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Performance Evaluation of Polymer-Modified Lime Mortar Incorporating Recycled Brick Powder

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***Abstract*— The increasing environmental impact of Portland cement production has accelerated the search for sustainable and eco-friendly construction materials. Lime mortar, a traditional binder extensively used in historical masonry, offers excellent compatibility, breathability, and durability; however, its relatively low early-age strength restricts its wider structural applications. The present study investigates the mechanical performance of polymer-modified lime mortar incorporating recycled brick powder (surkhi) as a sustainable pozzolanic material. Hydrated lime, recycled brick powder, a commercially available polymer additive, plasticizer, and potable water were used to prepare mortar mixes with lime-to-surkhi ratios of 1:2, 1:3, 1:4, and 1:5. Polymer dosages ranging from 0% to 25% by weight of lime were investigated while maintaining a constant plasticizer dosage of 1%. Experimental investigations included lime classification, water absorption test, sieve analysis, specimen preparation, curing, and compressive strength evaluation at curing ages of 14, 28, and 60 days. The results demonstrated a continuous increase in compressive strength with curing age for all mortar mixes owing to the progressive pozzolanic reaction between lime and recycled brick powder. The optimum mortar composition consisted of a lime-to-surkhi ratio of 1:4 with 20% polymer, which achieved a maximum compressive strength of 34.12 MPa at 60 days, representing approximately 49.26% improvement over the control mix. The findings confirm that recycled brick powder can effectively function as a sustainable pozzolanic material while polymer modification significantly enhances the strength and durability of lime mortar. The proposed mortar offers an environmentally responsible alternative for restoration works and sustainable masonry construction.**

***Keywords*— Compressive strength, Lime mortar, Polymer modification, Pozzolanic reaction, Recycled brick powder, Surkhi, Sustainable construction.**

I. Introduction

The construction industry is one of the largest contributors to global carbon dioxide emissions due to the extensive use of Ordinary Portland Cement (OPC). Consequently, there is growing interest in developing sustainable binders that reduce environmental impacts while maintaining satisfactory engineering performance.

Lime mortar has historically been used in masonry construction because of its excellent compatibility with stone and brick masonry, high vapour permeability, flexibility, and self-healing characteristics. These properties make lime mortar particularly suitable for the conservation and restoration of heritage structures. Despite these advantages, conventional lime mortar exhibits slow strength development and relatively low compressive strength, limiting its application in modern construction. The incorporation of pozzolanic materials and polymer modifiers has emerged as an effective approach to overcome these limitations. Recycled brick powder (surkhi), obtained from construction and demolition waste, contains reactive silica and alumina that participate in pozzolanic reactions with calcium hydroxide released during lime hydration. This reaction produces additional cementitious compounds, thereby improving the mechanical performance and durability of lime-based mortars.

The utilization of industrial and construction waste in cementitious materials has gained considerable attention in recent years because of increasing environmental concerns and the depletion of natural resources. Among various waste materials, recycled brick powder (surkhi) has emerged as a promising supplementary cementitious material due to its high silica and alumina content. When finely ground, brick powder exhibits pozzolanic activity and reacts with calcium hydroxide liberated during lime hydration, producing additional calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-H) compounds. These reaction products improve the strength, durability, and long-term performance of lime mortars.

Several researchers have investigated the influence of pozzolanic materials on lime-based mortars. González-Sánchez et al. (2020) reported that polymeric admixtures significantly improved the cohesion, adhesion, and mechanical properties of lime-based grouts used in heritage conservation. Similarly, Malathy et al. (2022) demonstrated that incorporating silica fume and rice husk ash into lime mortar enhanced compressive strength and refined the microstructure due to increased pozzolanic reactions.

Sales et al. (2023) observed that ceramic waste powder could effectively replace conventional pozzolans in lime mortars while improving sustainability and reducing construction waste.

