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PERFORMANCE AND MECHANISTIC INTERPRETATION OF MODIFIED β-HEMIHYDRATE GYPSUM DRY-MIX PLASTERS CONTAINING MICROCALCITE AND FUNCTIONAL ADMIXTURES

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Abstract

The development of workable, dimensionally stable gypsum finishing mortars requires coordinated control of water demand, calcium sulfate hydration and early-age interfacial bonding. This paper presents an expanded scientific interpretation of previously reported laboratory observations on modified dry-mix plasters formulated with β-calcium sulfate hemihydrate, ground microcalcite, hydrated lime, cellulose ether and a commercial superplasticizer (Poliplast SP-1). The available source records an initial water requirement of 55–65% for G-6 gypsum, a relative decrease of 18–23% in the water-to-gypsum ratio after admixture modification at a reported dosage of 0.3–0.5% of binder mass, and a seven-day adhesion strength of 2.6 MPa compared with 2.0 MPa for the control. The corresponding calculated improvement in adhesion is 30%. Citrate-related addition at 0.03–0.05% was reported to delay setting; a setting duration of up to 90 min was also mentioned, although the source does not consistently distinguish citric acid from a citrate salt or identify the setting endpoint. These observations are critically examined using established models of particle dispersion, hemihydrate dissolution–dihydrate precipitation, crystal growth inhibition, cellulose-ether-mediated water retention and filler packing. Plausible mechanisms are distinguished from experimentally demonstrated findings. The interpretation indicates that lower mixing-water demand and improved interfacial water management could contribute to the higher measured adhesion, whereas claims about pore refinement, water resistance and crack suppression require independent verification. A targeted experimental validation framework is proposed to separate the contributions and interactions of each ingredient. The resulting formulation concept is promising for interior plaster applications but remains a preliminary, incompletely characterized materials system.

Keywords: β-hemihydrate gypsum; dry-mix plaster; microcalcite; cellulose ether; citrate retarder; superplasticizer; water demand; adhesion strength; hydration kinetics.

1. Introduction

Gypsum-based finishing plasters are widely used for interior wall and ceiling applications because they can be processed at moderate temperatures, are compatible with conventional application methods and develop a coherent mineral network through hydration of calcium sulfate hemihydrate. Their practical performance, however, is governed by several coupled properties: the amount of mixing water required to reach a spreadable consistency; the duration of the working window; the ability of the fresh mortar to retain water on an absorbent substrate; and the strength and dimensional stability of the

hardened interface. Optimizing only one of these characteristics may create adverse changes in another. For example, stronger retardation can extend open time yet alter the crystal habit and mechanical interlocking of calcium sulfate dihydrate [1–3].

On contact with water, β-$CaSO_4 \cdot 0.5H_2O$ undergoes dissolution followed by supersaturation, nucleation and growth of $CaSO_4 \cdot 2H_2O$. The intergrowth of dihydrate crystals progressively transforms a flowable suspension into a load-bearing porous solid. The nominal hydration reaction is $CaSO_4 \cdot 0.5H_2O + 1.5H_2O \rightarrow CaSO_4 \cdot 2H_2O$. This stoichiometric water is only part of the water used to prepare a plaster: additional water is needed to lubricate the mineral particles and obtain an application-appropriate rheology. The excess eventually leaves capillary porosity as the material dries. The process can therefore be influenced by particle-size distribution, admixture adsorption, ionic composition and drying history, even when the identity of the principal hydration product does not change [1,2].

Fine carbonate powder, alkaline additives, water reducers and cellulose ethers are frequently combined to achieve competing fresh-state and hardened-state objectives. A superplasticizer can disperse particle agglomerates and reduce the water needed at a specified consistency. A cellulose ether can slow water loss into the substrate while increasing viscosity and the resistance to segregation. Citrate species may delay dihydrate nucleation and growth, thereby extending the application window. Microcalcite can affect particle packing and potentially serve as a heterogeneous substrate for crystal formation. Hydrated lime may alter pore-solution alkalinity and interactions with organic admixtures. None of these effects should be considered universally beneficial: their direction and magnitude depend on individual dosages, raw-material variability and compatibility within the complete formulation [4–8].

