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Durability Analysis of Lime Mortar Using Silica Fume

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Abstract - *The application of lime mortar for the purpose of bonding, protecting, and enhancing constructions has been a common activity throughout history. Understanding the mechanical properties and carbonation process of lime mortar is essential for the successful repair and conservation of architectural heritage. The compatibility and durability of lime mortar within architectural history require an analysis of related mechanisms to guarantee its suitability for modern settings. This research delineates the mechanical properties of lime mortar and examines the mechanism of its carbonization. The main objective of the present study is to study the properties of lime mortar with the addition of silica fume. From the test results, the properties such as consistency limit, setting time and flow rate was analyzed. Also, the compressive strength was increased around 38% with the addition of silica fume. The results of this study will help to utilize lime mortar with additives a s a repair material for historical structures and as masonry mortar.*

***Key Words*: carbonation, compatibility, durability, lime mortar and silica fume**

1. INTRODUCTION

Ancient buildings all over the world are examples of the architectural skills of their respective eras. These buildings are notable for their monumentality, impressiveness, and durability, and they continue to express their strength even today. Academics are gaining a grasp of the materials and methods necessary for environmentally responsible building practices due to the enduring and magnificent structures built throughout history, which also resist a wide range of climatic conditions. "Lime" is a primary binder material utilized since the beginning of construction, which has been thoroughly examined in this research. Early improvements in construction technology around the world used lime as the main binder material. Lime is easy to find and can be quickly processed by burning it (calcination) and then slaking it into a form that can be used. This made it easier to build structures that would last longer (Frankeova et al. 2020). The slaking of lime is a simple process that involves adding water (sprinkling) to limestone, which converts calcium oxide into calcium hydroxide.

There are a number of natural processes that can result in lime formation. These include the sedimentation of organic materials such as shells, corals, algae, feces, and other organic debris, as well as chemical sedimentary processes such as the precipitation of calcium carbonate from aquatic settings. It is a sedimentary rock that is calcined to produce calcium oxide, which when combined with water, produces a binding agent with minimal processing. There is no further processing required. This matrix material absorbs atmospheric carbon dioxide when exposed to environmental conditions, resulting in the formation of stable calcium carbonate (the carbonation process). Since ancient times, people have observed the global use of bio-additives as admixtures in lime mortar. Local We have included locally sourced organic materials in lime mortar to enhance its qualities by speeding up the carbonation process within the lime mortar matrix. These additives were easily obtainable and abundant in adjacent regions. The use of locally sourced materials in these structures allowed for environmentally sustainable builds, commonly referred to as traditional construction. The fermentation procedure significantly enhances the characteristics of lime mortar in contrast to ordinary lime mortar (Shivakumar et al., 2021).

Roman mortar matrixes (Kuckova et al. 2021) have produced positive results, which are still visible today in their stability and resilience to disasters (Cultrone *et al.* 2005; Hamdy *et al.* 2019; Cultrone *et al.* 2005; Hamdy *et al.* 2019; Hwang *et al.* 2019; Kuckova *et al.* 2021; Luxbn *et al.* 1995; Ventol *et al.* 2011). Lanas et al. (2003) tested 108 natural lime mortars. The researchers extensively examined the compressive strength, flexural strength spanning curing durations, binder-to-aggregate ratio, and porosity using natural hydraulic lime mortars. In this paper, the enhancement of carbonation strength through the utilization of three different hardness stages, namely C3S and C2S was investigated. It appears that there is a connection between the two properties because the mortar matrix has higher strength and porosity when it contains a high amount of binder. Also, it is suggested to avoid using rounded fine aggregate to maximize the cohesiveness of the mortar matrix.

