”DURABILITY AND PERFORMANCE OF LIME MORTAR USING KADUKKAI (Terminalia chebula)“

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Kadukkai,TerminaliaChebulla,Jaggery,Lime.

Introduction:

Lime, a traditional construction material, has been used for centuries due to its durability and versatility in various building applications. It is commonly produced by mixing lime with aggregates such as sand, gravel, or crushed stones, the incorporation of jaggery, a natural sweetener derived from sugarcane or palm sap, into lime cement offers a sustainable and eco-friendly alternative with enhanced properties.

1.Kadukkai also known as Haritaki, is sometimes used in traditional lime mortar due to its beneficial properties.

2.Kadukkai acts as a natural setting retarder, slowing down the setting time of lime mortar.

2.It helps prevent biological growth like algae fungi on walls, improving durability.

3.Lime mortar is one of the world's oldest construction materials. It has a long and rich history from all around the world and can be found in many of the world's most iconic buildings.

6500-4000 BCE The f ist mortars contained no lime and were found to mainly contain a mix of mud, clay or sand. These materials were used because of their low cost and general availability. The Ancient Egyptians used gypsum mortars as a lubricant so that the large stones used to build the pyramids could be dragged into place.

4000 BCE The beginning of the use of the Egyptian mortar found that Limestone, when burnt and combined with water, produced a material that would harden with age. The first documented use of this was when the pyramids were plastered using a lime based plaster.

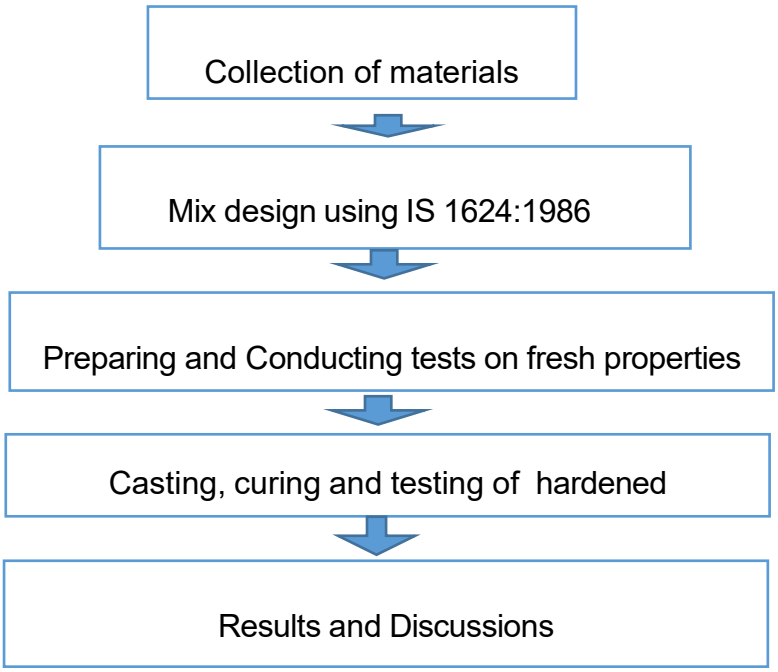
150 BCE It is unclear when the Romans started to use lime mortar but by around 150BCE it was a common practice. The Romans developed a hydraulic setting lime mortar with the addition of volcanic ash which is a pozzolan.

150BCE Present Day Lime mortar continued to be used from the Roman Empire up until around the 19th century where it was surpassed in usage by portland cement mortars.

