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Study on the performance enhancement of lime mortar used in ancient temples and monuments in India

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Abstract

Lime is arguably the world first true green and versatile building material. The traditional lime binder offers greater durability but less strong compared to cement. The objective of the study is to improve the strength parameters of lime using traditional herbs. Lime mortar prisms (mix proportion: 1:2 i.e., one part of lime to 2 parts of sand) were cast after 15 days of fermentation with traditional herbal extract [aqueous extract of oonjalvalli (*Cissus glauca* Roxb.), pananchikaai (*Cochlospermum religiosum*), kulamavu (*Persea macrantha*), gallnut (*Terminalia chebula*) and palm jaggery (from *Borassus flabellifer*)] and tested for its Flexure, Tension and Compressive strengths. The lime mortar prism fermented with plain water was used as control. The transverse strength of herbal lime mortar (5% herbs) is 1.6 times greater than lime mortar fermented with plain water. Besides, there was an increase in the tensile strength by three folds, due to elastic nature of herbal lime mortar. The compressive strength is greatly enhanced up to 2.5 times on the addition of 5% herbs. This may be due to the fact that herbal extract enhanced the density of lime mortar by bringing the particles of lime mortar closer to each other, thereby producing a more compact mass. Traditional structures built with lime mortar, which are more than 4,000 years old like Mohanjo-Daro is still a heritage monument of Indian civilization. It is more appropriate to blend the traditional concept with modern structures. The present work may also help in reviving ancient monuments.

Keywords: Lime mortar, herb, Compression strength, Ancient building material.

Introduction

Cement forms an integral part of the modern construction industry for past 100 years. Though cement mortar offers early strength, faster construction, it has number of disadvantages such as the environmental impacts during its manufacture, energy consumption during manufacture and behavior under seismic forces is under great question (Holmes Stafford, 2002)**.**

Compared to modern structures, traditional structures in India can be adopted by the people of all generation since the fundamental nature of construction is always flexible and in tune with the rhythmic spatial forms to suit the taste of every generation. Indian traditional structures built with lime mortar, which are more than 4,000 years old like Mohanjo-Daro is still a heritage monument of Indian civilization. The traditional construction concepts will definitely provide inputs to supplement modern construction methods and this will pave a flexible way by extracting the essence from ancient texts and interpret it to suit modern constructions (David S Mitchell, 2007)**.**

In recent past, attempts are being made to enhance the strength parameters by addition of chemical admixtures in cement concrete, though it is performing well in all mechanical characteristics. But the long term durability of cement has not been ascertained since cement came into existence in the past century. Lime is exceptionally durable. Lime's durability is evident throughout the ages. Though its durability aspect of lime mortar is time tested, its strength criterion stands lower than the Portland cement (Palomo *et al.,* 2003)**.**

Lime allows the building to "breathe". Water can escape by evaporation, unlike cement where the only way the water can escape is by being absorbed into the bricks. Lime is soft and flexible. It allows the building to move without cracking and letting water in and thus "self-healing". Lime is normally considerably cheaper to produce, needs much lower or even negligible capital inputs to get started. Lime is biodegradable and recyclable. Lime is burnt at a lower temperature than cement in the production process (900°C as opposed to 1300°C), therefore making lime production is not only more environmentally friendly but also more economic as well. Lime can also be produced on a small scale to supply a local market. This greatly reduces transportation costs (Pritchett, 2003)**.**

The Ancient Egyptians were the first to use lime mortars. About 6,000 years ago, they used lime to plaster the pyramids at Giza. In addition, the Egyptians also incorporated various limes into their religious temples as well as their homes. The Greeks have enabled us to witness the beauty and incredible durability of true lime stuccos. Innovative Greek builders used these fine lime plasters in creating the Parthenon and many other classic structures that survive into the present day (Lauren B. Sickels-Taves, 2005). Lime was used extensively throughout the Roman Empire. The builders during that time possessed a firm knowledge of lime's many beneficial features, as a mortar and as a decorative finishing material. As the Empire grew, the Romans influenced architecture and structures throughout the civilized world. Consequently, many more people learned to appreciate the benefits of lime and embraced it as a building material.