The supplied laboratory manuscript describes gypsum dry mixes containing locally relevant mineral components and reports encouraging reductions in water demand together with improved seven-day adhesion. Yet its brief reporting format does not contain full formulation tables, test protocols, replicate measurements, phase analysis or micrographs. Consequently, the objectives of the present expanded manuscript are threefold: (i) to reproduce faithfully the quantitative observations explicitly stated in the source, (ii) to develop a literature-supported, falsifiable interpretation of the likely controlling phenomena, and (iii) to define the minimum additional evidence required for a reproducible full research article. The novelty claimed here is an integrated interpretation of the reported formulation behavior, not an assertion that unreported mechanistic tests have been performed; recent syntheses emphasize the same need for admixture-specific validation [14].

2. Materials and scope of the available experimental evidence

2.1. Starting materials and formulation strategy

The starting binder is identified in the source as low-temperature-calcined G-6 gypsum based on the β-hemihydrate modification of calcium sulfate. The mineral microfiller is microcalcite prepared by grinding and classifying marble chips. Hydrated lime (calcium hydroxide), methyl hydroxyethyl cellulose (MHEC; a Walocel product) and the commercial admixture Poliplast SP-1 are mentioned as constituents of the composite system. The original description also refers to a citrate-type set-control additive. The formulation thus combines a rapidly hydrating calcium sulfate phase, fine carbonate particles, an alkaline component and water-soluble organic functionality.

The source does not report chemical purity, binder phase assemblage, Blaine surface area, particle-size distributions, exact proportions of gypsum, lime and microcalcite, solid content or chemical class of the commercial superplasticizer, molecular characteristics of the cellulose ether, mixing sequence, or curing conditions [13]. Its 0.3–0.5% admixture dosage therefore cannot be assigned unequivocally to any one product. Similarly, the description first specifies a citric-acid salt at 0.03–0.05%, but subsequently

refers to citric acid. These are chemically non-identical descriptions, and they are retained as an unresolved reporting inconsistency rather than silently normalized.

2.2. Consolidated source-reported observations

Table 1 separates statements recorded in the supplied manuscript from calculations made from those statements and from endpoints that remain undefined.

Table 1. Quantitative observations and reporting status of the supplied gypsum-plaster study.

Parameter	Value	Evidence level	Qualification
G-6 gypsum water requirement	55–65% by mass	Reported descriptive range	Basis and test procedure not identified
Modifier dosage	0.3–0.5% of binder mass	Reported	Specific admixture(s) included are unclear
Decrease in water-to-gypsum ratio	18–23%	Reported relative reduction	Baseline and consistency endpoint not supplied
Citrate-related dosage	0.03–0.05%	Reported	Citric acid versus citrate salt unresolved
Setting duration	Up to 90 min	Reported	Initial/final set and test method unspecified
7-day adhesion, modified plaster	2.6 MPa	Reported	Substrate, geometry and variability unspecified
7-day adhesion, control plaster	2.0 MPa	Reported	Same reporting gaps
Relative adhesion improvement	30%	Calculated from 2.6 and 2.0 MPa	(2.6 − 2.0)/2.0 × 100; not an additional experiment

Qualitative observations in the source include good workability, reduced segregation, apparent absence of cracking and shrinkage on drying, and higher resistance to water exposure. These are treated as preliminary claims because the document does not provide numerical test results or specimen photographs for the corresponding endpoints.

3. Results and mechanistic discussion

3.1. Water reduction: dispersion, consistency and pore structure

The reported 18–23% reduction in the water-to-gypsum ratio is potentially important for both fresh plaster processing and hardened structure. At comparable flowability, lowering mixing water should generally diminish the volume of evaporatable water, potentially decreasing capillary-pore volume after drying. Such a relationship is mechanistically plausible but cannot be translated into a measured porosity decrease without knowing whether control and modified specimens had the same consistency, whether hydration reached comparable extents, and whether air entrainment changed with admixture dosage.

A convenient operational descriptor is W/G = m(water)/m(gypsum), where the denominator must be defined consistently and should not be confused with water-to-total-powder or water-to-total-binder ratios. If a 55–65% initial water requirement and a reduction of 18–23% referred to the same reference formulation and identical measurement protocol, they would correspond illustratively to a post-modification W/G interval of approximately 0.42–0.53. This interval is a conditional arithmetic

illustration, NOT a separately reported experimental result. In the final manuscript, measured values for each mix should replace this illustration.

