Experimental Investigation on Masonry Mortar by Using Waste Material

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ABSTRACT - This study examines the viability of blended lime-cement mortars as an alternative to blended lime-natural hydraulic lime mortars in restoration projects, given the limited availability of natural hydraulic lime in many regions compared to cement. The research emphasizes the pore structure of both types of mortars and its impact on water transport properties, early mechanical strength, and compatibility risks. The effects of binder type, binder composition, and binder-to-aggregate ratios on pore structure were analyzed. Cement was found to have a more pronounced influence on the mechanical and water transport characteristics of the mortars compared to hydraulic lime, which affects their compatibility. Based on the findings, lime-cement mortars can be a feasible option, provided the cement content exceeds 25% of the total binder mass to enhance early strength but remains below 50% to preserve compatibility. However, the mortar containing 25% natural hydraulic lime demonstrated the most promise for use in restoration efforts.

Key Words: *hydraulic lime, pore structure, masonry mortar*.

1.INTRODUCTION

Masonry mortar is a uniform mixture comprising specific proportions of cement, lime, fly ash, cement block powder, and water. It is regarded as the strongest type of masonry mortar, making it a preferred choice for structural construction. Historically, masonry has been a widely used and effective method for cladding and constructing load-bearing structures. Today, it represents a significant portion of buildings globally, many of which hold historical and cultural value. Unlike materials such as concrete or steel, masonry is a heterogeneous material with complex, non-linear, and anisotropic behavior due to its varied components and numerous interfaces. For centuries, lime mortars served as the primary binding material in masonry. However, because lime gains strength slowly through carbonation, it was gradually replaced—first by hydraulic lime and later by Portland cement (PC), which provides rapid strength through hydration. In the last two decades, there has been a resurgence of interest in using hydrated and hydraulic lime mortars for restoration projects and new construction. This study aims to enhance understanding of lime-mortar masonry's properties. Understanding the strength and deformation characteristics of masonry is crucial, as these factors influence its long-term performance and determine allowable stresses and stiffness in modern building design codes.

1.1 Advantages of Masonry Mortar

1. Maintenance free – Most of wall not require painting.
2. Economic – Use of locally available materials and availability of labour.
3. Without expensive plant and machines.

1.2 Disadvantage of Masonry Mortar

1. A moisture uses – If not properly designed and constructed masonry mortor can absorb a moisture. Leading two issues like mold or a deterioration.
2. Limited flexibility- Once constructed structure are not easily modified
3. Significant operation and maintain requirement.

2. RESEARCH SIGNIFICANCE

1. Mortar-based materials are among the most essential building materials globally, with annual production exceeding 10 billion tons.
2. Reducing the environmental footprint, as well as the energy and CO2 emissions associated with cement used in construction, is gaining importance due to resource depletion and the growing impact of greenhouse gas emissions.
3. The premature failure of cement composites, which leads to increased consumption of natural resources, poses a significant challenge in the pursuit of sustainable infrastructure systems.

3. LITERATURE REVIEW

A) R.M. Damle, N. Khatri, R. Rawal (2023):- The aim of this study was to evaluate and compare the hygrothermal performance of lime plaster and cement plaster. Two identical test cells, each with a volume of 1 m³, were constructed using brick masonry. One cell was finished with cement mortar and plaster, while the other was finished with lime mortar and lime plaster. Over a period of 74 days, environmental parameters such as indoor air temperature, relative humidity, globe temperature, surface temperatures, and moisture content were monitored. The results showed that the cell with lime plaster maintained a temperature 3–5°C lower, and the indoor conditions were comfortable for 40% longer compared to the cement-plastered cell. Additionally, the lime plaster demonstrated a greater moisture buffering capacity, helping to stabilize indoor humidity levels. These findings were based on passive responses to external weather conditions without internal influences. Further studies involving full-sized buildings would be needed to confirm the benefits of lime plaster observed in this experiment.