Shiqiang et al. (2015) conducted an experimental investigation on air lime mortar containing animal blood, a common element in ancient European building materials. Incorporating blood from pigs or lambs into the mortar blend reduced the extended setting time and insufficient strength development of air lime. The protein concentration in the blood boosted the alkaline lime mortar matrix, leading to improved binding strength and greater weather resistance. Thirumalini et al. (2018) performed research utilizing lime in conjunction with organic materials (Kadukkai and Jaggery) to enhance the properties of the lime mortar matrix. When organic matter is mixed in, stable stone structures called weddeddlite are made. These structures act as filling agents, making the lime mortar matrix stronger by reducing the size of the pores in it. Zhong et al. (2019) conducted experiments and studies on the application of shell lime sourced from China's coastal areas. They investigated the water-to-lime ratio, the sand-lime ratio, the curing period, and the addition of glutinous rice as a natural admixture. β-CS was developed as a hydraulic component to enhance the durability of shell lime mortar. Calcination occurred at 1000 degrees Celsius. The glutinous rice improved the properties of conventional shell lime mortar, which were further enhanced with the age of the hardened shell lime mortar. This study investigated the utilization of organic waste materials to enhance the durability characteristics of lime mortar.

Maximo et al. (2020) examined natural products comprising Escherichia coli and microbial cultures that employed a crude glycerol substrate in aqueous solutions for air lime mortar applications. The use of these additions improved the workability of the air lime mortar mix, albeit at the expense of its strength. The decline in strength was seen to enhance in samples subjected to water and ambient conditions that expedited the carbonation rate. The research indicates that the integration of these microbial products is not economically viable relative to the often-employed natural by-products in lime mortar.

In this research, silica fume, an industrial waste, is chosen to be the pozzolanic additive material alongwith the lime mortar. The requirement to enhance critical attributes of these composites in the fresh and hardened stage, namely workability, durability and prolonged setting time, necessitated the introduction of additives/admixtures in lime mortars.

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2. MATERIALS AND METHODS

2.1 Quick lime

Numerous aesthetically pleasing structures exist globally, and lime serves as a binding agent for bricks. The unrefined environment, together with its physical capabilities, mechanical durability, and dependability attributes, may influence the textural properties of the robust clean complex. The procurement technique may vary based on the private utilization of the textural system. Consequently, it is essential to evaluate the characteristics of lime mortar while analyzing the conventional construction of unmodified structures. Assessing the properties of lime mortar is essential for acquiring intermediary mortars that facilitate the restoration of buildings in excellent shape.

2.2 Fine aggregate

The fineness, specific gravity and the bulk density of the M sand were found as 2.39, 2.66 & 1560 kg/m^3 respectively. The particle size distribution curve is shown in Figure 1.

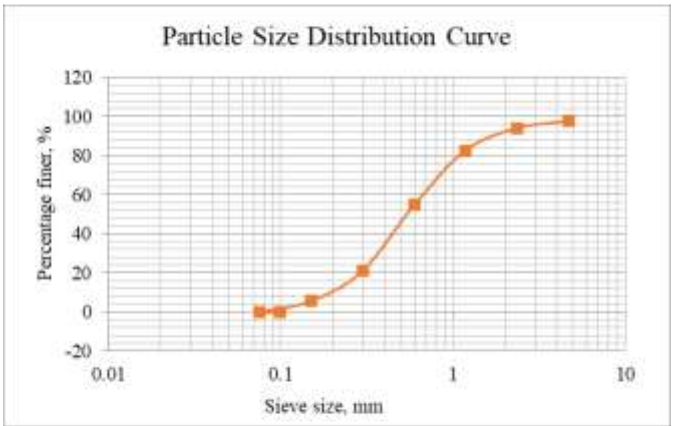

Figure 1. Particle size distribution curve

2.3 Silica fume

The Silica Fume was sourced from an industrial supplier. Silica fume functions as a partial replacement for cement. The composition of silica fume is as follows: Consists of over 90 percent silicon dioxide Supplementary ingredients comprise carbon, sulfur, and oxides of aluminum, iron, calcium, magnesium, sodium, and potassium. The composition of silica fume is as follows: The diameter varies from around 0.1 micron to 0.2 micron. Surface area is approximately 30,000 m^2/kg. The density varies from 150 to 700 kg/m^3.