Recent investigations have also focused on the incorporation of polymers in lime mortar systems. Polymer modification improves internal bonding by forming a continuous polymer film within the mortar matrix, thereby reducing capillary pores and increasing resistance to cracking, shrinkage, and water penetration. RILEM TC 277-LHS (2023) reported that suitable polymer additives significantly improve the workability and durability of modern lime-based mortars without compromising compatibility with traditional masonry. Zhang et al. (2022) further demonstrated that polymer-modified lime mortars exhibited improved carbonation behaviour and superior long-term mechanical performance.

The utilization of recycled brick powder offers additional environmental benefits by diverting demolition waste from landfills and reducing the consumption of natural resources. The brick manufacturing industry generates a considerable quantity of defective and broken bricks during production and transportation. Crushing these waste bricks into fine powder provides an economical pozzolanic material capable of partially replacing conventional binders in masonry mortars. Such practices contribute directly to sustainable construction, waste management, and circular economy principles.

Although numerous studies have investigated either polymer-modified mortars or pozzolanic lime mortars independently, limited research has been conducted on the combined influence of recycled brick powder and polymer additives using different lime-to-surkhi proportions. Furthermore, available literature provides limited information regarding the optimum polymer dosage required to maximize the compressive strength of lime mortar prepared with recycled brick powder. This knowledge gap forms the basis of the present investigation.

The present research experimentally evaluates the engineering performance of polymer-modified lime mortar prepared using recycled brick powder as a pozzolanic material. Various lime-to-surkhi ratios and polymer dosages were investigated to determine the optimum mortar composition capable of providing enhanced compressive strength while maintaining sustainability. The study also evaluates the physical properties of constituent materials, water absorption characteristics of surkhi, particle size distribution, curing behaviour, and compressive strength development at different curing ages.

The outcomes of this investigation are expected to contribute toward the development of environmentally friendly masonry materials suitable for both heritage conservation and modern sustainable construction.

II. Objectives Of The Study

The present investigation was undertaken to achieve the following objectives:

1. To investigate the influence of different lime-to-surkhi mix proportions on the engineering properties of lime mortar.
2. To evaluate the effect of polymer dosage on the compressive strength development of polymer-modified lime mortar.
3. To determine the optimum combination of lime, recycled brick powder, and polymer additive for maximum compressive strength.
4. To assess the suitability of recycled brick powder as a sustainable pozzolanic material for masonry mortar applications.
5. To study the influence of curing period on the strength development of polymer-modified lime mortar.
6. To promote the utilization of construction and demolition waste for environmentally sustainable construction practices.

III. Materials Used

The performance of lime mortar is significantly influenced by the physical and chemical characteristics of its constituent materials. In the present investigation, hydrated lime, recycled brick powder (surkhi), polymer additive, plasticizer, and potable water were used for preparing polymer-modified lime mortar. All materials were selected considering their suitability for sustainable construction and compatibility with lime-based masonry systems. The physical properties of the materials were determined prior to specimen preparation in accordance with relevant Indian Standards.

A. Hydrated Lime

Commercially available hydrated lime conforming to IS 712:1984 was used as the primary binding material. The lime was tested using the Ball Test in accordance with IS 1624:1986 and was classified as Class II Building Lime. The material appeared as a fine white powder with excellent workability and good water-retention characteristics.

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Table I. Physical Properties of Hydrated Lime

Property	Value
Type	Hydrated Lime
Classification	Class II
Colour	White
Specific Gravity	2.20–2.30
Fineness	Very Fine Powder
Standard Consistency	70–80%
Initial Setting Time	4–6 Hours
Final Setting Time	48–72 Hours
Soundness	Satisfactory

Figure 1: Hydrated Lime Used in the Study

Figure 2: Recycled Brick Powder (Surkhi)

B. Recycled Brick Powder (Surkhi)

Waste clay bricks collected from demolished masonry structures were crushed using a Los Angeles Abrasion Machine and subsequently ground to obtain finely powdered brick dust (surkhi). The material was sieved to achieve a grading suitable for mortar preparation.

