



INFLUENCE OF HYDROXYPROPYL METHYLCELLULOSE HPMC DOSAGE ON SETTING AND STRENGTH OF CEMENT MORTAR WITH PARAFFIN-TREATED SAWDUST

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ABSTRACT: Incorporating sawdust into cement mortars can reduce their environmental footprint, but it is often accompanied by lower performance and increased variability. To date, the influence of hydroxypropyl methylcellulose (HPMC) dosage in mortars containing paraffin-coated sawdust at a fixed water-to-cement ratio remains scarcely documented. The objective of this study is to isolate and quantify, at a strictly fixed water-to-cement ratio ($w/c = 0.40$) and 2% paraffin-treated sawdust, the effect of HPMC dosages of 0%, 1%, and 2% (by cement mass) on setting times and 28-day mechanical strengths, with result dispersion treated as an explicit indicator of reproducibility. The experimental program includes Vicat setting-time measurements, three-point bending tests for flexural strength, and 28-day compressive strength tests, complemented by one-way ANOVA and Tukey's post hoc procedure. HPMC delays setting: the initial setting time increases from 115 min (0%) to 150 min (1%) and 145 min (2%), while the final setting time increases from 165 min (0%) to 250 min (1%) and 240 min (2%). An optimum is observed at 1% HPMC (flexural strength: 4.56 ± 0.37 MPa; compressive strength: 29.68 ± 3.27 MPa), whereas 2% reduces compressive strength (25.04 ± 5.93 MPa) and increases dispersion. These results identify a practical formulation window for producing more reliable sawdust-modified mortars and support their relevance for sustainable construction.

Keywords: Cement mortar, Treated sawdust, HPMC, Setting time, Mechanical strength

1. INTRODUCTION

The production of Portland cement represents a major component of anthropogenic CO₂ emissions, making the development of low-impact cementitious systems a major priority in contemporary research in the world of construction materials [1]. The valorization of industrial, agricultural and forestry by-products in the formulation of mortars makes it possible both to divert residues from their disposal in landfills and to partially substitute natural sand, which remains one of the most extracted natural resources in the world [2-4]. Beyond conventional structural masonry, these modified mortars are used in plastering and rendering systems, lightweight partitioning, thermal insulation overlays, repair of aging structures, and digitally fabricated construction, where rheological control and water retention govern processability.

Reducing the environmental footprint of cement-based materials relies on valorizing by-products and partially substituting natural resources while maintaining performance and robustness. In mortars, fresh-state properties (workability, stability, water retention) strongly condition

packing, porosity, and final performance. Recent studies show that the incorporation of additives often involves trade-offs between rheology, microstructure and strength, which justifies multi-criteria optimization. [5-7] and a system-wide perspective [8]. Studying fine aggregate substitutions at a constant water-to-cement ratio helps isolate the "material effect" without confounding it with water adjustment [9], in line with frameworks centered on water availability at the particle scale [10-11]. The valorization of lignocellulosic waste, particularly sawdust, is promising, but it raises challenges related to water exchange and the organic-mineral interface.

Wood wastes have been investigated to lighten materials and reduce the use of natural aggregates [12-13]. However, sawdust increases water sensitivity and may affect setting; therefore, a trade-off emerges between functional benefits and mechanical penalties when absorption and induced porosity are not controlled [14-15]. With increasing sawdust content, Abdul-Awal et al. [16] reported lower density and workability, higher water absorption, and reduced strength, despite strength development with age. There are many studies in

the literature that confirm this idea: it has been shown that the long-term behavior of wood-cement composites depends strongly on the type of wood and the morphology of the particles, with the chips showing a reduction in strength of around 25% after prolonged hardening. [17], and wood-derived biochar has been investigated as a partial cement replacement to reduce the carbon footprint while preserving early-age mechanical performance [18]. Discrepancies across studies are largely explained by wood variability and treatment methods, which modify absorption, interfacial bonding, and packing density [19-20]. Ensuring reproducibility, therefore, requires controlling both effective water and the interface.

Two complementary methods are generally used, either the compatibilization of the lignocellulosic load by a treatment aimed at reducing what is called the sponge effect [20], in our case the use of a paraffin coating and/or the stabilization of the fresh state without the addition of additional water by acting on the rheology, water retention and air content. Formulations containing paraffin have shown combined effects on workability and setting kinetics, for instance, in injection grout systems [21]. Beyond paraffin-based systems, the compatibility between organic phases and the cementitious matrix has been documented as a governing factor for workability and mechanical performance in organically modified mortars [22]. The literature also confirms the coupling between water demand, water retention, and setting time [23], and shows that substitutions may simultaneously affect air content, setting, and strength [24]. Optimization is therefore governed by the balance between water, air, and rheology.

