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Analysis of Traditional Masonry Building Units with Natural Sustainable Additives

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Abstract

India has a history that belongs to both victor and vanquished which consists of a rich and sundry cultural heritage in the form of built architecture. All these ancient structures were constructed in a variety of traditions and styles, which were systematize into a characteristic architecture. Preservation of built structures requires special skills and these skills are bewitched by engineers, especially structural engineer. The aim of this research is to characterize the mortars, using sustainable additives and study the stability aspects of the house under static and dynamic loads by creating a 3D model of ancient wall in India which was built 200 years ago. Lime has been used for millennia in construction, and its importance has only recently been rediscovered, especially in the field of conservation architecture. Lime mortars harden by carbonation, and this dissertation is an examination of this process. In order to improve strength property, workability, durability and adhesion of lime mortar certain additives had been used such as surkhi or powdered brick, animal fur (especially goat), volcanic pozzolona, egg white, jaggery, fenugreek seeds were added. The different characteristics such as

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elasticity module, Poisson ratio, young's modulus, water content and dry density were observed by casting walls with lime and other additives such as nutmeg and palm jaggery in the ratio 1:3 and the compressive strength and Flexural Strength of the walls has been studied.

Keywords: Compressive Strength, Flexural strength. Sustainable Natural additives, Lime mortars, Masonry Units.

1 Introduction

The use of lime mortar as bedding, pointing and plastering material is clearly seen in the historic structures . Lime mortars are mostly used today to preserve buildings that were originally built using lime mortar, but can be used as an alternative to normal Portland cement . Lime mortars have also been used for plaster applications due to their beneficial characteristics such as sticky nature, flexibility, workability, frost resistance, water retention, greater strength, vapor permeability, autogenic healing, etc. Admixtures and additives are essential components of lime mortar that provide advantages in physical, mechanical and durability properties and greatly enhance its use by improving and modifying their properties.

2 Related works

B. Dhilipkumar et al [1] In India, during the mid-4th and 6th century AD, the use of different varieties of flowers, fruits beans and leaves that are soaked in oils in the preparation of mortar came into picture.

A.Spewiek et al. [2] Some of the mortars with components such as whale oil and lime have been used over the years, thus resulting in improving the properties of the material used.

S.McKee et al. [3] In India, most of the heritage buildings are in deteriorated conditions and main cause of their deterioration is environmental conditions.

Guofeng et al. [4] In most of the cases, one will observe that deterioration starts from bedding and joining mortars. There is a need to investigate the usefulness of these materials from the present day point of view.

J.John et al. [5] Although Portland cements have been introduced to mitigate the use of lime mortars owing to their elevated workability and compressive strength, the use of lime mortar in building has acquired momentum in latest years owing to its versatility and eco-friendly nature.

This literature review is primarily about the prominent synthetic and natural lime-based study work.

L. Ventola et al. [6][7] The research showed that adding coconut fiber to concrete results in improved concrete torsion and tensile stress. However, Additional research is needed to assess the long-term durability of coconut fiber reinforced concrete .

P. G. Racines et al. [8][9][10][11][12][13] Studied the effects caused by organic admixtures made from extract of plants like cactus and marigumpuli On hydraulic lime mortar mechanical and natural properties and suggested the organic modification increased the resistance of lime mortar due to increased bond strength among adjacent lime particulates.

Ravi et al, [14][15][16][17][18],The intrusion of organic chemical containing polysaccharides and hydraulic lime blending was investigated, creating numerous calcium complexes that permitted additional air into lime mortar and improved the carbonation cycle, leading to increased compressive resistance of modified lime.

M. A. Aziza et. al [19] This review summarizes the attempts taken to highlight the comprehensive lime mortar use fiber study and thus proves to be an efficient instrument for encouraging further research on these sustainable building products, which orients the construction industry towards contributing to the sustainable future.