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The Pont du Gard at Nimes in southern France, a Roman aqueduct built in 18AD with hydraulic lime-based mortar, is still water- proof; the excellence of the mortar is attributed to the selection of the materials used as well as to the time spent tamping the mix into place during construction (Quach, 2005). Into the middle Ages, lime remained an important element in the continuity of life. Lime was widely utilized throughout Europe as a plaster and paint décor, and it served as a principal building material for homes, protecting inhabitants from inclement weather. Lime has proven itself as a durable, useful, and aesthetic construction material for thousands of years. The reasons for using lime as a mortar and for decorative art remain valid today. The Charminar in Hyderabad was the first monument in the world constructed using lime mortar and granite. It was only after its construction that the architects throughout the world recognized the strength of lime-mortar in raising huge structures. High workability, water retention, plasticity, more adhesive power and a few other qualities seem to have encouraged the Qutub Shahi kings to make extensive use of lime-mortar in almost all the monuments and palaces built by them. Chandra and Aavik (1987) discussed about the influence of natural proteins on properties of cement mortar. Natural organic materials were incorporated in building materials in ancient times. The major content in these materials are proteins. some proteins have been tested in Portland cement mortar as admixture, air entrainment, adhesiveness and hydrophobic properties introduced to cement mortar by the proteins are measured. It is seen that the proteins worked like a air entraining agents, improved the adhesiveness and hydrophobic property. They also acted as retarders because of complex formation with calcium by cross linking. Chandra et al. (1998) has investigated the natural polymers have been used in ancient times to improve the durability of the lime mortars and concrete. The cactus extract from Mexico has been tested in Portland cement mortar. Cactus extract increases the plasticity, improves water absorption and freeze salt resistance. Calcium hydroxide produced by Portland cement interacts with the components of cactus extract forms complexes of polycharides of proteins.

Joseph C. Salamore (1996) has discussed the various natural polymers used in different forms of construction around the world. Polished gelatinous rice paste , viscous liquid obtained from elm shavings in water, pluses, molasses, boiled stems and leaves of banana plants ,oils , egg whites cashew nut shell, liquid resin, gluey fluid from cactus palnts, natural rubber latex are some of the natural proteins and polymers.

Venus Vinod Upadhyaya (2008) stated that the retrofitting of centuries old vadakkunnathan temple at Thirrsur, Kerala was done using powdered shells, nine different herbs and jaggery. The whole preparation, which took 40 days, required skilled traditional craftsmen which are very few. Keeping in mind the hugeness of the temple, a separate workshop had to be established and labour had to be trained to make the special plaster.

Manmadhan Nair (2003) on reclaiming heritage discussed about the revonation work carried out at Fort at Vettimurichakotta, Pazhavangadi, East Fort, West Fort, Puthen Street, Sreevaraham and Virakupurakkotta, Kerala, India using different composition of the plaster mixture which was discovered from a palm leaf manuscript found in the Padmanabhapuram Palace. An assortment of elements including a variety of herbs and fruits and a particular species of cactus were blended with palm jaggery and left to ferment for 15 days. This concoction was mixed with lime to prepare the plaster.

The objective of our study is to improve the strength properties of lime mortar by admixing with herbal extract. We studied the mechanical properties such as compression, tension and flexural strength of traditional herbal lime mortar used in retrofitting of temples and monuments and compared that with plain lime mortar.

Materials and methods

The prism moulds in triplicate of 40mm X40mm X 160mm is used. While tested for its flexural strength, the mould was split into two equal halves. One half was tested for compressive strength and the other for split tensile strength. Two types of lime namely hydraulic lime and lime shells in equal proportions were used. The mix proportion is in the ratio1:2 i.e., one part of lime to 2 parts of sand. Experiments were done in triplicate and the average values are presented.

Preparation of lime putty

The lime stone and shell lime are taken in equal proportion and mixed with two parts of fine river sand most of the particles passed through 800µm sieve. Then it is mixed with equal amount of water and ground in mill for 3 hours or until it gets like a paste. Then it is fermented at room temperature for 15 days either by adding water equal proportion (w/v) or with herbal juice in place of water. At the end of fermentation, most water gets evaporated and the lime mortar becomes air-dried. It is then again grounded to paste by either adding required amount of water or herbal juice (5% or 20% w/v) while making paste.

Preparation of herbal juice

0.25 kg (wet weight) of each herb and palm jaggery is taken and crushed well. Crushed herbs and jaggery were soaked together in water (as per IS construction water quality standards) for 15 days at ambient temperature (27-29^{o}C) and the Relative humidity was 90%. At the end, the juice is separated and used. For preparation of one kg of lime putty, equal amount (one litre) of herbal cocktail juice is used.