Mechanistically, superplasticizers adsorbed at gypsum-particle interfaces can reduce flocculation, allowing a given amount of liquid to produce greater particle mobility. Published comparisons of naphthalene-based and polycarboxylate admixtures indicate that adsorption characteristics and the balance between electrostatic and steric dispersion depend on molecular chemistry [4]. Comparable gypsum studies have shown that water reduction can markedly improve mechanical properties at optimized admixture loadings [9]. However, these literature mechanisms cannot establish the exact action of Poliplast SP-1 here without the product's technical composition and an independent compatibility test.

A stronger scientific assessment would use flow spread or vane rheometry at matched water content and, separately, matched workability. These two protocols answer different questions: fixed W/G isolates dispersing and thickening effects, whereas equal workability quantifies achievable water saving. Rheological fitting could report apparent yield stress, plastic viscosity and thixotropic recovery, with testing initiated at a fixed interval after mixing because gypsum hydration evolves rapidly.

3.2. Citrate-mediated regulation of setting and gypsum crystallization

The source associates 0.03–0.05% citrate-related addition with delayed setting and reports a working or setting interval approaching 90 min. Such retardation is consistent with published work showing that citric acid and other low-molecular-weight carboxylic acids can perturb hemihydrate dissolution, the supersaturation trajectory of dissolved calcium sulfate and the attachment of ions to growing dihydrate faces [1–3]. Synchrotron diffraction studies have further demonstrated that modifiers alter hydration kinetics while preserving a heterogeneous nucleation component [1].

A central qualification is that retardation is not equivalent to improved microstructural strength. Adsorption of citrate-containing species can modify crystal aspect ratio and decrease the density of intercrystalline contacts; some investigations report reduced mechanical interlocking or reduced strength at excessive retardant dosages [3]. Conversely, other specific compositions have produced denser crystal habits or favorable strength responses under their particular conditions [2]. The direction of the mechanical response must therefore be determined experimentally rather than inferred from setting time alone.

Pore-solution pH is especially relevant because it influences citrate speciation, calcium complexation and surface interactions. This concern is heightened by the inclusion of hydrated lime, which can elevate alkalinity. A recent study of systems containing $Ca(OH)_2$, citric acid and a polycarboxylate water reducer provides external evidence that ternary admixture interactions can modify hydration, water requirement and strength simultaneously [8]. It does not, however, establish an optimum for the present formulation because the commercial admixture and formulation are not proven to be identical.

To resolve the source ambiguity, the formulation record should identify the exact citrate species, purity, counterion, addition basis and whether 90 min denotes initial set, final set, or usable open time. Initial and final set should then be measured independently at controlled temperature and humidity, with a separate practical assessment of retained workability. Isothermal calorimetry, in situ diffraction and time-resolved conductivity could relate the apparent setting delay to dissolution, crystal growth and hydration completion rather than assuming these endpoints coincide.

3.3. Cellulose ether, water retention and application rheology

MHEC has a distinct functional role from the water reducer. Through hydration of polymer chains and the formation of a viscous aqueous phase, cellulose ethers can reduce rapid water uptake by porous substrates and increase cohesion of the fresh mortar. These effects help maintain a workable interfacial water supply while limiting sedimentation and segregation. They may also raise yield stress or modify bubble stability, so the amount suitable for hand-applied plaster may differ from that required for pumping or spray application [5,7].

Research on MHEC has established a concentration-dependent mechanism for water retention involving polymer hydration and molecular association [5]. Importantly, gypsum pore solutions contain substantial sulfate, and a gypsum-specific study of a related methyl hydroxypropyl cellulose found that sulfate could suppress colloidal association, thereby reducing water-retention efficiency compared with cementitious systems [6]. This is a reason to measure water retention in the actual gypsum formulation, rather than transfer dosage recommendations unchanged from cement mortars.

The source's qualitative observation of reduced segregation is compatible with these principles but is not a quantitative validation of MHEC action. It remains unknown whether the chosen cellulose ether changed air content, fresh density, surface skinning or water transport at the interface. A filter-paper or suction-based retention test, paired with flow measurements and mass-loss monitoring over time, would establish whether the hypothesized balance of cohesion and spreadability was attained.