Surkhi contains appreciable quantities of amorphous silica and alumina, which react with calcium hydroxide released during lime hydration. These pozzolanic reactions form calcium silicate hydrate (C–S–H) and calcium aluminate hydrate (C–A–H), thereby improving compressive strength and durability.

The measured water absorption of surkhi was 26.3%, indicating relatively high porosity. Therefore, additional mixing water was incorporated during mortar preparation to compensate for water absorption and maintain consistent workability.

Table II. Physical Properties of Recycled Brick Powder

Property	Value
Material	Recycled Brick Powder (Surkhi)
Colour	Reddish Brown
Specific Gravity	2.40–2.60
Fineness Modulus	1.5–2.5
Water Absorption	26.3%
Bulk Density	1400–1800 kg/m³
Particle Size Zone	Zone II
Pozzolanic Nature	High

C. Polymer Additive

A commercially available polymer additive was incorporated to improve the bonding characteristics, cohesion, workability, and mechanical performance of lime mortar. Polymer dosages of 5%, 7.5%, 10%, 15%, 20%, and 25% by weight of lime were investigated.

The polymer forms a continuous film within the mortar matrix during curing, reducing internal micro-cracks and capillary pores while improving adhesion between hydrated lime and brick powder particles. This contributes to enhanced compressive strength and improved resistance against moisture penetration.

Figure 3: Polymer Additive Used in the Study

Figure 4: Plasticizer Used in the Study

D. Plasticizer

A liquid plasticizer was incorporated at a constant dosage of 1% by weight of lime throughout the investigation.

The plasticizer improved workability and facilitated uniform mixing without increasing the water content. The use of plasticizer also minimized segregation and improved the consistency of fresh mortar.

E. Water

Clean potable water free from harmful salts, organic matter, oils, and impurities was used for mortar preparation and curing. The quantity of mixing water was adjusted to compensate for the 26.3% water absorption of recycled brick powder, thereby ensuring uniform workability for all mortar mixes.

F. Selection of Materials

The selection of hydrated lime, recycled brick powder, and polymer additive was based on their combined potential to produce a sustainable masonry mortar with improved mechanical performance. Hydrated lime provides compatibility with traditional masonry, recycled brick powder promotes waste utilization and enhances pozzolanic activity, while polymer modification improves bond strength, reduces porosity, and increases durability.

The combination of these materials offers an environmentally friendly alternative to conventional cement-based mortars by reducing carbon emissions, promoting the recycling of construction waste, and extending the service life of masonry structures

IV. Experimental Programme

The experimental programme was designed to evaluate the influence of recycled brick powder (surkhi) and polymer additive on the engineering performance of lime mortar. The study consisted of material characterization, mix proportioning, specimen preparation, curing, and compressive strength testing. All experimental work was carried out in the Civil Engineering Laboratory following relevant Indian Standards to ensure consistency and reliability of the test results.

Table III. Sieve Analysis of Recycled Brick Powder

Sieve Size (mm)	Percentage Passing (%)
4.75	100.00
2.36	97.37
1.18	90.00
0.60	71.05
0.30	43.68
0.15	20.53
0.075	5.79

The well-graded particle size distribution enhanced particle packing, minimized voids, and contributed to improved mechanical performance of the hardened mortar.

A. Mix Proportions

Four different lime-to-surkhi ratios were adopted to investigate the influence of recycled brick powder on mortar performance.

The selected mix proportions were: 1: 2, 1 : 3, 1 : 4, 1 : 5

For each mix proportion, polymer dosages of: 0%, 5%, 7.5%, 10%, 15%, 20%, 25% were investigated.

The plasticizer dosage was maintained at 1% throughout the investigation, while the water content was adjusted considering the measured water absorption of recycled brick powder.

The complete experimental programme consisted of 28 different mortar mixtures, enabling systematic evaluation of the influence of polymer dosage and lime-to-surkhi ratio on compressive strength development.