F. Sarasinia et.al [20] Such an article reports on the recent decade and ongoing research and innovation to utilize natural fibers from coconut, sisal, sorghum hemp fibers, bamboo, jute, timber and papaya. The possibilities of this new material for future building applications are also highlighted.

S.H.Ghaffar et al. [21] This paper examines the extraction methods, chemical, morphological, thermal and properties recorded in the survey of these less utilized natural additives, addressing their advantages and challenges by comparing them with different conventional plant additives.

B.MicheleBetti et al. [22][23]The use of this less than traditional natural additives in thermoplastic and thermosetting matrices is discussed critically compared to the various generic bio composite.

3 Materials and Methodology

3.1 Sand

Sand is a naturally obtained granular substance that is composed of fine grains of rock and minerals. River sand which is passed from 2.36 mm sieve, then washed to make it free from organic, inorganic impurities and other contaminant is used for the preparation of mortar. Sand is dried in sunlight before using . Table 1 shows the physical properties of the fine aggregate.

Table 1 Physical properties of fine aggregate

Sl. No	Properties	Values
1.	Specific gravity	2.65
2.	Sieve analysis	Zone II

3.2 Water

Water is one of the important ingredients in the preparation of mortar which makes it strong, workable and controls setting time. Potable water which is free from impurities is used. The presence of impurities affects the strength and durability property of the mortar. Impurities present in water may affect the strength and durability of mortar. The ph level of water used should be 7.

3.3 Admixture

Palm jaggery and Kadukkai used as the admixture to the mortar of Chettinad house. They are purchased from locally available shops in Potheri, Chennai and made into fine powder. This powder is then added to water and left for 7 days to initiate the fermentation.

3.4 *Oil*

During casting of cubes and prism, the oil is applied on the inner sides of the mould for smooth removal of moulds after 3 days.

3.5 Admixture Description

Palm Jaggery

Palm jaggery is the extract of date palm tree. Palm jaggery as natural additive in construction industry decreases the segregation and bleeding of mortar. In the process of making jaggery from plant does not involve any addition of chemical agents. 250 grams of powdered palm jaggery is fermented for 7 days in 1 liter of water and then mixed in lime mortar which is shown in Figure 1.

Kadukkai

Kadukkai is known as "Sarvaroga Nivarani" which means universal medicine. 250 grams of crushed and grounded Kadukkai is added to 1 liter of water to set for fermentation and then added to lime mortar.

Brick description

A detailed description of the basic elements is required to better understand the behavior of any structure or structural component. In this section, the work conducted to classify basic materials has been discussed within detail, which is a prerequisite for the experimentation of this review.

Lime description

Sections of the original mortars that have been damaged by ordinary weathering require restoration in many of the historical masonries of Crete, Greece. In many other cases, restoration measures used cement and polymer-based materials, leading to a further degradation, as toxic by-products caused severe damage to the surrounding blocks of stone . Methodologically, the first step would be the thorough characterization of the initial mortars, and instead repair mortars are created using this knowledge. Those repair mortar rounds are finally described to determine their suitability to use.Both lime and sand are mixed in the ratio of 1:3 and kept aside to preshrink for 24 hours . Lime used is natural hydraulic lime which was purchased from Chennai, Tamil Nadu. The mixing of lime and sand is shown in figure 2. The below mentioned field tests are done on lime as per IS 1624: 1986.

Figure 1 Mixing of lime mortar

4 Results and discussions

4.1 Tests on Lime

Field Tests on Lime

The outcome of the field tests conducted as per IS: 1624 - 1986 are presented in Table 2. The three different tests are discussed below

Visual Inspection

Lime is examined for colour, presence of lumps, soft or hard nature.

Ball Test

Lime sieved from 850 microns sieve is added with sufficient amount of water to make it into a ball of 50 mm diameter. Now, the ball is kept undisturbed for 6 hours and then immersed in jar of water. After few minutes of immersion in water there were no signs of disintegration. So, as per code provision the lime comes under class A lime.