B) B.A. Silva, A.P. Ferreira Pinto, A. Gomes (2023):- This paper examines the potential of using blended lime-cement mortars as alternatives to traditional blended lime mortars in restoration projects. This is particularly relevant due to the limited availability of natural hydraulic lime in many regions, whereas cement is more widely accessible. The study focuses on the pore structure of both types of blended mortars and its impact on water transport, initial mechanical strength, and the risk of incompatibility. It also explores how variations in binder type, composition, and binder-to-aggregate ratio influence pore structure. The findings revealed that cement had a more significant effect on both the mechanical and water transport properties of the mortars compared to hydraulic lime, which affected their compatibility. Based on these properties, blended lime-cement mortars can be used in restoration, provided that the cement content does not exceed 25% of the total binder mass, to ensure early-age strength gain, and remains below 50% to avoid compromising compatibility. However, the blended lime mortar containing 50% natural hydraulic lime showed the greatest potential for restoration applications.

C**)Aranzazu Sierra-Fernandez (2024**):- This research examined the impact of red-clay ceramic aggregates (RCC) and nanoparticle-based solutions of $Ca(OH)_2$ and SiO_2 on the mineralogical, hydraulic, surface, and mechanical properties of lime-based mortars. The incorporation of nanoparticle solutions enhanced the carbonation reactivity, while the ceramic aggregates promoted a greater conversion of portlandite to calcite on the surface, suggesting a reduction in porosity during carbonation. The study observed pozzolanic reactions and the formation of new calcium silicate compounds, alongside improved compaction, smoother surfaces, and the formation of microcracks. Adding ceramic aggregates increased porosity, while nanoparticles significantly raised the number of mesopores. The inclusion of both ceramic aggregates and nanoparticles led to an increase in the specific surface area of the mortars, but also resulted in higher open porosity and lower density and compressive strength. These results provide a foundation for future work aimed at optimizing lime-based mortars to achieve a balance between hydraulic properties, surface characteristics, and mechanical strength, all while maintaining porosity.

D) Omid Dehghania (2024):- This study contributes to the development of more sustainable solutions for pedestrian pavement construction. In the search for environmentally friendly alternatives to ordinary Portland cement, which is widely used in concrete paving blocks, the research investigates the potential of using ceramic waste powder. A parametric study was conducted to examine the effects of replacing cement with ceramic waste powder on the mechanical properties and durability of mass-produced pressed concrete blocks. The results indicate that incorporating ceramic waste powder as a partial replacement for cement significantly improves the strength and durability of the paving blocks. Specifically, mixtures with 20% and 30% ceramic waste powder showed a 30% increase in compressive strength and a 19% increase in tensile strength compared to the control samples.

4. MATERIAL USED IN THE STUDY

4.1 Cement: Masonry mortar is composed of cement combined with fine aggregates, whereas concrete is made using sand and gravel. Concrete is one of the most commonly used materials worldwide, second only to water in terms of global consumption. The cement used in construction is generally inorganic, derived from lime or calcium silicate, and classified as either hydraulic or non-hydraulic depending on their ability to set when exposed to water (as seen with hydraulic and non-hydraulic lime plaster).

4.2 Lime: Hydrated lime, also known as calcium hydroxide, is identified by various other names such as caustic lime, builders' lime, slack lime, cal, or pickling lime. Though relatively insoluble in water, it dissolves to form an alkaline solution with a pH of around 12.4 when in pure water at room temperature. This solution, known as limewater, is a moderate strength base that reacts with acids and can corrode certain metals like aluminum, while protecting others, such as iron and steel, through a process called passivation. Hydrated lime has a polymeric structure, typical of metal hydroxides, and is commercially produced by adding water to lime.

4.3 Concrete Block Powder: A concrete block, or concrete masonry unit (CMU), is primarily used in the construction of walls. It is a precast concrete product, meaning the blocks are molded and hardened prior to being delivered to the construction site. Concrete blocks often feature one or more hollow cavities, and their surfaces can be smooth or designed with patterns. These blocks are stacked and bonded with fresh concrete mortar to form walls of varying lengths and heights.