3.4. Microcalcite packing, lime addition and possible nucleation effects

Microcalcite is identified as the ground and classified product of marble waste or chips. Depending on its fineness relative to the hemihydrate and the aggregate fraction, calcium carbonate may occupy interparticle voids and alter the packing density of the composite powder. A more favorable size distribution could lower the liquid volume needed for particle lubrication or alter drying pathways. Nevertheless, excessive fines can increase specific surface area and therefore water demand; packing improvement should not be assumed without particle-size and specific-surface measurements.

Calcium carbonate surfaces may also participate in heterogeneous nucleation of gypsum, as suggested by published hemihydrate hydration studies [2]. This is a reasonable mechanistic hypothesis for the present mix, not a demonstrated finding: the manuscript supplies no time-resolved diffraction or micrographs showing dihydrate growth on microcalcite. Likewise, the presence of hydrated lime introduces a possible alkalinity effect and can change the chemical environment experienced by citrate and the organic water reducer. The extent of the influence would depend on lime content, calcium activity and mixing sequence [8].

A four-level microcalcite replacement series combined with independent lime-free and lime-containing controls could distinguish filler packing from chemical modification. X-ray diffraction with quantitative phase analysis, SEM imaging, particle-size analysis and image-based pore characterization would provide complementary tests. Microcalcite provenance and processing energy should be documented before quantitative environmental claims are made.

3.5. Seven-day adhesion strength and interface formation

The strongest explicitly quantified hardened-state result is the seven-day adhesion strength: 2.6 MPa for the modified composition versus 2.0 MPa for the control. The absolute difference is 0.6 MPa and the relative increase is 30%. These are straightforward descriptive comparisons; without specimen counts, scatter or a named statistical test, they do not establish statistical significance. The result is nevertheless

technically relevant because adhesion integrates both cohesive behavior in the plaster and bonding at the plaster–substrate interface.

Several mechanisms could contribute to this improvement. Reduced mixing-water demand may limit large capillary defects; adequate water retention could prevent premature dehydration against a porous surface; an appropriately dispersed binder could improve contact and penetration into substrate asperities; and a favorable hydration rate could enable mechanical interlocking of dihydrate crystals. Conversely, high cellulose-ether dosage or pronounced retardation might weaken contact through entrained air, delayed load development or altered crystal habit. Thus, the adhesion response most plausibly reflects multiple coupled factors rather than a single additive-related process [3–7].

A critical omission is the adhesion-testing configuration. Reportable pull-off adhesion should specify substrate material and roughness, moisture conditioning, specimen size, test standard, loading rate, number of replicates and the failure mode (cohesive in plaster, adhesive at interface or cohesive in substrate). Without failure-mode information, it is impossible to determine whether the 2.6 MPa result reflects stronger interfacial bonding or simply a stronger plaster layer. Further, a result at seven days does not establish long-term bond durability after humidity cycling.

3.6. Drying stability and moisture resistance: evidence versus expectation

The source describes the modified plasters as resistant to visible cracking and shrinkage after drying. Although reduced water content, adequate water retention and balanced setting may be favorable for dimensional stability, the submitted document does not report restrained-shrinkage tests, free-shrinkage measurements, microscopy, observation periods or environmental conditions. The absence of visible cracks in unspecified specimens should therefore be recorded as a qualitative observation, not a verified zero-shrinkage result.

Water resistance must be evaluated even more cautiously. Gypsum dihydrate remains sensitive to prolonged liquid-water exposure because of its solubility, and improved compactness alone does not demonstrate waterproofing. The source suggests better resistance to moisture, but it gives no water absorption, capillary uptake, immersion softening coefficient or wet-strength retention measurements. The term “waterproof” would be inappropriate. For interior finishing materials, short-term moisture tolerance should be assessed separately from prolonged immersion performance; contemporary research shows that improved water durability often requires dedicated supplementary binding or hydrophobic mechanisms beyond simple water reduction [10].

The last paragraph of the Russian text briefly shifts to “cement–polymer mortar mixtures.” Because no separate cement–polymer formulation or data set is documented, that sentence should not be taken as evidence for the gypsum system. In an internally consistent article, the discussion is confined to β-hemihydrate-based gypsum plasters.