B. Mortar Mixing Procedure

Figure 5: Mixing of Polymer-Modified Lime Mortar

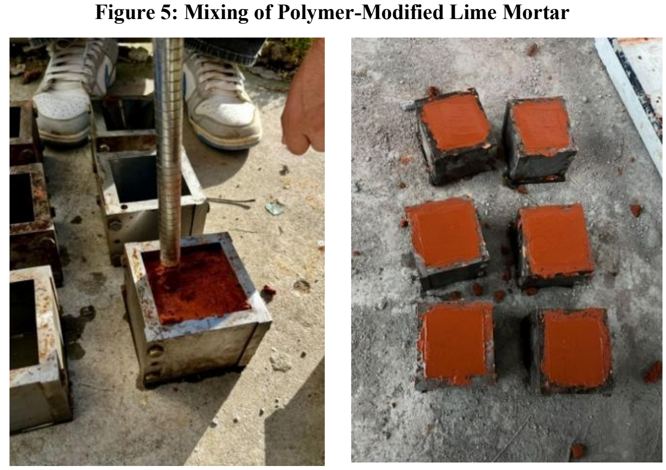

Figure 6: Specimen Casting

All mortar mixes were prepared under controlled laboratory conditions to ensure uniformity and reproducibility. Before mixing, the required quantities of hydrated lime, recycled brick powder (surkhi), polymer additive, plasticizer, and potable water were accurately measured according to the predetermined mix proportions.

Initially, hydrated lime and recycled brick powder were dry mixed for approximately 3–5 minutes to obtain a homogeneous blend. Subsequently, the polymer additive and plasticizer were mixed with the calculated quantity of water to prepare a uniform liquid solution. The liquid mixture was then gradually added to the dry ingredients while continuous mixing was carried out until a consistent and workable mortar was obtained.

Additional water was incorporated to compensate for the 26.3% water absorption of recycled brick powder, thereby maintaining uniform workability for all mortar mixes. The prepared mortar was used immediately for specimen casting to avoid loss of consistency due to premature setting.

Compressive strength specimens were prepared using standard steel cube moulds of dimensions 70.6 mm × 70.6 mm × 70.6 mm, in accordance with IS 2250:1981. Before casting, the moulds were cleaned thoroughly and coated with a thin layer of mineral oil to facilitate easy demoulding.

Fresh mortar was placed in the moulds in three equal layers. Each layer was compacted uniformly using a standard tamping rod to eliminate entrapped air and achieve proper compaction. The top surface of each cube was finished using a steel trowel to obtain a smooth and level surface.

Three specimens were prepared for each mix proportion and testing age to ensure the reliability and repeatability of the experimental results. The average value of the three specimens was considered as the representative compressive strength.

C. Curing Procedure

Immediately after casting, all specimens were kept in the laboratory at room temperature for 24 hours. After demoulding, the cubes were immersed in a potassium sulphate solution for three days to accelerate the initial stabilization of lime mortar. Subsequently, the specimens were transferred to moist sand curing, where adequate moisture was maintained throughout the curing period.

Moist sand curing was selected because lime mortars require gradual moisture retention to facilitate both hydration and carbonation processes.

This curing method also minimizes rapid moisture loss and promotes continuous pozzolanic reactions between hydrated lime and recycled brick powder.

Compressive strength tests were conducted after 14 days, 28 days, and 60 days of curing.

Figure 7: Moist Sand

Figure 8: Placing Cubes in Moist Sand

D. Compressive Strength Test

The compressive strength of mortar cubes was determined using a calibrated Compression Testing Machine (CTM) having adequate load capacity. Testing was performed in accordance with the recommendations of IS 3495 and IS 2250:1981.

Before testing, the surfaces of the specimens were cleaned to remove loose particles. Each cube was centrally placed between the loading platens of the CTM, and the load was applied continuously without shock until failure occurred.

For each mortar mix, the average compressive strength of three specimens was reported at 14, 28, and 60 days.

E. Experimental Matrix

A total of 28 mortar mixtures were prepared by combining four lime-to-surkhi ratios with seven polymer dosages.