Results and discussion

The various strength properties such as flexural, tensile and compression are studied for the lime mortar with or without herbal juice. The results obtained from the tests are given in Table 1. The table provides comparison

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Table1.Comparison the strength of Modern and Traditional Binders (ungrinded)

Binder	Flexural Strength		Tensile Strength		Compressive Strength	
	load(N)	Strength N/mm ^{2}	load(N)	Strength N/mm^2	Load (N)	Strength N/mm ^{2}
Lime	233.33	0.656	333.3	0.1326	816.66	0.5104
Lime with herbs (5%)	316.66	0.890	400	0.1591	833.33	0.5208

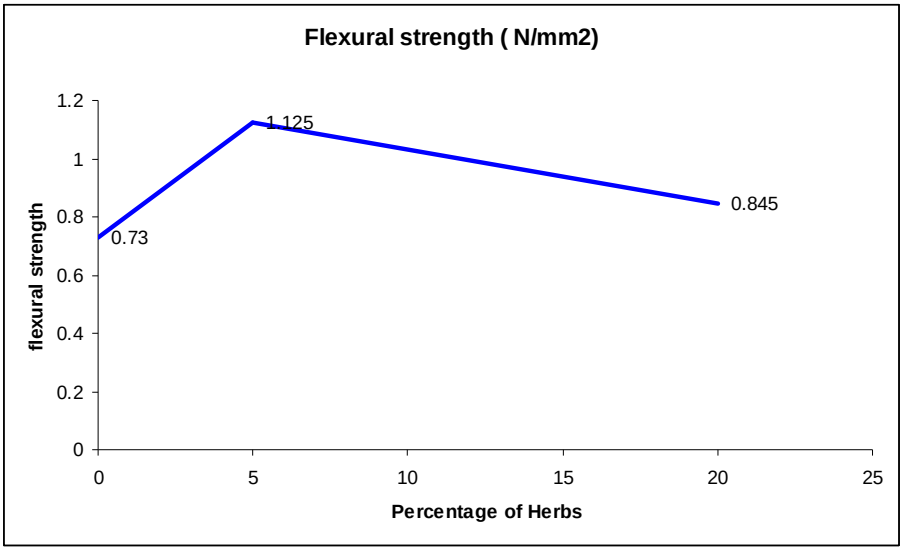
Table 2. Comparison of Strength properties of Traditional Binders (grinded)

Lime	250	0.703	466.66	0.186	833.33	0.521
Lime with herbs (5%)	400	1.125	850	0.55	1500	1.210
Lime with herbs (20%)	300	0.845	700	0.265	1400	0.949

of strength properties of modern and traditional binders. There is no appreciable variation in the strength parameters when herbs are added to the ungrounded lime which may be due to the fact that the herbal extract might have not blended with the ingredients of the lime mortar.

The density of lime mortar is around 14KN/ m^3, where as there is a marked increase in the density of herbal based lime mortar as shown in Table 1. Thus there is an incremental increase in density on addition of herbal admixture. With 5% addition of herbal extract the density of lime mortar raises to 17.7 KN /m^3 which shows 25.8% increase compared to plain lime mortar. The above density analysis ensures an appreciable increase in the density of lime mortar. The above analysis also indicates the reduction in the percentage of voids on the addition of herbs, thereby cause better performance and durability on herbal lime mortar.

Fig.1. Flexural strength analysis grinded Traditional binder



The flexure strength of lime and herbal mortar are tabulated in Table 2. The flexure strength of lime mortar is 0.703 N/ mm^2. As shown in the Fig.1, the transverse strength is maximum for 5% herbs (1.125N/ mm^2) which is 1.6 times greater than that of plain lime mortar. However, there is an increase of flexure by around 20% for 20% of herbs. Therefore for a better flexibility 5% herbs can be added with the lime mortar (5% replacement of water by herbs) during the conduct of experiment it is seen that herbal lime mortar undergoes more deflection without cracking on the application of load. This indicates the flexible nature of lime mortar. Hence it is expected to perform better under seismic attack.

The results of the split tension for various lime mortar are represented in Table 2. Lime mortar is poor in tension. However, the attempt is fruitful with addition 5% herbs to the lime mortar. It increased the tensile strength by almost three folds (0.55N mm^2) which shows the elastic nature of herbal lime mortar. With the addition of 20% herbs there is an increase in tension of lime mortar by around 45%. However, there is a landslide fall in the tensile strength compared to 5% herbs as indicted in Fig. 2. Hence, for maximum tensile strength it is recommended to add 5% herbs to the lime mortar.

The average compressive strength of various lime based mortars are sited in Table 2. The compressive strength of plain lime mortar is low of the order of 0.52N/mm^2. The strength is greatly enhanced up to 2.5 times on the addition of 5% herbs. Further addition of 20% herbs, the compressive strength declined to 1.82 times that of lime mortar as indicted in Fig.3. Hence, once again 5% addition of herbs produces lime mortar of superior compressive strength.