Objective:

1. To investigate the fresh and hardened properties of lime mortar using KADUKKAI (Teminalia chebula).

Methodology:



EXTRACT PREPARATION:

KADUKKAI **Jaggery** **Fermented water**

Explanation: For 1L of water add 200g of Kadukkai ,200 g of Jaggery and egg white only.Then, keep it for 15 days fermentation

MORTAR PREPARATION:

Mould size:

50mmx50mmx50mm

70mmx70mmx70mm

Mortar preparation:

Lime (1 part) Sand (2 part) lime and sand (1:2)

LABORATORY TESTS ON LIME:

- ❖ VISUAL EXAMINATION
- ❖ BALL TEST
- ❖ WORKABILITY TEST
- ❖ HYDROCHLORIC ACID TEST
- ❖ PLASTICITY TEST
- ❖ COMPRESSIVE TEST
- ❖ WATER ABSORBTION TEST
- ❖ CARBONATION TEST

1.VISUAL EXAMINATION TEST:

LIME POWDER

Examine the lime for colour and for state of aggregation, namely, lumpy, powdery, soft, hard, ete. Class C and D limes mostly used for whitewash have white colour. Lumpy form may indicate quick lime or unburnt limestone but the former may be differentiated by its porous structure. The hydrated lime supplied should not contain coarse and gritty lime pieces larger than about 250 mm when rubbed in be tween the thumb and the finger.

2.BALL TEST

SIZE:50mm

Make a balls of about 50 mm diameter of quick lime mixed with just sufficient water to give a stiff paste, and leave them undisturbed for a period of six hours. Immerse in a basin of water**.**

3.HYDROCHLORIC TEST

Place sufficient quantity of powder lime into a 50-ml graduated glass cylinder, which on gentle tapping for about two minutes or so, settles down to about S-ml mark with a neat surface on the top. Into this cylinder, fill up to 25-ml mark hydrochloric acid 1 : 1 preferably along a glass rod placed in the cylinder so that the acid does not get smeared aU over the side of the cylinder. The contents, after stirring with a glass rod, should not leave much inert material at the bottom of the cylinder. To ensure that the

inert material left at the bottom of the cylinder after stirring with a glass rod, does not contain any calcium carbonate, add excess of hydrochloric acid drop by drop with constant stirring till there is no effervescence. The cylinder with its contents shall then be kept standing for about 24 hours for observation of gel formation.

4.WORKABILITY TEST:

Size: H=9cm,Dia:4cm

1:2

Mortar mixing

casting

The test shall be performed on the same mortar as is subsequently required to be used in the construction. By throwing, with the same effort as for rough-cast work, a handful of the mortar on the surface on which it is to be used and by noting how much area is covered and how much mortar is picked up, the mason may be able to judge the workability. The spread of mortar on throw of a spadeful of mortar on trowel to the wall shall be at least double in size and greater part of it shall remain stuck to the wall for a good workability.

5:PLASTICITY TEST:

1:2

Mix the lime with water to a thick cream like consistency and leave preferably overnight.Then, spread it like butter with the help of a knife on a blotting paper.

Test on Hardned Lime Mortar:

6.WATER ABSORBTION TEST:

CURING

WET WEIGHT

IN OVEN

DRY WEIGHT

Prepare standard lime mortar cubes or specimens.Allow the mortar to cure for the required time (usually 28 days) in a controlled environment.Drying the specimen place the cured specimens in a ventilated oven at a temperature of 105 ± 5°C until a constant weight is achieved.Record the dry weight of the specimen after cooling it to room temperature.Water Immersion Submerge the specimen completely in water at room temperature (20–30°C) for 24 hours. Ensure no air bubbles are trapped on the surface during immersion. After 24 hours, remove the specimen from the water. Wipe the surface gently with a damp cloth to remove excess water without disturbing the saturated state.Weighing the Saturated Specimen.Immediately weigh the specimen to get the saturated weight .

7.COMPRESSION TEST:

The compressive strength test of lime mortar is performed to determine its load-bearing capacity and suitability for various applications.The procedure begins with preparing the lime mortar mix according to the specified design, ensuring uniformity.The mortar is then placed in molds, typically of 50 mm cube dimensions and compacted in layers to remove air voids.After setting in molds for 24 hours under controlled conditions.Once cured, the specimens are tested in a compression testing machine.The specimens are placed centrally on the machine platen and a gradual load is applied uniformly until the specimen fractures. The maximum load at failure is recorded. The compressive strength is then calculated using the formula =P/A, where P is the maximum load at failure, and A is the cross-sectional area of the specimen. The typical compressive strength values for lime mortar range from 0.2–1.0 MPa for pure lime mortars and 2–5

MPa for hydraulic lime mortars, depending on curing conditions, lime type and mix proportions as shown in the figure.