3.7. The formulation as a coupled multiparameter system

The reported benefits can be interpreted through a sequence of coupled processes: powder packing and initial particle dispersion influence water demand; the liquid-phase chemistry and citrate speciation influence hemihydrate dissolution and dihydrate crystallization; cellulose-ether solution structure influences water retention, application rheology and substrate suction; and these factors together determine capillary defect formation and interfacial adhesion. This description is a mechanistic framework and does not imply that each link has been confirmed for the supplied samples.

Admixture optimization should consider interactions rather than one-factor maximum responses. A lower W/G ratio may increase strength but make application difficult unless dispersion is sufficient.

Higher viscosity may limit bleeding yet impair wetting. Longer setting may improve application time but reduce early strength. Increased microcalcite surface area may refine packing but adsorb more organic admixture. A factorial design testing superplasticizer × cellulose ether × citrate, with microcalcite and lime as independent factors or controlled covariates, is therefore better suited to identifying an operational window than selecting each dosage in isolation [4,6,8,9].

4. Experimental program required for mechanistic verification

To transform this preliminary report into a fully reproducible original research article, the following paired comparisons and instrumental measurements are prioritized. All formulations should use a consistent mass denominator (gypsum binder or total powder, clearly declared), a documented mixing procedure and randomized preparation order. At least three independently prepared batches per condition are advisable as a starting point, with final replication determined by a power or precision analysis.

Table 2. Recommended verification matrix; these are proposed future tests, not experiments reported in the supplied manuscript.

Research question	Suggested measurements	Inference enabled
Chemical and physical identity	XRD/Rietveld; XRF; PSD; BET/Blaine; admixture data sheets	Quantify hemihydrate content, impurities, particle packing and admixture identity
Fresh-state dispersion	Flow table; rheology at fixed W/G and at matched spread; air content	Separate dispersing efficiency from water saving and air entrainment
Setting / hydration	Vicat initial and final set; calorimetry; time-resolved XRD; pH	Connect retardation to the kinetics of dihydrate development
Water retention / stability	Filter-paper or suction test; bleeding; slump retention; drying curves	Measure transport effects attributed to cellulose ether
Hardened microstructure	SEM; pore-size distribution; bulk density; total porosity	Test the proposed pore-filling and interlocking explanations
Mechanical / interface	Compressive and flexural strength; 7/28-day pull-off; failure-mode classification	Locate changes in cohesive versus adhesive performance
Moisture durability	Capillary absorption; 24-h immersion uptake; wet/dry strength; humidity cycling	Verify moisture tolerance without overclaiming waterproofing

At the reporting stage, present values as mean ± standard deviation together with n and 95% confidence intervals. Analyze planned factorial effects through ANOVA or suitable regression with diagnostics of residual assumptions, and report effect sizes rather than p-values alone. Graphs should distinguish wet-state properties, dry-state strengths and moisture-conditioned strengths. Such a workflow would make the claimed formulation-property relations testable and provide a sound basis for comparison with relevant gypsum-plaster standards, including EN 13279-1 and the physical-test methods in ASTM C472 [11,12].

5. Conclusions

The source-reported modified gypsum dry-mix plaster system, composed of β-hemihydrate gypsum, microcalcite, hydrated lime and organic functional admixtures, exhibits three potentially useful performance outcomes: an 18–23% relative reduction in the reported water-to-gypsum ratio, setting

retardation associated with citrate-containing addition, and a seven-day adhesion increase from 2.0 to 2.6 MPa. The latter represents a calculated improvement of 30%. These values are preserved from the original source and are not supplemented with invented replicate data.

The available literature supports an integrated interpretation in which particle dispersion reduces mixing-water demand, cellulose ethers control interfacial water loss and fresh mortar cohesion, citrate species modify nucleation and crystal growth, and fine mineral fillers may influence packing and nucleation. These pathways are mechanistically credible but have not been directly measured in the investigated mixture. Particularly important unresolved issues are the chemical identity and dosage of the citrate modifier, the distribution of admixture dosages, the definition of setting time, and the origin of the adhesion gain.

