southeast Asia. They are found widely in the backwaters of Kerala. They can breathe in air and crawl on land, as they have additional respiratory organs to survive periods of drought. Their slime secretions were commonly used in areas adjoining the backwaters or rivers, for example in the traditional mud houses of Thrissur, Guruvayoor and the Kottayam region.

Usage & benefits

Unlike examples in Africa where the fish (silurus) is steamed to acquire oils or extracts for mixing into the mud plaster [7], here the fish is unharmed. The mucus or slime that it naturally secretes into water is taken and mixed with the mud to form a more resistant plaster. The sticky water from the mucus secreted by the fish helps to improve bonding of all the components and makes for a stronger plaster that is more resistant to water. Varaal mucus is rich in protein and contain networks of amino acids namely collagen

05 Process of extracting the juice from the vine

06 Process of extraction – Panachikaya

(the chemical composition is a hypothesis based on the presence of amino acids and needs scientific verification). Proteins react strongly with clays as the clay absorbs the hydrophilic particles so that the hydrophobic particles are concentrated near the surface of the plaster making it more water resistant [2 p.30].

Oonjalvalli – Cissus glauca Roxb

Oonjalvalli is a climbing herb found in eastern India, Maharashtra, Konkan southwards up to Kerala and the Andamans. The plant is also called Marigampuli in Malayalam.

Usage & benefits

The stem of this climber is crushed and immersed in water which makes it viscous within a few hours (of the consistency of an egg white). The vegetal gel obtained from the stem of this climber is used as an additive in lime and earth plasters. The gel belongs to the family of polysaccharides, and most traditional stabilisers that come from plants/herbs fall into this category. By grinding the stem to produce the gel helps it stick to the clay molecules in the mud. Polysaccharides consolidate the mud by forming microscopic reinforcement with the clay particles. It also modifies the consistency of the mortar and facilitates the application of the plaster [2 p.14].

Panachikaya – Cochlospermum religiosum

Pananchikaya is a tree found in tropical climates, in Kerala and in the Kochi district and has traditionally been used for many purposes. The restoration of the Vadakkanathan Temple in Thrissur uses the same composition of lime plaster that was used during its construction, and some structures inside the temple complex date back to the 5th century. During the restoration process, the lime used was shell lime (from powdered shells) along with nine different herbs and jaggery (sugars). The herbs include oonjalvalli and panachikaya [5].

Usage & benefits

The fruit of this tree secretes a sticky liquid that is used as an additive in natural plasters. The fruit has a thick skin (approx. 5 mm) and is crushed and put into water along with its thick skin so that the water becomes slightly frothy and sticky. While not as viscous as the gel of oonjalvalli, it is used mainly as an additive in lime plaster. The gel belongs to the family of polysaccharides, like most traditional plant-based stabilisers, and, as with oonjalvalli, crushing the fruit releases a gel that promotes adherence to the clay. Polysaccharides from vegetal gels modify the consistency of the mortar and improves the application of the plaster [2 p.14].

Performance tests

The performance tests were conducted with some of the above ingredients to understand their resistance to water and abrasion. The tests carried out during this research were also selected keeping in mind the facility and ease of replicating these tests on construction sites and makeshift laboratories. In the view of continued research on the performance of natural additives found in different villages in India, basic tests were selected which would help to understand performance enhancements without requiring complicated equipment. The test samples with the natural additives were tested against a control sample with a 1:2 soil:sand ratio in order to understand how their performance differed from a base earth plaster mix. The water content added to obtain the desired con-