Results & Conclusions:

- **Result of Fresh lime mortar test:**

1.Hydrochloric Acid Test:

If the effervescence indicating the liberation of carbon dioxide is abundant, it may be inferred that either the lime has a substantial proportion of calcium carbonate because it has not been burnt properly and adequately and/or stored properly.The lime will give some effervescence.The volume of insoluble residue at the bottom of the cylinder compared with the original volume of lime will indicate the proportion of inert material and give an idea if it is excessive or not.In case of hydraulic lime, a good thick gel will be formed and below it some inert material will be deposited.If the gel is so thick, as not even to flow when the cylinder is turned upside down, the inference may be that the lime is of Class A. If the gel formed is not quite thick and tends to flow on being tilted, the lime may be class B or E. If there is no gel formation the lime may be Class C, D Or F.

2.Ball test:

Signs of disintegration within a few minutes show that time may be of Class C or D. Very little expansion and numerous cracks sometimes seen on the surface show that lime may be of Class B. No signs of disintegration under water show that lime may be of Class A.

3.Impurity test:

The extent of residue calculated as percentage of the initial mass of material gives an idea about the burning efficiency of the kiln or the presence of unreactive portions in the lime lupplied as given below: a) Class B and F will have residue not more than 10 percent, and b) Class C and D will have residue not more than 5 percent

4.Plasticity test:

A comparison with the behaviour of performances of standard lime of known good quality with a little experience helps in judging its plasticity. If it is spreadable with ease without any gritty material and with soft strokes, then it may have good plasticity.

5.Workability test:

The true slump is obtained.The slump reduced by 2cm after removal of slump cone. It is flexible and allows buildings to breathe, preventing cracks.Compared to cement mortar, it is more environmentally friendly.

- **Result of hardned lime mortar:**

6.Water absorption test

The water absorption rate for lime mortar without additives is quite high at 23.75 percent refer table 4.7 .The water absorption rate for lime mortar with additives starts at 71.2 percent at 28 days refer table 4.8, which is lower than that without additives. As the mortar cures, the absorption rate drops significantly.The addition of additives to lime mortar significantly reduces its water absorption, enhancing its moisture resistance and durability over time.

WATER ABSORPTION TEST LIME MORTAR FOR 28 DAYS

PROPORTION	**WET WT(W1) GM**	**DRY WT(W2) GM**	**WATER ABSORPTION TEST(%)=(W2-W1)/W1*100**
1:2	600.2	450.3	24.99
1:2	599.06	466.3	22.16