Hydrochloric Acid Test

Take 50 ml glass cylinder and add lime till 5ml mark. Now add hydrochloric acid till 25 ml mark and stir it with glass rod. Leave it undisturbed for 24 hours and observe the gel formation. If the gel formation is very thick and is hardly flowing when turned upside down, then the lime is class A lime.

Table 2 Test on lime

Test	observation	Inference
Visual inspection	Hard in nature and presence of lumps	Class A, structural lime
Ball test	No sign of disintegration was found when the ball of 50mm diameter was immersed in water for 6 hours and tested	Class A, structural lime
Hydrochloric acid test	Formation of gel was observed and hardly flowing nature when turned upside down	Class A, structural lime

4.2 Laboratory Tests on Bricks

It is very important to have a detailed description of properties of materials used to understand the stability aspects of any structure. Also, any development of analytical models requires the mechanical properties of basic materials used. Bricks are the most important and oldest building materials used. They are given such importance due to its resistance, durability, reliability, low cost and strength. A good quality structure requires materials of good quality. The laboratory tests on bricks help us to find the quality of bricks used, which is explained below and tabulated in Table 3.

Dimensions of Brick Wall

For this design work, its clay bricks used to cast the masonry structures sample were of dimensions 210 × 100 × 70 mm. The materials available locally are used as a whole for research. Not that all bricks have been of exact dimensions.

Compressive Strength of Brick Wall

Compressive strength test is one of the important properties and it is done accordance to IS: 3495 (part 1) 1992. Compressive strength of masonry

is one of the important parameter in the stability of masonry structures. The results of compressive strength are shown in Table 3.

Table 3 Compressive Strength of Brick Wall

Sl. No.	Dimensions (mm)	Maximum Load (KN)	Compressive Strength (N/mm^2)	Average (N/mm^2)
1.	210 × 100 × 70	104	5.31	5.23
2.	209 × 100 × 70	111	5.04	
3.	210 × 100 × 70	119	5.64	
4.	211 × 100 × 69	98	4.72	
5.	210 × 101 × 70	109.5	5.45	

Water Absorption Test

Water absorption test on bricks is done accordance with IS: 3495 (part 2). Generally, water absorption test on bricks is done to determine the durability property of the brick. Usually bricks contain pores. So when the water is absorbed by the brick that is entering through pores, the degree of compactness of bricks is determined. The strength of brick relies on its absorption capacity.

Density of Bricks

One essential parameter is the brick density. Density reflects brickwork weight. An oven-dried brick is measured in mass and volume. One can determine the bulk density by dividing the mass by volume. The average brick mass density had been Made to be 1604.123 Kg/m^3 and the average weight density of bricks is found to be 15.731 KN/m^3.

Modulus of Rupture of Bricks

Modulus of rupture is a material property which is also called as flexural strength or bends strength or transverse rupture strength. Brick specimen is tested in Universal Testing Machine (UTM) of capacity 100 tonnes. In loading frame, bricks are supported by rollers at edges and load is applied at

centre till failure occurs .

Efflorescence of Bricks

Efflorescence of bricks test is done to examine the presence of any crystalline or alkaline substance on the surface of bricks. To observe the efflorescence presence the bricks are kept in water and when the water id dissolved into the bricks the salts are transported on to the top surface of the bricks. For the present study 5 bricks are tested for efflorescence and there is no sign of any deposit on all the bricks.

Poisson's Ratio of Bricks (μb)

The ratio of transverse contraction strain to longitudinal extension strain in the direction of stretching is known as Poisson's ratio. It is also known as Poisson coefficient. The results of Poisson's ratio are 0.277, 0.249 and 0.252 for different samples. Furthermore, Poisson's average scale value is 0.26.

Modulus of Elasticity of Bricks (Eb)

Modulus of elasticity is also called as elasticity modulus. Modulus of elasticity is a number that represents the measure of resistance of an object being elastically deformed when applied load on it. The elastic modulus of an object in the elastic deformation region is known as the slope of its stress strain curve.