The above analysis clearly indicates the influence of herbs on lime mortar; with the addition of 5% herbs compressive strength is increased by 2.5 times; tension by 3 times and flexure by 60% over the plain lime mortar. This better performance characteristic of herbs may be due to the fact that herbs increase the density of lime mortar. It is also noted that the herbs brings the particles of lime mortar closer to each other, thereby producing a more compact mass.

Conclusions

Treating lime mortar with 5% herbal juice provides greater flexural, tensile and compressive strengths. The transverse, tensile and compressive strengths are increased by 1.6 times, 3 times and 2.5 times respectively in comparison with plain lime mortar. Hence, addition of herbs can greatly enhance the compression and tensile stress of lime mortar that can be used in repair of ancient monuments and also in building eco-friendly structures.

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Fig.2. Tensile strength analysis grinded traditional binder

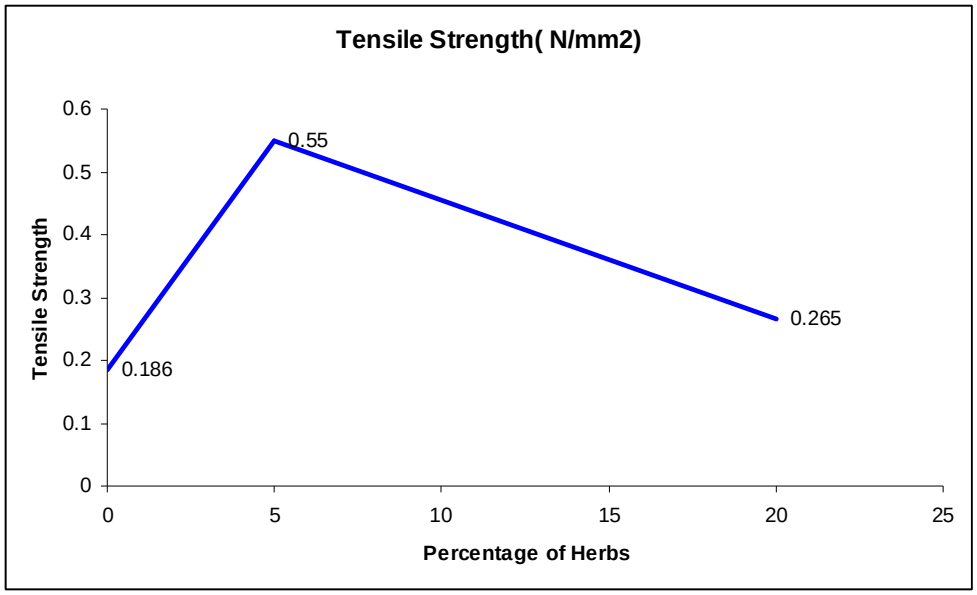
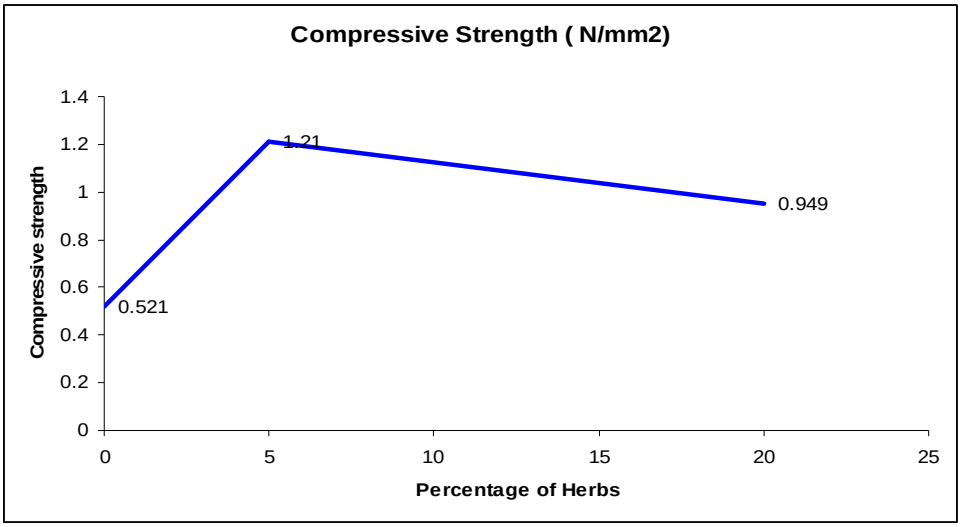


Fig. 3. Compressive strength of grinded traditional binder



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