WATER ABSORPTION TEST LIME MORTAR WITH BIO ADITTIVES FOR 28 DAYS

PROPORTION	WET WT(W1) GM	DRY WT(W2) GM	WATER ABSORPTION TEST(%)=(W2-W1)/W1*100
1:2	550	450	18.8
1:2	545.32	460.3	15.73

WATER ABSORPTION TEST LIME MORTAR FOR 56 DAYS

PROPORTION	WET WT(W1) GM	DRY WT(W2) GM	WATER ABSORPTION TEST(%)=(W2-W1)/W1*100
1:2	600	500.3	16.64
1:2	590	510.4	13.39

WATER ABSORPTION TEST LIME MORTAR FOR 90 DAYS

PROPORTION	WET WT(W1) GM	DRY WT(W2) GM	WATER ABSORPTION TEST(%)=(W2-W1)/W1*100

1:2	**600**	**500.3**	**16.64**
1:2	**600**	**510.4**	**13.39**

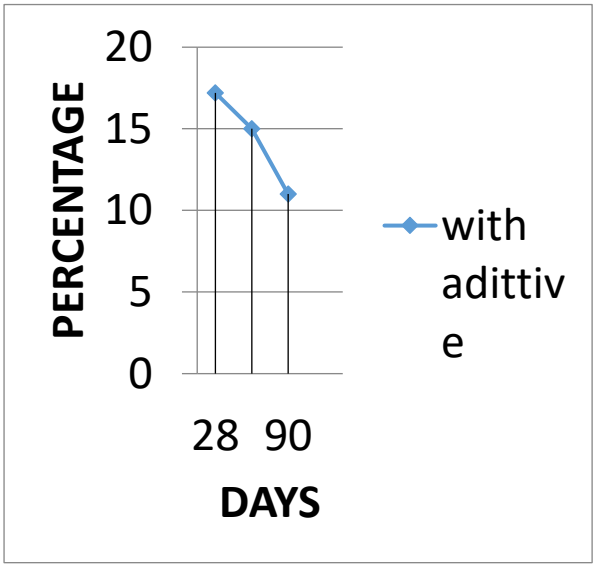


Fig. Water absorbtion

7.COMPRESSIVE TEST:

The compressive strength of lime mortar is significantly enhanced with the addition of bio-additives.At 28 days, the compressive strength of lime mortar without additives is 0.25 N/mm², refer table 4.1.While with additives refer table 4.2 it reached 0.61 N/mm². At 56 days, the strength improved to 0.47 N/mm² without additives and 0.69 N/mm² with additives refer table 4.3 and table 4.5 respectively. By 90 days, the mortar without additives achieved 1.10 N/mm², whereas the mortar with additives recorded the highest strength of 1.22 N/mm² by reffring 4.6 and 4.4 respectively. These results demonstrate the effectiveness of bio-additives in improving the strength and durability of lime mortar over time and the graph from the result.