HPMC increases viscosity, improves water retention, and limits bleeding, with direct implications for rheology and application properties [25]; it may also interact with hydration and fresh-state behavior [26]. Conversely, higher viscosity can promote air entrapment and increase porosity, with consistent observations when HPMC is used as a foam stabilizer [27]. Non-linear responses to dosage have been reported [28-29], and the resulting effect on water retention and viscosity has been shown to depend markedly on the formulated system [30].

Furthermore, it has been shown that the molecular determinants of HPMC (degree of substitution, molecular weight and functional groups) condition its multifunctional behavior in cementitious systems and determine its suitability for sustainable construction applications. [31]. An optimal dosage is therefore plausible, especially in the presence of an absorbent filler.

Three limitations remain critical: (i) w/c is often adjusted to reach a target workability, which confounds the effect of HPMC with that of water, even though water availability at the microstructural scale is central [10-11]; (ii) heterogeneity in dosage bases, criteria, and test protocols leads to contradictory conclusions; and (iii) dispersion and reproducibility are rarely treated as performance criteria. Design-of-experiments approaches (e.g., orthogonal arrays) could disentangle the relative influence of parameters, yet they are seldom applied to Portland cement mortars with absorbent fillers under a strictly fixed w/c [32]. Finally, data-driven prediction approaches do not replace a mechanistic experimental clarification under controlled water conditions [33].

Given these limitations, the present study differs from previous work in three specific ways. First, a paraffin coating is applied to the sawdust to reduce its water demand by capillary action and to stabilize the organic-mineral interface, thus transposing to the mortar scale an approach previously validated in grout injection systems. [21]. Second, the water-to-cement ratio is strictly fixed at 0.40 across all formulations, which isolates HPMC dosage as the sole experimental variable and avoids the confounding effect of water adjustment commonly encountered in the literature [28-30]. Third, result dispersion is treated as a primary performance criterion through replicate-intensive testing ($n = 18$ per formulation), so that performance and reproducibility are assessed jointly. Reproducibility, although decisive for engineering transfer of bio-based mortars, is rarely quantified in earlier studies and constitutes the principal methodological contribution of the present work.

In order to give meaning to this contribution and make it explicit, it is useful to situate the current approach in relation to the most closely related studies. Yalçinkaya [28] varied HPMC dosage in 3D-printable mortars, but water content was co-adjusted to preserve printability, so that the effect of HPMC remained confounded with that of water. Chen et al. [30] clarified the water-retention mechanism of HPMC in cement mortar, yet without an absorbent lignocellulosic filler and without treating reproducibility as an outcome. Rahman and Khondoker [20] studied the treatment of sawdust to improve compatibility, but did not control the dosage of HPMC at a fixed w/c ratio. On the other hand, the present work is, to the authors' knowledge, the first to combine a paraffin-treated lignocellulosic filler, a strictly fixed w/c ratio and a quantification of dispersion based on repetitions, thus establishing reproducibility itself - measured by the coefficient of variation - as a design criterion for

bio-based mortars, beyond the simple identification of an optimal dosage.

Therefore, the objective of this study is to isolate and quantify the effect of HPMC dosage at 0%, 1% and 2% of the mass of cement on the fresh state structure and the mechanical performance at 28 days of a cement mortar by incorporating a quantity of 2% of paraffin-treated sawdust, at a strictly fixed w/c ratio of 0.40.

The evaluation covers setting time (Vicat), compressive strength and flexural strength at 28 days measured in three-point bending, using a protocol designed to improve statistical reliability and explicitly treat dispersion as an indicator of robustness. The objective is to clarify, in controlled proportions of water, the relationship between dosage, fresh state and performance in the presence of an absorbent load, and to propose a more reproducible basis for the controlled valorization of lignocellulosic waste. The remainder of the paper is structured as follows. Section 2 articulates the research significance. Section 3 describes the materials, mix proportions, paraffin coating protocol, and test procedures. Next, in section 4 reports and discusses the experimental results, with emphasis on the non-linear effect of HPMC dosage on both mean performance and dispersion. Section 5 presents the limitations and future research directions. Finally the section 6 summarizes the principal conclusions and the practical formulation window identified for the controlled valorization of paraffin-treated sawdust in cement mortars.

