

Rheotechnological properties of mortars based on low water demand cements

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Abstract: *Low water demand cement offers a route to reduce mixing water while retaining the flow needed for mortar preparation and placement. However, a lower water content or a larger spread diameter does not independently demonstrate satisfactory processing behaviour. This article critically examines selected studies on cementitious rheology and develops a practical framework for evaluating mortars based on low water demand binders. The review distinguishes binder manufacture from the addition of a superplasticiser during mixing and links rheological measurements to fresh-state stability and later strength. The proposed framework combines controlled comparisons at equal water content and equal initial spread, rotational rheometry, time-dependent flow tests, bleeding observations and strength measurements. A staged experimental design is presented for separating the effects of water-to-binder ratio, admixture dosage and mixing sequence. The main analytical conclusion is that water demand should be evaluated as a constrained performance criterion rather than a single material label: an acceptable mortar must satisfy flow, retention, stability and strength requirements simultaneously. The article introduces no new laboratory dataset and makes no numerical claim of water saving or strength improvement. Its contribution is a transparent evaluation protocol and a set of testable hypotheses for subsequent work with locally available cement, sand and chemical admixtures.*

Keywords: *low water demand cement, mortar, yield stress, plastic viscosity, thixotropy, superplasticiser, flow retention*

Introduction

The preparation of construction mortar requires enough mixing water to wet the solid particles and allow the material to spread, fill irregular spaces and be compacted. Reducing water without checking these operations can produce a mixture that is difficult to handle. Conversely, selecting a mortar solely because it spreads easily can overlook excessive viscosity, loss of flow during transport or instability after placement. Ferraris (1999) identifies yield stress and viscosity as distinct quantities needed to describe cementitious flow. This distinction provides the starting point for the present analysis.

The term low water demand cement needs a clear operational meaning. Here it refers to a binder intended to reach a specified fresh-state consistency at less effective mixing water than a defined reference binder under matched test conditions. A cement manufactured by incorporating a dispersant during grinding is not automatically equivalent to an ordinary cement receiving a liquid admixture in the mixer. Korovkin and Eroshkina (2016) examined these introduction routes and reported benefits of co-grinding for their investigated cement and S-3 superplasticiser. Their result supports testing the manufacturing route, but does not establish that every cement–admixture combination will behave identically.

This paper addresses a methodological question: how should the rheotechnological performance of a low water demand cement mortar be evaluated without confusing reduced water content with improved processing? The objective is to develop an experimentally testable framework that connects binder identity, mixing conditions and measurable mortar performance. The intended application is

laboratory screening before a larger production trial. No named local cement, supplier or completed experiment is claimed.

2 Review approach and scope

A focused narrative review was conducted using selected publisher records and National Institute of Standards and Technology publications accessed on 6 October 2026. Search concepts included cement paste rheology, mortar, low water demand cement, superplasticiser introduction, yield stress, viscosity and flow retention. Sources were selected for direct relevance to measurement, time dependence or binder–admixture interaction. The approach is not a systematic review: no exhaustive database coverage, screening count or meta-analysis is claimed. Where only a publication abstract or record was accessible, interpretation is restricted to the findings stated in that record.

Seven publications were used to establish the conceptual basis. Concrete-level research is considered where it clarifies measurement principles, while quantitative concrete results are not transferred to mortar. The synthesis separates published findings from the proposed protocol. Values in the experimental plan are starting design choices for pilot testing, not observations or optimised settings. The resulting framework should therefore be read as a methodological contribution requiring laboratory validation.

3 Findings from the literature

3.1 Flow measurements answer different questions

A mortar may require only a small stress to start flowing yet still resist rapid deformation. Ferraris and de Larrard (1998) investigated approximately 80 mortar and concrete formulations and found that a nonlinear description could outperform the linear Bingham representation for the tested fresh concretes. Accordingly, selecting a constitutive model should follow the measured curve rather than the material label. A fitted viscosity has limited meaning if the tested material is undergoing substantial structural change or if the chosen shear range is undocumented.

Ferraris et al. (2001) compared rheological measurements with simpler paste tests and reported that the simpler methods did not adequately characterise workability in their study. This finding does not make spread measurements useless. It indicates that spread should be used as an operational consistency measure, with rheometry providing additional information. For the present framework, a spread diameter is a control and acceptance variable, not a substitute for measured yield stress and viscosity.

3.2 Dispersion does not remove every processing limitation

Ilg and Plank (2020) reported that some low water-to-cement mixtures remained highly viscous even when polycarboxylate superplasticisers produced substantial spreading. Their investigation of auxiliary dispersants illustrates why reducing the resistance to flow initiation and reducing viscosity should be evaluated separately. It would be inappropriate to assume that increasing an admixture dose necessarily solves a sticky mortar. The proposed protocol therefore requires both fresh-state measurements and an independent strength check before a formulation is accepted.