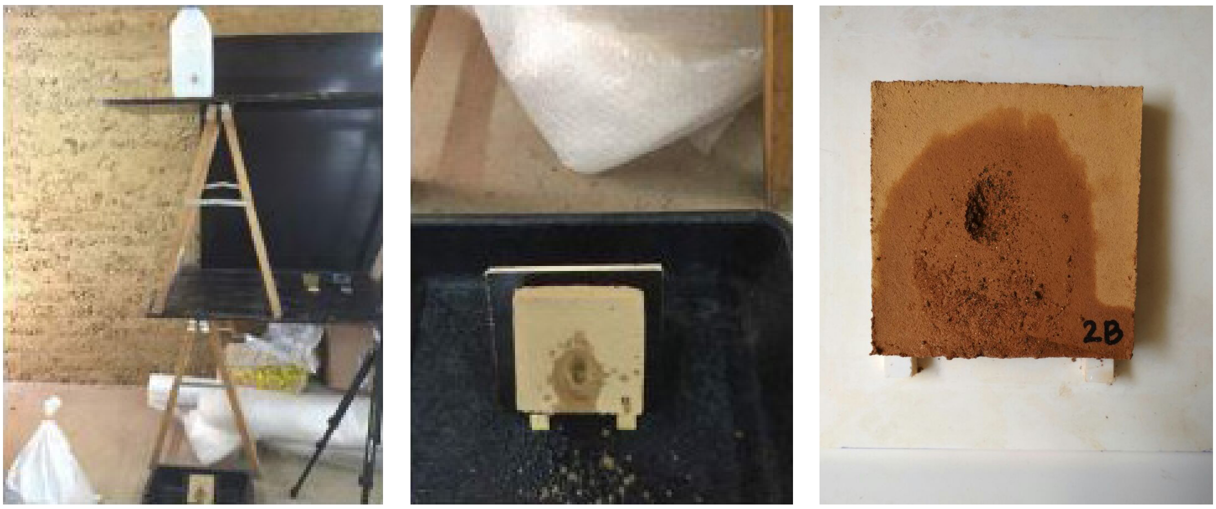
Table 1 Sample details

Additives	5%	5% after 5 days
Plain	0	0
Kanjivellam	1B	1B/5
Varaal	2B	2B/5
Pananchikaya	3B	3B/5
Oonjalvalli	4B	4B/5

Table 2 Water erosion test results

Sample	Dry weight kg	Time interval min	Wet weight +Stand kg	Wet weight kg	Hole Ø mm	Depth Ø mm
0	0.345	10	Nil	0.249	30	10
		30	Nil	Sample didn't exist	Nil	Nil
1B	0.372	10	0.71	0.401	7	1.5
		30	0.72	0.409	d1-25, d2-32	15
1B/5	0.383	10	0.72	0.411	18	15
		30	0.74	0.435	22	18
2B	0.366	10	0.70	0.389	8	7
		30	0.721	0.409	d1-33, d2-25	18
2B/5	0.371	10	0.71	0.401	d1-20, d2-25	10
		30	0.72	0.416	d1-20, d2-25	19
3B	0.365	10	0.71	0.398	Nil	Nil
		30	0.71	0.404	d1-8, d2-20	13
3B/5	0.379	10	0.72	0.412	15	1.5
		30	0.73	0.425	d1-22, d2-25	18
4B	0.346	10	0.68	0.368	18	20
		30	0.71	0.392	30	20

07 Water erosion – drip test



08 Abrasion test

sistency for plastering was kept constant for all the testing samples. All the samples were made using a mould 10 × 10 × 2 cm and were dried in a hot air oven at low temperatures between 50-100°C. The temperature and relative humidity during preparation of the mixes was on average 28°C and 80% RH.

The natural stabilisers were added to the base mix of earth plaster at a percentage by weight of 5% – named B – and another at 5% by weight was allowed to rest for 5 days before being put into the mould – and named B/5.

Water erosion test – Drip test

The principle of this test is to take the test samples and subject them to water droplets falling from a height (145 cm) for a certain duration (30 minutes). This test makes it possible to observe the behaviour of each mixture to sustained exposure to water and therefore deduce its behaviour in the wall and the water resistance.

Table 2 shows the performance of each of the samples under continuous exposure to water (1 drop per second). Of the five ingredients, the best performing mixes were 3B mixes, i.e. those using Panachikaya as an additive.

Abrasion test – Metal brush test

A metal brush with a specific mass of 3 kg is used to scrub the face of the test sample. A single back and forth motion of the brush is regarded as one cycle of abrasion. Brushing is continued for 10 cycles. The measurement consists of weighing the sample before and after brushing.