2. RESEARCH SIGNIFICANCE

Sawdust-modified mortars face a persistent trade-off between environmental benefit and mechanical reliability, and the role of HPMC in such absorbent-filler systems remains poorly resolved when water content is left uncontrolled. This study addresses that gap by isolating, at a strictly fixed w/c of 0.40 and 2% paraffin-treated sawdust, the effect of HPMC dosage on setting kinetics and 28-day strengths, with dispersion treated as a primary performance criterion ($n = 18$). This work determines an optimum at 1% HPMC by combining higher flexural and compressive strengths with significantly reduced variability; moreover it provides a quantified design window for the reproducible valorization of lignocellulosic waste in sustainable construction.

3. MATERIALS AND METHODS

3.1 Experimental Plan

A one-factor experimental design was adopted to isolate the effect of HPMC dosage on a cement mortar incorporating hydrophobic sawdust, at a constant w/c ratio (0.40) and a fixed sawdust content (2%). The studied factor is HPMC dosage (0%, 1%, 2% by cement mass). The measured responses are Vicat setting times and 28-day strengths (three-point flexural tests followed by compressive tests on half-prisms).

3.2 Materials

The binder is Portland cement CEM I 52.5 N-SR (standard NA 442v2013). The fine aggregate is an alluvial sand from the northeastern Algerian Sahara, with a maximum particle size (D_{max}) of 4 mm, a fineness modulus of 1.87, a particle density of approximately 2.7 g/cm³, a bulk density of 1640 kg/m³, and a sand equivalent of 80%.

Table 1. Materials and main characteristics

Material	Designation/ origin	Key characteristics	Role
Cement	CEM I 52,5 N-SR	Complies with NA 442v2	Binder
Sand	Alluvial(south-east Algeria)	D_{max} 4 mm; FM 1.87; $\rho \approx 2.7$ g/cm ³ ; ES 80%	Fine aggregate
Sawdust	Wood waste ≤ 3 mm	Hydrophobised (TimberPure)	Partial sand substitution
HPMC	Cellulose ether (powder)	Incorporated by dry pre-mixing	Admixture
Water	Potable water	Clean, uncontaminated	Mixing water



Fig. 1 Materials used in the mortar

The admixture is a commercial HPMC powder; to prevent lump formation, it is incorporated by dry pre-mixing with the powders before adding water. Sawdust (wood waste, ≤ 3 mm) is used as a partial substitute for sand. To limit water absorption and swelling, we treated the sawdust with a paraffin coating to make it hydrophobic and this is done

with a commercial oil called TimberPure. Mixing water is clean and drinking water, free from impurities that could interfere with cement hydration. The main materials and their key characteristics are summarized in Table 1. The constituents used are shown in Fig. 1.

3.3 Sawdust Pre-Treatment

The sawdust, with a size ≤ 3 mm, is sifted and homogenized, then coated by gradually adding paraffin oil while mixing until a continuous film is formed. It is then drained and air-dried for stabilization, and sifted again to remove any clogging before being incorporated into the mortar.

3.4 Formulations

Four mixes were prepared: a control without sawdust (M0) and three sawdust-modified mortars (MS0–MS2) incorporating 0%, 1%, or 2% HPMC (by cement mass). The water-to-cement ratio is kept constant at 0.40. The mix proportions for each formulation are given in Table 2.

Table 2. Mix design (quantities per reference batch)

Code	Cement (g)	Water (g)	Sand (g)	Sawdust (g)	HPMC (g)	w/c
M0	400	160	1200	0	0	0.40
MS0	400	160	1176	24	0	0.40
MS1	400	160	1176	24	4	0.40
MS2	400	160	1176	24	8	0.40

Note (definition of sawdust content). The sawdust content is fixed at 2% of the sand mass: a sand mass equal to 2% of the sand mass in the control mix is replaced by the same mass of paraffin-treated sawdust. For a reference batch containing 1200 g of sand, 2% corresponds to 24 g. Thus, mixes MS0–MS2 contain 1176 g of sand and 24 g of sawdust, so that the total fine granular mass remains constant (1200 g).