The proposed material is best described at present as a promising preliminary interior-plaster formulation. Verification of phase evolution, rheology, pore structure, repeatable adhesion and moisture durability is necessary before strong claims can be made concerning optimized composition, waterproofing performance or mechanistic causality.

References

1. Gurgul, S. J., Seng, G., & Williams, G. R. (2022). The effect of additives on the hydration of $CaSO_4 \cdot 0.5H_2O$: A synchrotron X-ray diffraction study. Journal of Solid State Chemistry, 305, 122671. https://doi.org/10.1016/j.jssc.2021.122671
2. Magallanes-Rivera, R. X., Escalante-García, J. I., & Gorokhovsky, A. (2009). Hydration reactions and microstructural characteristics of hemihydrate with citric and malic acid. Construction and Building Materials, 23(3), 1298–1305. https://doi.org/10.1016/j.conbuildmat.2008.07.022
3. Lanzón, M., & García-Ruiz, P. A. (2012). Effect of citric acid on setting inhibition and mechanical properties of gypsum building plasters. Construction and Building Materials, 28(1), 506–511. https://doi.org/10.1016/j.conbuildmat.2011.06.072
4. Peng, J., Qu, J., Zhang, J., Chen, M., & Wan, T. (2005). Adsorption characteristics of water-reducing agents on gypsum surface and its effect on the rheology of gypsum plaster. Cement and Concrete Research, 35(3), 527–531. https://doi.org/10.1016/j.cemconres.2004.04.016
5. Bülichen, D., Kainz, J., & Plank, J. (2012). Working mechanism of methyl hydroxyethyl cellulose (MHEC) as water retention agent. Cement and Concrete Research, 42(7), 953–959. https://doi.org/10.1016/j.cemconres.2012.03.016
6. Bülichen, D., & Plank, J. (2013). Water retention capacity and working mechanism of methyl hydroxypropyl cellulose (MHPC) in gypsum plaster—Which impact has sulfate? Cement and Concrete Research, 46, 66–72. https://doi.org/10.1016/j.cemconres.2013.01.014
7. Mróz, P., & Mucha, M. (2018). Hydroxyethyl methyl cellulose as a modifier of gypsum properties. Journal of Thermal Analysis and Calorimetry, 134, 1083–1089. https://doi.org/10.1007/s10973-018-7238-3
8. Sun, H., Cai, C., Tang, F., Qian, J., & Zhang, J. (2024). Optimization of strength and microstructural properties of building gypsum by ternary $Ca(OH)_2$–citric acid and PCEs additives. Case Studies in Construction Materials, 20, e03396. https://doi.org/10.1016/j.cscm.2024.e03396
9. Cao, W., Yi, W., Yin, S., Peng, J., & Li, J. (2021). A novel low-density thermal insulation gypsum reinforced with superplasticizers. Construction and Building Materials, 278, 122421. https://doi.org/10.1016/j.conbuildmat.2021.122421

10. Feng, C., Wang, Y., Wang, L., Zhao, X., Zhang, W., Zhu, J., & Du, M. (2024). Improving the water resistance of gypsum-based building materials with slag activated by calcium oxide. Journal of CO_2 Utilization, 90, 102996. https://doi.org/10.1016/j.jcou.2024.102996
11. British Standards Institution. (2008). BS EN 13279-1:2008, Gypsum binders and gypsum plasters—Part 1: Definitions and requirements. https://doi.org/10.3403/30171553
12. ASTM International. (2026). ASTM C472-26, Standard test methods for physical testing of gypsum, gypsum plasters, and gypsum concrete. https://www.astm.org/
13. Qi, H., He, L., Tan, H., He, X., Yang, J., Su, Y., Jin, Z., & Zhang, J. (2024). Effect of phosphate impurities on the properties of β-hemihydrate gypsum pastes plasticized by polycarboxylate superplasticizer. Materials Today Communications, 40, 109737. https://doi.org/10.1016/j.mtcomm.2024.109737
14. Bouhayek, A., & Cherkaoui, K. (2026). Chemical admixtures for sustainable gypsum plaster: A comprehensive review of mechanisms, performance trade-offs, and eco-friendly pathways for construction applications. Next Materials, 102800. https://doi.org/10.1016/j.nxmate.2026.102800