4.4 Fly Ash: Fly ash is a byproduct produced during the combustion of pulverized coal in power plants. It is captured from exhaust gases through electrostatic precipitators or bag filters. While fly ash may appear similar to Portland cement in form, it differs chemically. It reacts with calcium hydroxide, a byproduct of cement and water reactions, to create additional cementitious compounds that enhance concrete properties. The extent of fly ash's cementitious qualities varies depending on its chemical composition and physical properties. The chemical reaction between fly ash and calcium hydroxide occurs more slowly compared to that of cement and water, resulting in delayed hardening of concrete. This delayed hardening, along with the variability of fly ash, can present challenges for concrete producers, especially when finishing steel-troweled floors.

5. METHODOLGY

This are the steps to be followed in this project

1. Selection Of Material
2. Lab Testing (Chemical & Physical Properties)
3. Proportioning
4. Casting And Drying
5. Testing On Cubes
6. Analysis Of Result
7. Conclusion

5.1 PREPARATION OF TEST BLOCK

1. Prepare a neat cement paste by gauging the cement with 0.85 times the water required to give a paste of standard consistency. Potable or distilled water shall be used in preparing the paste. The paste shall be gauged in the manner and under the conditions prescribed in IS:4031(Part4)-1988.
2. Start a stop-watch at the instant when water is added to the cement. Fill the Vicat mould with a cement paste gauged as above, the mould resting on a nonporous plate. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block.
3. Immediately after moulding, place the test block in the moist closet or moist room and allow it to remain there except when determinations of time of setting are being made.

5.2 TESTINGS OCCURRED IN PROJECT

5.2.1. INITIAL SETTING TIME

1. Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle (C); lower the needle gently until it comes in contact with the surface of the test block and quickly release, allowing it to penetrate into the test block. In the beginning, the needle will completely pierce the test block.
2. Repeat this procedure until the needle, when brought in contact with the test block and release das described above, fails to pierce the block beyond 5.0 ± 0.5 mm measured from the bottom of the mould. The period elapsing between the time when water is added to the cement and the time at which the needle fails to pierce the test block to a point 5.0 ± 0.5 mm measured from the bottom of the mould shall be the initial setting time.

5.2.2. FINAL SETTING TIME

1. Replace the needle (C) on the Vicat apparatus with the needle equipped with an annular attachment (F).
2. The cement will be considered fully set when the needle gently applied to the surface of the test block makes an impression, while the annular attachment does not.
3. The time taken from the addition of water to the cement until the needle creates an impression on the block, while the attachment fails to do so, will be the final setting time.
4. In case a scum forms on the surface of the test block, use the underside of the block for the test.

5.2.3. FINENESS OF CEMENT (IS 4031:1991)

The fineness test of cement determines the particle size, as shown in Fig. 3.9. As a general rule, finer cement particles result in better-quality cement, while coarser particles are less desirable. According to Indian standards, no more than 10% of the cement particles should remain on the sieve (90 µm).

5.2.4.SOUNDNESS TEST OF CEMENT (IS 4031 PART 3)

Specific gravity refers to the ratio of a substance's density to the density of a reference substance at a fixed temperature. In other words, it is the ratio of the mass of a substance to the mass of the reference substance. This principle applies to cement as well. The volume must remain constant in both the substance and reference material; if not, the concept of specific gravity becomes invalid, as the mass or density would change.

5.2.5. TEST ON SPECIFIC GRAVITY OF CEMENT:-

The specific gravity of cement is defined as the ratio of the weight of a given volume of cement to the weight of an equal volume of water. It is a dimensionless number that indicates how much heavier the substance is compared to water. To determine the specific gravity of cement, the weight of a specified volume of cement is compared to the weight of an equal volume of water.