3.5 Mixing, Casting, and Curing

Mixing followed a reproducible sequence: start timing at water–cement contact, initial mixing (30 s), gradual sand addition (30 s), mixing at higher speed (30 s), rest (90 s) with scraping, then final mixing (60 s). Prismatic specimens (40×40×160 mm) were cast immediately after mixing, stored for 24 h under controlled conditions, then demoulded and cured in water at 20.0 ± 1.0 °C for 28 days.

3.6 Testing and Data Analysis

Setting times were measured using the Vicat apparatus (Fig. 2) in accordance with EN 196-3:2016 [34]. The strength of the specimens at 28 days was determined by three-point bending on 40×40×160 mm prisms, followed by compression tests on the half-prisms resulting from the bending test, in accordance with EN 196-1:2005 [35].



Fig. 2 Vicat apparatus used to determine setting time

For each formulation named (MS0–MS2), we prepared and tested 18 samples in order to reliably estimate both the mean and the dispersion. The results are mentioned in the form of mean $\pm$ standard deviation (SD) and coefficient of variation (CV). The effect of dosage was evaluated using one-way ANOVA [36], followed by Tukey's HSD post-hoc test ($\alpha = 0.05$).

Note that the use of a quantity of wood as a substitute for sand is intended to preserve natural sand, which is the second most extracted resource in the world, and the use of sawdust is intended to reduce waste across the world.

4. RESULTS AND DISCUSSION

4.1 Setting Time (Vicat)

For a constant water/cement ratio of 0.40, the addition of HPMC significantly delays the setting of mortars containing paraffin-treated sawdust. The initial setting time increases from 115 min (0%) to 150 min (1%), then decreases slightly to 145 min (2%), while the final setting time increases from 165 min (0%) to 250 min (1%) and 240 min (2%). (see Fig. 3).

Beyond the delay itself, the key point lies in its non-linearity. Under current conditions, a concentration of 1% induces the maximum delay, suggesting an optimal dosage range for HPMC to

most effectively modify early structuring. This trend is consistent with the proposed interpretation. HPMC therefore influences water migration and the viscosity of the interstitial phase, thus slowing down early structuring processes.

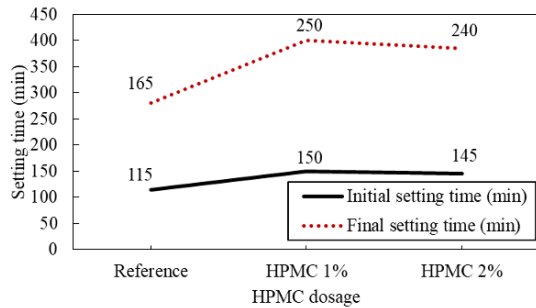


Fig. 3 Effect of HPMC dosage on Vicat initial and final setting times of sawdust-modified cement mortar

4.2 Mechanical Strengths at 28 Days

The 28-day strengths were measured by three-point bending on 40×40×160 mm prisms, followed by compressive testing on the resulting half-prisms. For each formulation (MS0–MS2), 18 individual values were obtained, allowing assessment of both mean performance and specimen-to-specimen dispersion through SD and CV (Fig. 4).



Fig. 4 testing flexural and compressive strength

The main result is the existence of an optimum at 1% HPMC. At this dosage, flexural strength increases from 3.27 ± 0.65 MPa (0%) to 4.56 ± 0.37 MPa ($\approx +39\%$), while compressive strength increases from 26.19 ± 4.01 MPa to 29.68 ± 3.27 MPa ($\approx +13\%$). Beyond the gain in average strength, the most relevant characteristic lies in the marked reduction of dispersion, in flexure, the coefficient of variation (CV) decreases from 19.95% to 8.02%, which indicates a more homogeneous and mechanically more reliable response at 1% HPMC. (Table 3).

The distributions of the individual results were represented as box-and-whisker plots, with flexural and compressive strength on the y-axis and HPMC dosage (%) on the x-axis.

This interpretation is consistent with the distributions of the individual results. In flexure, Fig. 5 shows a general shift toward higher values at 1% together with a narrower distribution, reflecting more uniform behavior at the specimen scale. By contrast, increasing the dosage to 2% reveals an overdosing effect: flexural strength falls back toward the reference level (3.51 ± 0.57 MPa), and compressive strength decreases to 25.04 ± 5.93 MPa, with a clear increase in dispersion in compression (CV=23.69%). This loss of reproducibility reduces the overall robustness of the formulation (Table 3 and Fig. 6).