Table IV. Experimental Matrix

Lime: Surkhi Ratio	Polymer Dosage (%),	Plasticizer(%)	Testing Ages (Days)
1 : 2	0, 5, 7.5, 10, 15, 20, 25	1	14, 28, 60
1 : 3	0, 5, 7.5, 10, 15, 20, 25	1	14, 28, 60
1 : 4	0, 5, 7.5, 10, 15, 20, 25	1	14, 28, 60
1 : 5	0, 5, 7.5, 10, 15, 20, 25	1	14, 28, 60

Thus, the experimental programme generated a comprehensive dataset for evaluating the influence of polymer dosage and recycled brick powder on the compressive strength development of lime mortar

V. Results And Discussion

The performance of polymer-modified lime mortar containing recycled brick powder (surkhi) was evaluated through laboratory testing. The results were analysed to assess the influence of polymer dosage, lime-to-surkhi ratio, and curing period on the compressive strength of mortar.

A. Water Absorption Characteristics of Recycled Brick Powder

The water absorption test revealed that the recycled brick powder possessed an average water absorption of 26.3%, indicating its highly porous nature. The relatively high absorption is attributed to the porous microstructure of fired clay bricks, which contain interconnected capillary pores capable of retaining moisture.

Although high water absorption increases the water requirement during mortar preparation, it also provides favourable conditions for prolonged hydration and pozzolanic reactions. Consequently, additional mixing water was incorporated to compensate for moisture absorption and to maintain a uniform workability for all mortar mixes.

The high porosity of recycled brick powder contributes to gradual moisture release during curing, thereby promoting continuous reaction between calcium hydroxide and reactive silica. Similar observations have been reported by Sales et al. (2023) and Malathy et al. (2022), who concluded that ceramic waste materials improve the long-term performance of lime mortars through sustained pozzolanic activity.

B. Particle Size Distribution

Sieve analysis demonstrated that the recycled brick powder possessed a well-graded particle size distribution corresponding to Zone II grading. A properly graded fine material improves packing density, reduces internal voids, and enhances the bond between hydrated lime and pozzolanic particles.

The grading results also confirmed that the crushed brick powder is suitable for use as a fine pozzolanic material in lime mortar production.

Table V. Sieve Analysis Results of Recycled Brick Powder

Sieve Size (mm)	Percentage Passing (%)
4.75	100.00
2.36	97.37
1.18	90.00
0.60	71.05
0.30	43.68
0.15	20.53
0.075	5.79

The well-graded nature of the material contributed to improved particle packing, resulting in better workability and higher compressive strength compared with poorly graded materials.

C. The average compressive strength values obtained after 14 days are presented in Table VI.

Table VI. Average 14-Day Compressive Strength of Polymer-Modified Lime Mortar

Polymer (%)	1:2	1:3	1:4	1:5
0	5.98	6.66	6.64	7.29
5	8.20	7.12	9.67	9.88
7.5	8.56	8.95	9.92	10.14
10	8.92	8.11	10.03	10.36
15	10.87	10.34	11.76	12.18
20	13.62	14.11	14.47	14.59
25	12.72	13.49	13.68	14.06

(Compressive Strength in MPa)

The results indicate that the compressive strength increased with increasing polymer dosage for all mix proportions up to 20% polymer content. Beyond this dosage, a slight reduction in compressive strength was observed.

The increase in strength can be attributed to the formation of a continuous polymer film surrounding lime and brick powder particles. This film enhances internal cohesion, improves adhesion between particles, and reduces micro-crack formation within the mortar matrix.

Among all mixes, the 1:5 lime-to-surkhi ratio exhibited the highest early-age compressive strength of 14.59 MPa at 20% polymer, closely followed by the 1:4 mix (14.47 MPa). The improvement demonstrates the beneficial effect of recycled brick powder on early-age pozzolanic reactions.

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The reduction in strength beyond 20% polymer dosage is likely due to excessive polymer content creating a comparatively flexible matrix, which slightly decreases the rigidity of hardened mortar. Similar observations have been reported by González-Sánchez et al. (2020) and RILEM TC 277-LHS (2023), who recommended optimum polymer dosages rather than excessive incorporation.