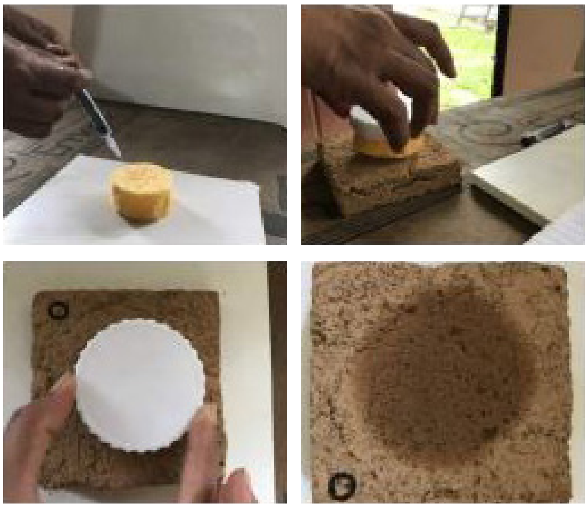
Table 3 Abrasion test results

Sample	Dry weight before kg	Dry weight after kg
0	0.373	0.363
1B	0.372	0.367
1B/5	0.389	0.379
2B	0.358	0.344
2B/5	0.379	0.366
3B	0.373	0.367
3B/5	0.378	0.368
4B	0.347	0.335
4B/5	0.355	0.346

Table 3 shows the resistance of each of the samples to abrasion.

Sponge test

This test is an easy means of measuring the capillarity of the soil sample. A sponge of a certain size containing a measured amount of water is pressed against the test sample for a specific amount of time (3 minutes). The plastic case in which the sponge sits ensures that pressure exerted to the sponge is the same for every sample. The sponge is measured before and after the experiment and the co-efficient of capillarity can be calculated from the difference in



09 Sponge test

Coefficient of capillarity

$$Wa = P_i - P_f/23.75t \quad \text{in g/cm}^2$$

t = time of contact in minutes
P_i = initial weight in grams
P_f = final weight in grams

Surface area of sponge: 23.75 cm^2

Table 4 Sponge test results

Sample	Dry Weight/kg (sponge + cap)	Pi (initial weight)	Pf (final weight)	Wa	Observation
0	0.018	0.025	0.021	0.000168	Ø 7 cm watermark
1B	0.018	0.025	0.021	0.000168	Ø 6.2 cm watermark
1B/5	0.018	0.025	0.021	0.000168	Ø 6.5 cm watermark
2B	0.018	0.025	0.021	0.000168	Ø 5.8 cm
2B/5	0.017	0.025	0.022	0.000126	Ø 6.0 cm
3B	0.018	0.025	0.021	0.000168	Ø 6.5 cm
3B/5	0.018	0.025	0.018	0.000294	Ø 6.4 cm
4B	0.018	0.025	0.019	0.011281	Ø 6.7 cm
4B/5	0.018	0.025	0.019	0.011281	Ø 6.5 cm

its mass. Ideally it is best to conduct this experiment with a weighing scale precise to 0.01 grams, but for this experiment a weighing balance precise to 0.1 grams was used. Hence, Table 4 indicates the efficiency of these mixes in a broad range and not to a 0.01 g accuracy.

Future research

A primary objective of this research is to highlight the potential of these natural stabilisers for use in conventional construction. This would help reduce the carbon footprint of built structures by reducing dependency on cement and other materials that are so energy intensive to produce. During the course of this study it was alarming to see just how quickly this traditional know-how is being lost. In the case of earthen homes, the number of people who live or aspire to continue to live in earthen homes are diminishing.

There is, therefore, an urgent need not just to focus on documenting these techniques but also to look into their revival. Future research on traditional stabilisers in earthen plasters can be broadly categorised into three parts:

- advanced research and development of present findings,
- further documentation of traditional recipes in this region and other parts of India,
- revival of these traditional recipes for conventional construction practice.

Conclusion

Throughout this research, it was remarkable to see just how much in-depth traditional knowledge on natural resources exists that in turn have given rise to their various uses. Most of the ingredients discussed in this paper were found to be used not only in mud constructions but also for medicinal and other purposes.

The ingredients used in traditional plasters depended greatly on the natural resources available at the respective location. For example, we see that the areas with cultivated plains used rice and other derivatives as additives while the mountainous areas with access to wild trees like Kulamavu used its vegetal juice for the same purpose. These key elements of resource management and use of locally available materials are important factors that are often disregarded in constructions today. Building materials are imported from all corners of the world with no concern for the region or place of construction leading to structures with a higher embodied energy and greater carbon footprint. It is evident that borrowing from the knowledge of our ancestors can help us find key solutions to our future concerns for development.

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