Table 3. Descriptive statistics of 28-day strengths (mean $\pm$ SD) and coefficient of variation (CV)

Indicator	0% HPMC	1% HPMC	2% HPMC
N (specimens)	18	18	18
Flexural strength–Mean (MPa)	3.27	4.56	3.51
Flexural strength – SD (MPa)	0.65	0.37	0.57
Flexural strength – CV (%)	19.95	8.02	16.30
Compressive strength–Mean (MPa)	26.19	29.68	25.04
Compressive strength–SD (MPa)	4.01	3.27	5.93
Compressive strength – CV (%)	15.32	11.01	23.69

In cementitious materials, some coefficients of variation have exceeded 10%, particularly for flexural strength, due to its sensitivity to manufacturing defects and also to the heterogeneity of the material.

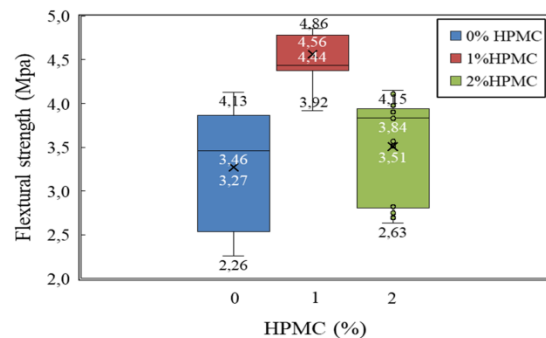


Fig. 5 Distribution of 28-day flexural strength vs. HPMC dosage in sawdust-modified mortars

The incorporation of sawdust alters the variability due to differences in particle size distribution,

paraffin coating, porosity, and air content. Since the test error is relatively low according to EN 196-1, the observed dispersion primarily reflects the material's behavior. The reduction in the coefficient of variation (CV) of flexural strength decreases from 19.95% to 8.02% for a 1% HPMC content, indicating improved reproducibility and enabling the identification of the optimal dosage. To maintain the validity of the variability assessment, no outliers were eliminated. However, further reduction of the dispersion will require better control of porosity and load distribution

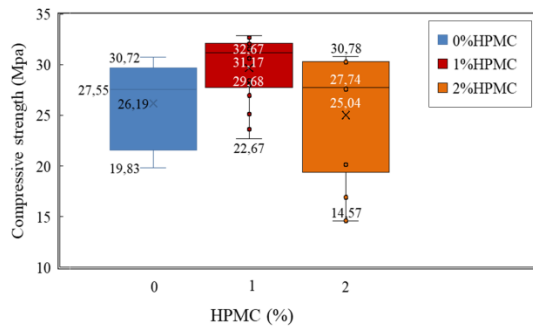


Fig. 6 Distribution of 28-day compressive strength vs. HPMC dosage in sawdust-modified mortars (w/c = 0.40; 2% paraffin-treated sawdust; n = 18)

4.3 Statistical Evidence: Significance and Effect Size

One-way ANOVA confirms that the effect of HPMC dosage is highly significant for flexural strength ($F(2,51) = 28.77$; $p = 4.32 \times 10^{-9}$) with a large effect size ($\eta^2 = 0.530$), and significant for compressive strength ($F(2,51) = 5.08$; $p = 0.0098$) with a more moderate effect size ($\eta^2 = 0.166$) (Table 4). Tukey's HSD post-hoc test (adjusted p-values) clarifies the ranking of mixes: in flexure, 1% is significantly higher than 0% and 2% ($p < 0.001$), while the difference between 0% and 2% is not significant; in compression, a significant difference appears only between 1% and 2% ($p = 0.0097$) (Table 4).

Table 4. ANOVA and Tukey HSD summary for 28-day strengths ($\alpha = 0.05$)

Statistic/Comparison	Flexural strength (MPa)	Compressive strength (MPa)
$F(2,51)$	28.77	5.08
p-value	4.32×10^{-9}	0.0098
η^2	0.530	0.166
0% vs 1%	S	NS
0% vs 2%	NS	NS
1% vs 2%	S	S

Note: S= significant difference; NS = no significant difference (Tukey HSD, adjusted p-values, $\alpha = 0.05$). η^2 = effect size, representing the proportion of variance explained by the HPMC dosage factor.