D. Compressive Strength Development after 28 Days

The compressive strength of polymer-modified lime mortar was further evaluated after 28 days of curing. The results indicate a significant increase in strength compared with the 14-day values, confirming the continuous hydration and pozzolanic reactions occurring within the mortar matrix. The interaction between hydrated lime and the reactive silica and alumina present in recycled brick powder resulted in the formation of additional calcium silicate hydrate (C–S–H) and calcium aluminate hydrate (C–A–H) gels, which contributed to the densification of the microstructure.

The average compressive strength values obtained after 28 days are presented in Table VII.

Table VII. Average 28-Day Compressive Strength of Polymer-Modified Lime Mortar

Polymer Content (%)	1:2	1:3	1:4	1:5
0	8.09	10.33	11.39	12.66
5	11.45	12.04	14.33	15.28
7.5	11.29	12.65	15.15	16.43
10	12.02	14.06	16.84	17.95
15	14.18	15.72	18.26	19.14
20	17.86	18.94	19.72	19.70
25	16.25	17.48	18.63	19.32

(Compressive Strength in MPa)

The compressive strength of all mortar mixes increased considerably between 14 and 28 days, indicating the continued progress of hydration and pozzolanic reactions. The increase in strength was more pronounced in mixes containing polymer additive, demonstrating its beneficial influence on the development of a dense and well-bonded mortar matrix.

For the control mixes (0% polymer), compressive strength ranged from 8.09 MPa to 12.66 MPa, depending on the lime-to-surkhi ratio. With increasing polymer dosage, a consistent improvement in strength was observed up to 20% polymer content.

Beyond this optimum level, a slight reduction in compressive strength occurred, although the values remained higher than those of the control specimens.

Among all combinations, the 1:4 lime-to-surkhi ratio with 20% polymer exhibited one of the highest compressive strengths (19.72 MPa), while the 1:5 mix achieved 19.70 MPa, indicating that both proportions provided excellent mechanical performance after 28 days of curing.

The improvement in compressive strength can be attributed to several mechanisms:

- Formation of additional C–S–H and C–A–H compounds due to the pozzolanic reaction.
- Improved interfacial bonding between lime and surkhi particles resulting from polymer film formation.
- Reduction in internal porosity and micro-cracking.
- Better particle packing owing to the well-graded recycled brick powder.
- Enhanced moisture retention during curing, promoting continued hydration.

These observations are in agreement with the findings of Malathy et al. (2022), who reported that pozzolanic materials significantly improve the microstructure of lime mortar. Similarly, RILEM TC 277-LHS (2023) concluded that appropriate polymer dosages enhance the mechanical properties and durability of modern lime-based mortars without adversely affecting compatibility with masonry substrates.

The graph clearly demonstrates a progressive increase in strength up to 20% polymer, followed by a marginal decline at 25% polymer. This behaviour suggests that excessive polymer content may produce a comparatively flexible matrix that slightly reduces compressive resistance.

Performance Evaluation

The 28-day results confirm that the incorporation of recycled brick powder together with polymer modification substantially enhances the engineering performance of lime mortar. The 1:4 lime-to-surkhi ratio containing 20% polymer exhibited the most balanced performance in terms of workability, strength development, and sustainability. This mix was therefore selected for further evaluation and comparison with the 60-day compressive strength results presented in the subsequent section

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E. Compressive Strength Development after 60 Days

The compressive strength of polymer-modified lime mortar was further evaluated after 60 days of curing to investigate the long-term influence of recycled brick powder and polymer modification. Unlike cement mortar, lime mortar continues to gain strength over an extended period due to the gradual carbonation of hydrated lime and the slow pozzolanic reaction between calcium hydroxide and the reactive silica and alumina present in recycled brick powder. Consequently, a substantial improvement in compressive strength was observed in all mortar mixes after prolonged curing.

The average compressive strength values obtained after 60 days are presented in Table VIII.