A wall panel in position for testing is shown in Figure 3. The vertical load was concentrated on the wall and transmitted from the head of the 600,000-lb hydraulic capacity testing machine through a 12-inch deep loading beam, a 1-inch square steel bar centred along the wall width, and a 2-inch steel plate covering the wall's top area. A piece of 1-in fibre board was used to provide an evenly distributed load to the top of the wall between the top of the wall and the 2-in steel plaque. The bottom of the wall was built inside a ring of steel that stood on fibreboard of one in.

Table 4 Properties of brick wall

Sl.no	Properties	Value
1.	Dimensions (mm)	430 x 110 x 540
2.	Water absorption (%)	14.169
3.	Weight density (KN/m^3)	15.731
4.	Mass density (Kg/m^3)	1604.123
5.	Modulus of rupture (N/mm^2)	1.182
6.	Efflorescence	Nil
7.	Poisson's ratio	0.26
8.	Modulus of elasticity (N/mm^2)	579
9	Compressive strength (N/mm^2)	7.12
10	Shear strength(N/mm^2)	0.19

Figure 2 Elevation of wall

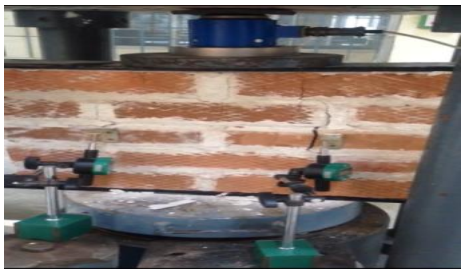

Figure 3 Sectional view of the wall

4.3 Properties of Wall

The main parameters to be considered are Compressive strength and shear strength . Figure 4 and Figure 5 explains about the casting of the wall and elevation of the panel. Table 4 provides Properties of brick wall

Figure 4 Casting of wall

Figure 5 Elevation of the panel

Properties of lime mortar with natural additives, In Table 5, the physical properties of natural additives such as density, Poisson's ratio, tensile strength, Young's modulus are tabulated.

Table 5 Properties of lime mortar

Sl. No:	Property	Value
1.	Density	18.82 KN/m^3
2.	Poisson's ratio	0.17
3.	Tensile strength	10.7 N/mm^2
4.	Young's modulus	800 N/mm^2

5 Analysis Using Ansys Finite Element Software

Ansys, Inc. is a public company based in Canonsburg, Pennsylvania. It develops and markets engineering simulation software. This software is used to design product. The analysis of the structure is the main feature of study of the project before designing the building components. This analysis should be given more importance to overcome the realistic design constraints.

5.1 Loads

The accelerations or deformations, forces or actions applied on a structure are known as loads. These loads can cause deformations, displacements and stresses in the structure where they act. Various methods are available in structural analysis to assess their effects.

5.2 Analysis of the wall

The analysis was done using ANSYS software. The analysis of the wall is done and below are the figures showing the results of the analysis. Figure 6 shows the equivalent stress in the wall with natural additives, Figure 7 shows the equivalent strain in the wall with natural additives, Figure 8, shows total deformation in the wall with natural additives and Table 6 , shows the maximum values from ANSYS.