After processing the data on the variation of tensile strength by bending and compression as a function of the HPMC content, we obtained the second-order equations which represent the experimentally obtained variation. Equation (1) represents the variation of flexural tensile strength as a function of HPMC content, while Eq. (2) represents the variation of compressive strength as a function of HPMC content.

$$b = -1.173h^2 + 2.464h + 3.273 \quad (1)$$

$$c = -1.173h^2 + 4.812h - 0.365 \quad (2)$$

With b: describe the flexural tensile function.

c: describe the compressive function.

h: denote the HPMC content.

4.4 Mechanistic Discussion

The interpretation developed in this section can be organized into the conceptual framework summarized in Fig. 7. Increasing HPMC dosage raises water retention and interstitial viscosity, which delay hydration and, depending on the dosage, follow one of two competing pathways: up to about 1%, the system gains cohesion and homogeneity, yielding a refined pore structure and an optimum in strength with reduced dispersion; at 2%, over-thickening and air entrainment coarsen the pore structure and reverse these gains. These links are proposed rather than demonstrated, and their verification is identified as a priority for future work.

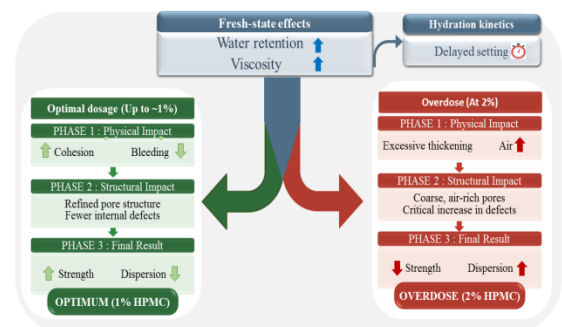


Fig. 7 Proposed conceptual framework relating HPMC dosage to fresh-state behavior, pore structure, hydration, and 28-day mechanical performance. Arrows denote hypothesized mechanistic links inferred from the observed trends, to be confirmed by direct air-void

Figure 7 Proposed conceptual framework relating HPMC dosage to fresh-state behavior, hydration, pore structure, and 28-day mechanical performance. Arrows denote hypothesized mechanistic links inferred from the observed trends, to be confirmed by direct air-void and porosity measurements. Green: beneficial pathway (dosage up to 1%); red: detrimental pathway (dosage of 2%).

With a strictly controlled w/c ratio and a fixed sawdust content, the effect of HPMC dosage is clearly non-linear. The 1% dosage corresponds to the best overall response, combining higher strength with a marked reduction in dispersion. This behavior is consistent with an improvement in mix cohesion and compaction efficiency, which would yield a microstructure less sensitive to local heterogeneities and defect concentration.

At the microstructural scale, these trends can be related to the action of HPMC within the fresh matrix. HPMC adsorbs at the solid–liquid and air–water interfaces and forms a water-retaining film around the cement grains, which limits bleeding and segregation and promotes a more uniform distribution of paste around both the sand and the sawdust particles—consistent with the lower dispersion measured at 1%. The accompanying delay in setting is attributed to the adsorption of HPMC onto the hydrating phases and to the reduced mobility of water and ions within a more viscous interstitial solution. The paraffin coating reinforces this picture by lowering the capillary water demand of the sawdust and stabilizing the organic–mineral interface, so that the water-retention effect of HPMC operates on a more stable system. By contrast, increasing the dosage to 2% is associated with a loss in performance, especially in compression, together with a clear increase in variability. An excessive HPMC content may lead to overly high viscosity and excessive water retention, which can favor entrapped or entrained air and hinder its release during mixing. Under these conditions, packing becomes more dependent on mixing and casting parameters, and compressive strength, being more sensitive to global porosity, is affected first. In microstructural terms, excess HPMC excessively thickens the interstitial phase and stabilizes the entrained air, which enlarges the pore structure and reduces the load-bearing section, which is consistent with the concentrated compression loss.

It should be emphasized that the mechanisms proposed above, namely improved cohesion and compaction at 1%, and also excessive viscosity with

2% air entrainment, are put forward as working hypotheses consistent with the observed trends; their confirmation requires a direct measurement of the entrained air content and the characterization of the porosity and pore size distribution.

4.5 Practical Implications and Originality

4.5.1 Formulation implications

Under the investigated conditions (w/c=0.40; paraffin-treated sawdust= 2%), the results support a directly actionable recommendation: a moderate HPMC dosage around 1% should be preferred, as it combines improved mechanical performance with better statistical stability. By contrast, 2% should be avoided, as it becomes detrimental, particularly in compression.