Table VIII. Average 60-Day Compressive Strength of Polymer-Modified Lime Mortar

Polymer Content (%)	1:2	1:3	1:4	1:5
0	21.56	23.13	22.86	24.96
5	23.48	25.12	26.45	27.18
7.5	24.86	26.74	28.52	29.36
10	26.15	28.43	30.86	31.72
15	29.22	30.12	32.00	32.89
20	30.98	32.13	34.12	33.59
25	29.52	31.22	32.85	33.44

(Compressive Strength in MPa)

The results clearly indicate that all mortar mixes exhibited continuous strength development throughout the curing period. The highest compressive strength of 34.12 MPa was achieved by the mortar containing a lime-to-surkhi ratio of 1:4 with 20% polymer additive. This confirms that the combined action of recycled brick powder and polymer modification significantly enhances the long-term performance of lime mortar.

The progressive increase in compressive strength can be attributed to the following mechanisms:

- Continued carbonation of hydrated lime, producing stable calcium carbonate.
- Ongoing pozzolanic reaction between lime and the reactive silica/alumina present in recycled brick powder.
- Formation of additional calcium silicate hydrate (C–S–H) and calcium aluminate hydrate (C–A–H) gels.
- Reduction in capillary pores due to polymer film formation.
- Improved bonding between lime paste and fine surkhi particles.

Although increasing the polymer dosage up to 20% significantly improved strength, a slight reduction was observed at 25% polymer. Excessive polymer content may increase the flexibility of the hardened mortar matrix and reduce its stiffness, thereby causing a marginal decrease in compressive strength.

Optimum Mix Identification

Based on the experimental investigation, the optimum mortar composition was identified as follows:

* Lime : Surkhi Ratio = 1 : 4
* Polymer Content = 20%
* Plasticizer = 1%
* Maximum Compressive Strength = 34.12 MPa
* Testing Age = 60 Days

The optimum mix demonstrated excellent workability, high compressive strength, and enhanced durability while utilizing recycled construction waste as a sustainable pozzolanic material.

The percentage improvement in compressive strength for the optimum mix was calculated by comparing it with the corresponding control specimen (without polymer).

Thus, the incorporation of 20% polymer increased the compressive strength by approximately 49.26% compared with the conventional lime mortar.

The experimental findings are consistent with previous investigations reported in the literature. González-Sánchez et al. (2020) observed that polymer additives improve the cohesion and mechanical performance of lime-based mortars through the formation of a continuous polymer network. Malathy et al. (2022) reported similar improvements in strength due to pozzolanic reactions involving silica-rich additives, while Sales et al. (2023) confirmed the suitability of ceramic waste powder as an effective pozzolanic material for sustainable lime mortar production.

Compared with these studies, the present investigation demonstrates that recycled brick powder combined with polymer modification provides a practical and environmentally friendly solution for producing high-performance lime mortar suitable for masonry repair, heritage conservation, and sustainable construction.

VI. Comparative Analysis

Comparative Analysis of Strength Development

The experimental investigation demonstrated a continuous increase in compressive strength with curing age for all mortar mixes.