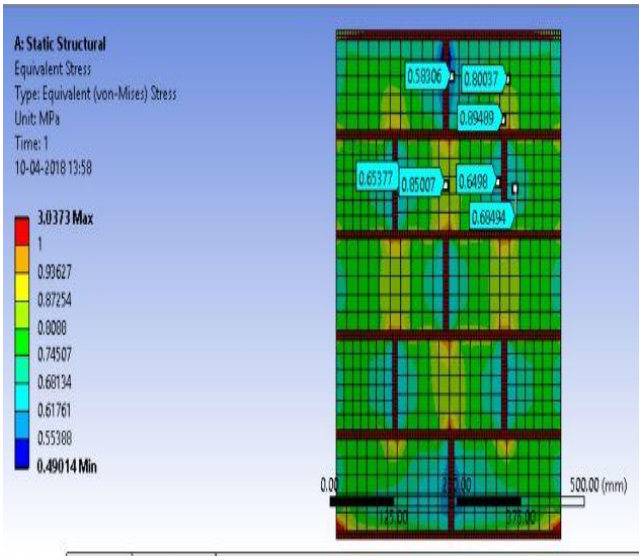

Figure 6 Equivalent stresses in the wall with natural additives

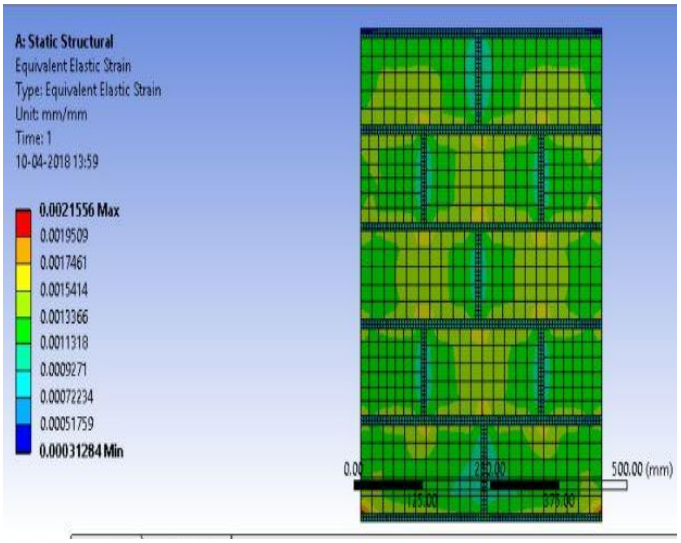

Figure 7 Equivalent strains in the wall with natural additives

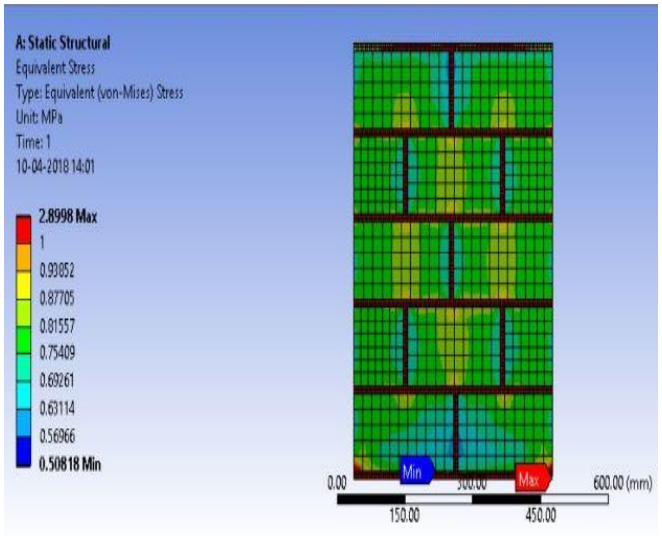

Figure 8 Total Deformation in the wall with natural additives

Table 6 Maximum Values from ANSYS

Result type	**Wall with natural additives**
Total deformation (mm)	0.713
Maximum equivalent stress(N/mm^2)	3.0373
Minimum equivalent stress (N/mm^2)	0.4901
Maximum elastic strain	0.0021
Minimum elastic strain)	0.0003

5 Conclusion

The physical and mechanical properties of the Kadukkai and palm jaggery mixed lime mortar were studied experimentally. The results show that Kadukkai and palm jaggery are found to be very useful natural admixture that can be added to lime mortar. Both Kadukkai and palm jaggery showed remarkable performance on strength property. The mortar has shown massive performance on resisting the formation of cracks. The use of these natural admixtures as repair mortar shows significant effect on durability and performance of the structure. Hence, this research certainly supports the use of this lime mortar built with natural admixtures in the future repair works of lime based monuments and also upcoming constructions.

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