4.5.2 Implementation implications

The setting delay is relevant for practical implementation. It may be beneficial in terms of open time and handling, but it also requires anticipation of longer setting times, especially at the 1% dosage.

4.5.3 Originality / added value

The main contribution in this study lies not only in identifying an optimum dosage, but also in demonstrating it through an experimental protocol designed to improve transferability: (i) sawdust pretreated by paraffin coating to limit water absorption, (ii) a strictly fixed w/c ratio to isolate the effect of HPMC, and (iii) explicit consideration of dispersion (n= 18 and CV) as a criterion of both performance and experimental robustness.

5. LIMITATIONS

The results should be interpreted within the deliberately controlled experimental framework adopted to isolate the effect of HPMC dosage. The one-factor design (w/c=0.40; sawdust= 2%; particle size≤ 3 mm; TimberPure-treated sawdust) makes it possible to attribute the observed variations primarily to the HPMC content. Accordingly, the optimum identified at 1% provides a robust reference under the conditions investigated, although its extension to other w/c ratios, sawdust contents, particle sizes, or wood species should be confirmed through additional experimental work.

The experimental assessment focused on key formulation indicators, namely Vicat setting times and 28-day mechanical strengths. Additional fresh-state measurements, such as workability/rheology,

density, stability, and entrapped or entrained air content, would strengthen the interpretation, especially by linking result dispersion more directly to fresh-state behavior and final packing. Similarly, the proposed mechanistic interpretation for the 2% overdosing effect, such as excessive viscosity, water retention, higher air content, and reduced compaction, becomes more consistent with observed trends, but it would benefit from being complemented by direct quantification of air content and microstructural investigations, particularly on porosity and pore size distribution. Durability was not addressed in this study, which was designed as a proof of concept in terms of formulation and mechanical performance.

The integration of durability-related indicators (water absorption, shrinkage, carbonation, chloride ingress, hygrothermal cycling, etc.), therefore, constitutes a logical next step for positioning these mortars with respect to practical applications. From a statistical point of view, the relatively large sample size ($n = 18$) and the ANOVA–Tukey approach strengthen the conclusions; however, explicit verification of normality and homoscedasticity assumptions, together with direct comparison to a no-sawdust control produced within the same experimental campaign, would further improve statistical traceability.

5.1 Recommendations for Future Research

To strengthen the mechanistic interpretation and improve transferability, the present “performance+ dispersion” approach should be complemented by more directly explanatory measurements, notably: (i) quantification of entrapped or entrained air and fresh density, and (ii) characterization of porosity and pore-size distribution by porosimetry or imaging. Such analyses would make it possible to verify more explicitly whether, at 2% HPMC, the decrease in compressive strength is effectively associated with increased porosity and/or air content. Expanding the formulation domain to other w/c ratios, sawdust contents, particle morphologies, or wood species is also necessary to assess the robustness of the optimum observed around 1% and to identify possible interactions between formulation parameters.

Finally, a dedicated durability campaign, including water absorption, shrinkage, carbonation, chloride penetration, and hygrothermal cycling, would help clarify the balance between mechanical performance and long-term durability, and would better define the practical relevance of mortars incorporating pretreated sawdust.

6. CONCLUSION

The objective of this study was to isolate, at a constant water-to-cement ratio ($w/c = 0.40$) and a fixed content of paraffin-treated sawdust (2%), the effect of HPMC dosage (0%, 1%, and 2%) on setting kinetics and 28-day mechanical performance, while explicitly considering result dispersion as an indicator of experimental robustness.

The results show, first, that HPMC delays setting, with the strongest effect observed at 1% under the investigated conditions. Second, the mechanical response is clearly non-linear, with an optimum at 1% HPMC: both flexural and compressive strengths increase, while dispersion decreases markedly. By contrast, increasing the dosage to 2% becomes detrimental, particularly in compression, and is accompanied by a clear increase in variability.

Beyond the simple observation of a strength increase, the main contribution of this work lies in identifying a practical formulation window for sawdust-modified mortars under strictly controlled w/c conditions. A moderate HPMC dosage, around 1%, appears to be an effective means of improving both mechanical performance and reproducibility, which is essential for practical implementation. Conversely, overdosing tends to increase the risk of packing- and porosity-related defects, thereby reducing the overall robustness of the formulation.

7. COMPETING INTERESTS

The authors declare that they have no competing interests.

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