COMPRESSIVE TEST OF LIME MORTAR FOR 28 DAYS WITHOUT ADDITIVES

PROPORTION	AREA mm^2 (A)	LOAD KN (F)	COMPRESSIVE STRENGTH=F/A(N/mm^2
1:2	4900	1.2	0.24
1:2	4900	1.3	0.26

COMPRESSIVE TEST OF LIME MORTAR FOR 28 DAYS WITH ADDITIVES

PROPORTION	AREA mm^2 (A)	LOAD KN (F)	COMPRESSIVE STRENGTH=F/A(N/mm^2
1:2	4900	2.7	0.54
1:2	4900	3.4	0.68

COMPRESSIVE TEST OF LIME MORTAR FOR 56 DAYS WITHOUT ADDITIVES

PROPORTION	AREA mm^2 (A)	LOAD KN (F)	COMPRESSIVE STRENGTH=F/A(N/mm^2
1:2	4900	2.3	0.469

1:2	4900	2.6	0.53
1:2	4900	2.1	0.42

COMPRESSIVE TEST OF LIME MORTAR FOR 56 DAYS WITH ADDITIVES

PROPORTION	AREA mm^2(A)	LOAD KN(F)	COMPRESSIVE STRENGTH=F/A(N/mm^2)
1:2	4900	3	0.61
1:2	4900	3.8	0.77
1:2	4900	3.4	0.7

COMPRESSIVE TEST OF LIME MORTAR FOR 90 DAYS WITHOUT ADDITIVES

PROPORTION	AREA mm^2 (A)	LOAD KN (F)	COMPRESSIVE STRENGTH=F/A(N/mm^2
1:2	4900	5	1.02
1:2	4900	5.5	1.12
1:2	4900	5.6	1.14

COMPRESSIVE TEST OF LIME MORTAR FOR 90 DAYS WITH ADDITIVES

PROPORTION	AREA mm^2 (A)	LOAD KN (F)	COMPRESSIVE STRENGTH=F/A(N/mm^2
1:2	4900	5.8	1.18
1:2	4900	6	1.22
1:2	4900	6.2	1.26

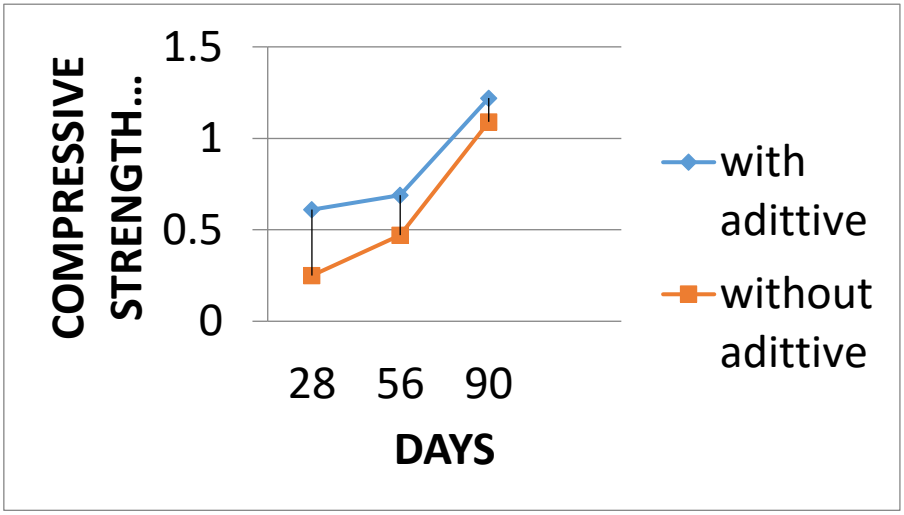


Fig . Compressive strength

8.CARBONATION TEST:

The first image shows unreacted lime ($Ca(OH)_2$) with a pink color, indicating an alkaline environment.The second image shows partial carbonation, with some areas turning neutral or white due to the formation of calcium carbonate ($CaCO_3$).The third image shows extensive carbonation, with most areas no longer pink, indicating the complete conversion of lime to calcite ($CaCO_3$).

Unreacted CaO yet to be activated by carbon dioxide

Portlandite and calcite

Formation of major amount of Portlandite and calcite

Fig .Carbonation test

Conclusion:

1. **Visual Examination :** From this discussion we conclude that the lime is powdery form and soft. Hence ,it is belongs to class C and D so ,it is used for white wash and repair works.

2. **Ball Test :** No signs of disintegration under water shows that lime is Class A.

3 .Hydrochloric Test : In case of hydraulic lime, a good thick gel will be formed and below it some inert material will be deposited.If the gel is so thick, as not even to flow when the cylinder is turned upside down, the inference may be that the lime is of Class A.

4. Workability Test : The true slump is 7cm obtained.The slump reduced by 2cm.Hence,it is sufficient to use in construction field.This test results helps to adjust the mortar mix propotions to achieve the desired consistency for effective masonry work.

5. Plasticity Test : The lime is spreadable with ease without any gritty material and with soft strokes , then it have good plasticity.

6. Carbonation Test : Carbonation test result prove the adittion of fermented bio adittives has enhanced the carbonation process when compared with the conventional lime mortar.Hence,the carbonated lime mortar indicates that the material has properly set and gained the strength over time.

7. Water Absorbtion Test : The addition of additives to lime mortar significantly reduces its water absorption, enhancing its moisture resistance and durability over time.The values obtained satisfy the permissible limit that is 30-40 percentage.

8. Compressive Test: The addition of bio-additives significantly enhances the compressive strength of lime mortar at all curing durations. Mortar with additives showed consistent improvement compared to mortar without additives, demonstrating the effectiveness of additives in accelerating the carbonation process and improving the long-term.

Future Scope of the Project:

• **Strength Improvement –** Test different Kadukkai concentrations to enhance mortar strength.

• **Heritage Conservation –** Check its suitability for restoring old buildings.

• **Eco-Friendly Applications –** Explore its use as a sustainable alternative to cement mortar.

• **Water and Crack Resistance** – Examine its ability to repel water and prevent cracks. • Modern Construction Use – Investigate its potential in contemporary building projects.