6. MIX PROPORTION CALCULATION

6.1 MIX CALCULATION:-

1:3 Ratio cement mortar (concrete bock powder)
Concrete block powder 1m^3
Cement 1/3 proportion of concrete block powder
= 1/3 *1m^3
= 0.33m^3
= 0.33*1440 kg/m3
= 475.2 kg/m3
Cement : Concrete block
4.75.2 : 1425.6
75mm 1 mould = 0.00042875*475.2
1 mould = 0.200 kg/m^3
Cement=200gm
Water Ratio :-
Ratio of mortar = 1:3
Weight of cement = 100 gm
Weight of Concrete block powder = 200gm
Amount of water = (100 + 200) *10/100= 30 ml

7. RESULT

7.1 The Initial Setting Time Of The Given Cement Sample Is Found To Be 1.9mm For 30minutes.

7.2 The Final Setting Time Of The Given Cement Sample Is Found To Be 0.6 For 60 Minutes.

7.3 Fineness Test -The result of a fineness test of cement shown in table-1 which will be 5.67% is below the IS value(10%) and hence cement is in good condition.

TABLE -1 RESULT OF FINENESS TEST

SR. NO.	WEIGHT OF CEMENT SAMPLE (gm	WEIGHT OF WATER	STANDARD CONSISTENCY (%)	PENETRATION RATE
1.	400	120	30	5mm
2.	400	112	28	5mm
3.	400	100	25	5mm

7.4 Specific Gravity of Cement

SR. NO.	W1 (gm)	W2 (gm)	W3 (gm)	W4 (gm)	SP. GR OF CEMENT
1.	178	228	428	386	3.23

TABLE 2 – SPECIFIC GRAVITY RESULT

(W2-W1) - (W3- W4)* 0.7
Where,
W1 = Weight of empty flask
W2 = Weight of flask + Cement
W3 = Weight of flask + Cement + Kerosene
W4 = Weight of flask + Kerosene
1 178gm 228gm 428gm 386gm 3.23
Here, the specific gravity of kerosene is 0.79 g/cc.
Result:- The specific gravity of sample of cement is 3.23.

7.5 Mix Calculation For Compressive Strength :-
Compressive strength = load failure / Specimen area
The size of cube is 75mmX75mmX75mm .
We apply the load 3000 KN on cube.

Mixed Design Result for 7 Days 14 Days 28 days

MIX DESIGN	LOAD FAILURE (KN)		
MIX DESIGN	**7 DAYS**	**14 DAYS**	**28 DAYS**
M1	-	-	-
M2	12	24	29
M3	22	32	39
M4	24	39	47
M5	25	52	60
M6	30	36	45
M7	25	37	46

Table 3 – LOAD FAILURE VALUES

MIX DESIGN	COMPRESSIVE STRENGTH (N/mm^2)		
	7 DAYS	**14 DAYS**	**28 DAYS**
M2	2.1	4.26	5.1
M3	3.91	5.68	6.93
M4	4.26	6.4	8.35
M5	4.44	6.93	9.66
M6	5.33	6.57	8
M7	4.44	9.24	8.177

TABLE 4- COMPRESSIVE STRENGTH RESULT

Where,
1. M1 = Ordinary Portland cement
2. M2 = Lime
3. M3 = Lime + OPC
4. M4 = OPC +Lime + Flyash
5. M5 = OPC+ Lime+ Flyash
6. M6=OPC+ Lime+ Concrete block powder
7. M7= OPC+ Lime+ Concrete block powder

8. CONCLUSION

In this test we determine the compressive strength of cement mortar, finally we got a result after doing all procedure accurate. We determine the compressive strength of all cubes because each cubes have a different compressive strength, if we compare aware result with standard which is the compressive strength must we greater than (7.5mpa) for 28 days. As we known our result is greater than standard. If we have an error in this test than we will have them in the processes especially in the compaction of cement mortar process, but we did the test on 7 cubes and we got the result. In conclusion the purpose this test is to determine the resistance of cement mortar from compression load and compare the result with standard finally we got the result.

9. PHOTOGRAPHS OF THE STUDY

Fig. 1 Weighing of Material

Fig. 2 Casting Process

Fig 3 Demould Blocks

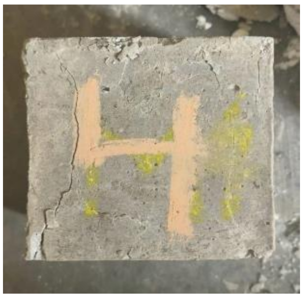

Fig 4 Cracks Developed

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