3. PROPERTIES OF LIME MORTAR

S NO	PARTICULARS	CEMENT VALUES	OBTAINED LIME VALUES
1.	CONSISTENCY TEST	5 to 7mm	8mm
2.	INITIAL SETTING TIME TEST	2 hours	3 hours
3.	FINAL SETTING TIME TEST	24 hours	48 hours

3.1 Consistency of lime putty

The amount of water that is required to achieve the acceptable level of workability in accordance with the standards for increased compressive strength is what determines the consistency of the binder material. In most cases, the mechanical qualities of hardened mortar are diminished when the water content is more considerable. On the other hand, the examination of lime mortar was carried out by means of a flow table test in accordance with IS 6932(Part 8)-1973. The Vicat apparatus was utilized in order to analyze the consistency of lime putty. To attain uniformity in lime putty, 400 grams of lime were employed, with the water content modified from 30% till the needle penetrated to a depth of 33 to 35 mm. The higher water content around 38% is needed in the case of lime compared to cement and shown in Figure 2.

Figure 2. Consistency test

3.2 Workability Testing

Water content is a key factor in workability and directly affects the initial flow of mortar. Due to the complexity of circumstances the workability of mortar is affected by the quality and quantity of aggregates and binders. An effective approach to ascertain the suitable water content for mortar is to find an optimal initial flow. The initial flow measures the prepared mortar, taking into account many elements that affect workability, such as porosity, aggregate size and shape, binder type, and the relative proportions of aggregate to binder. The mortar water content was suggested as 17-19% to possess the good workability. The flow table set up is shown in Figure 3.

Figure 3. Flow table set up

3.3 Setting Time Properties of Lime Putty

The setting time characteristics of lime were evaluated utilizing a Vicat apparatus in accordance with IS: 6932 (Part 11) - 1983, employing lime putty as specified in IS: 6932 (Part 8) - 1973. The initial setting time of lime putty, with varying amounts of silica fume, ranged from 2 to 3 hours, whereas the setting time with ordinary water was 5 to 6 hours. The ultimate setting time of the lime putty ranged from 5 to 8 hours.

3.4 Compressive Strength

Compressions tests were conducted on mortar cube after 28 days is shown in Figure 4. Cube specimens measuring 100mm X 100mm X 100 mm were subjected to compression testing after being exposed to environment for 28 days. Figure 5 shows a gradual increase in the strength of lime mortar samples. The compressive strength significantly increased with the addition of silica fume.

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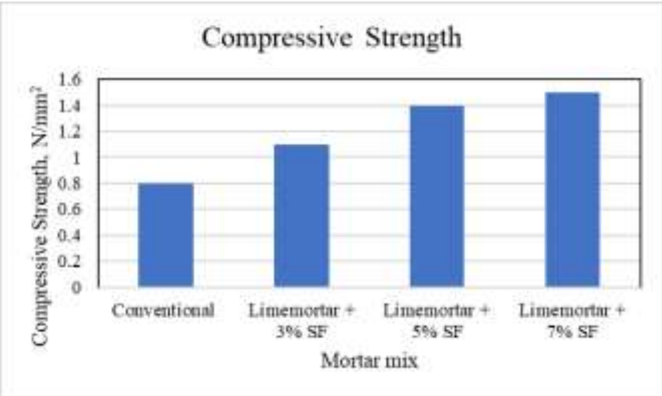
Figure 4. Compressive strength test



4. CONCLUSIONS

The characterization study offers varied perspectives into the ancient mortar samples. Understanding and formulating a comparable substance for ancient structure is a fundamental reason for generating an appropriate repair material in alignment with preservation standards. The notable improvement in compressive strength due to the inclusion of additives is clearly demonstrated in the results. The attainment of strength in lime mortar, characterized by an increased fine aggregate content and a reduced binder content ratio (1:3), was enhanced with the addition of silica fume, which exemplifies a superior strength principle. Moreover, it is significant that water curing was essential for the cement masonry chamber, but air curing sufficed for the lime masonry chamber, hence increasing the embodied energy of the cement masonry chamber in comparison to the lime masonry chamber.

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BIOGRAPHIES

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