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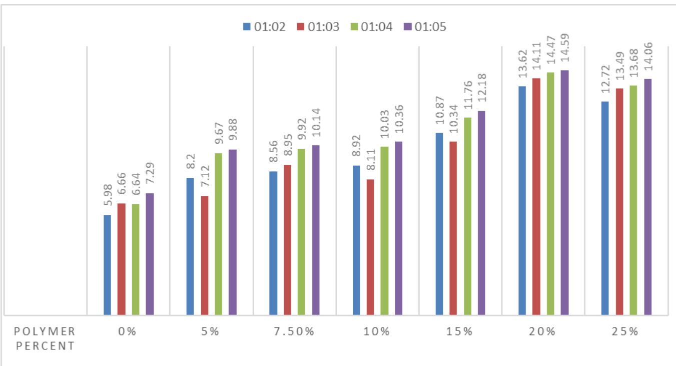
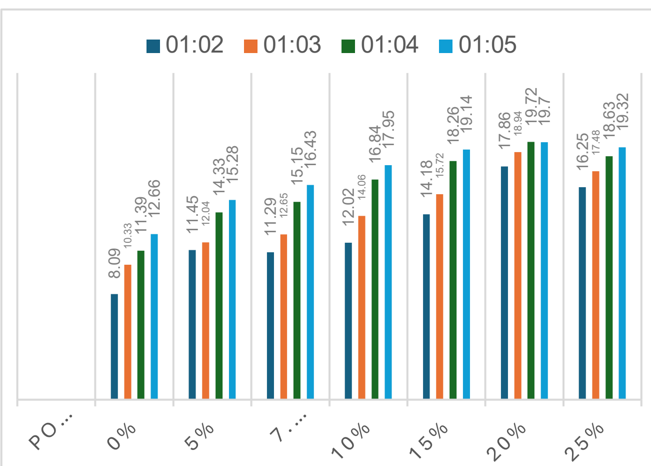
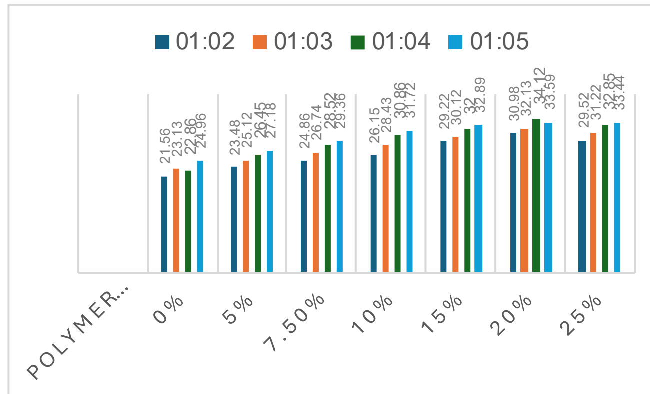
The strength gain observed at 14, 28, and 60 days confirms that polymer-modified lime mortar containing recycled brick powder undergoes gradual hydration, carbonation, and pozzolanic reactions, leading to continuous improvement in mechanical properties.



Graph 1: 14-Day Compressive Strength Graph



Graph 2: 28-Day Compressive Strength Graph



Graph 3 : 60-Day Compressive Strength Graph

The comparison indicates that Early-age strength (14 days) was comparatively lower because the carbonation process had only partially progressed.

- A significant increase in strength occurred between 14 and 28 days, indicating active pozzolanic reactions between hydrated lime and recycled brick powder.
- The highest strength gain was achieved between 28 and 60 days, confirming that lime mortar continues to gain strength over a longer curing period than conventional cement mortar.
- Polymer modification substantially accelerated strength development while simultaneously improving the density of the mortar matrix.

The optimum mortar mixture (1:4 lime-to-surkhi ratio with 20% polymer) consistently exhibited superior performance throughout the curing period.

VII. Conclusions

Based on the experimental investigation, the following conclusions are drawn:

1. The hydrated lime used in this study satisfied the requirements of Class II Building Lime.
2. Recycled brick powder exhibited an average water absorption of 26.3%, indicating significant porosity and high pozzolanic potential.
3. Polymer modification substantially improved the compressive strength of lime mortar at all curing ages.
4. Compressive strength increased continuously with curing period due to ongoing hydration, carbonation, and pozzolanic reactions.
5. The optimum polymer dosage was 20% by weight of hydrated lime.
6. Increasing the polymer dosage beyond 20% produced only marginal improvement and slightly reduced compressive strength.
7. The optimum mortar composition was identified as a 1:4 lime-to-surkhi ratio containing 20% polymer.
8. The highest compressive strength achieved was 34.12 MPa after 60 days of curing.
9. The optimum mix exhibited approximately 49.26% higher compressive strength than the corresponding control mortar.
10. The combined use of recycled brick powder and polymer additive provides a sustainable, environmentally friendly, and high-performance alternative to conventional lime mortar for heritage conservation and modern masonry construction.

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