Mineral additions also require material-specific assessment. Ferraris et al. (2001) found that one tested ultrafine fly ash improved the rheological response without increasing water or high-range water reducer demand. This is evidence for a particular addition in particular mixtures, rather than a universal rule for finer powders. In a local programme, replacing a binder component should be treated as a separate factor and documented by mass, particle properties and source.

3.3 Time and shear history affect interpretation

Roussel (2006) showed how structural build-up and recent flow history influence the transient behaviour of fresh concrete. Sant et al. (2008) linked the evolution of cement paste properties to early structure formation and observed transitions before the conventional initial setting point. Together,

these studies justify separating measurements made immediately after mixing from those made after rest. A single initial test cannot establish the period during which a mortar remains suitable for placement.

For practical evaluation, two histories should be distinguished. One represents storage without further agitation. The other represents controlled remixing before placement. Each condition can lead to a different measured response. Treating them as separate histories makes it possible to identify whether a formulation retains usable flow by itself or only after additional mixing. The framework does not assume that remixing can reverse changes caused by hydration.

4 Proposed experimental framework

4.1 Materials and reference conditions

The first stage should characterise the binder and admixture before mortar testing. Records should include binder composition, fineness, particle size information where available, storage age and manufacturing route. For the admixture, product type, solids content and supplier-recommended dosage interval should be retained. Sand grading, moisture and absorption should be measured consistently. Water contained in a liquid admixture should be included in effective mixing water, and sand moisture corrections should be applied.

Three comparison groups are proposed. Group A uses the reference cement without dispersant. Group B uses the reference cement with the selected dispersant added during mixing. Group C uses the low water demand binder, with its incorporated dispersant declared. Adding an extra dispersant to Group C would create a further treatment and should not be concealed within its base formulation. If a matched binder manufactured with incorporated dispersant is unavailable, the experiment can compare A and B, but its conclusions should concern admixture-modified mortar rather than a demonstrated manufacturing effect.

Two comparison modes should be run separately. Equal effective water-to-binder ratio identifies differences in fresh-state response at a common water level. Equal initial spread identifies how much water each system requires to reach the same chosen consistency. Binder mass, sand source and grading should remain matched. A water reduction claim should be based on the second mode and qualified by the required retention, stability and strength criteria.

Table 1

Proposed variables and controlled conditions

Variable	Initial design	Interpretation
Water-to-binder ratio	0.30, 0.35 and 0.40	Pilot levels only; adjust if mixtures cannot be prepared or tested reliably.
Dispersant dose	Three levels within supplier guidance	State dry solids per binder mass; include an appropriate zero-dose reference.
Sand-to-binder ratio	One fixed ratio in the main series	Select during pilot testing and report the mass basis.
Measurement age	0, 30, 60 and 90 min	Time zero must be defined from first water–binder contact.
Mixing sequence	Base sequence, then delayed addition	Use a separate series to avoid confounding dosage with mixing history.
Environment	Target 20 ± 2 °C	Record actual material and laboratory temperatures.

4.2 A staged design with independent replication

Pilot trials should establish whether the selected ratio range is feasible, whether the rheometer is suitable for the sand grading and whether the reference spread can be reproduced. The main screening stage can then use the three water ratios and three nonzero dose levels for Group B. These nine combinations require at least three independently mixed batches per combination, giving 27 batches before reference and validation groups are added. Measurements repeated on one batch are useful technical repeats, but they do not replace independently prepared batches.

Randomise the preparation order within each laboratory day and record day as a block. Reserve separately prepared batches of selected formulations for validation. Only after a promising formulation has been identified should the mixing sequence be varied. This sequential approach limits the number of factors changed at once and helps distinguish a composition effect from an effect caused by preparation. All decisions to exclude an untestable mixture should be recorded, with the reason and the stage at which exclusion occurred.

4.3 Rheological and technological measurements

A mortar-compatible rotational rheometer should measure stress as a function of shear rate under a declared pre-shear and rest procedure. Report geometry, gap, maximum particle size, shear schedule and the method used to convert instrument output into stress and shear rate. Check for wall slip and particle migration. If only torque and rotational speed are available, retain those quantities unless a validated conversion is available. Numerical stress values should not be inferred from a spread test. For steady flowing segments, the Bingham relation can be written as $\tau = \tau_0 + \mu_p \dot{\gamma}$, where τ is shear stress in Pa, τ_0 is the fitted dynamic yield stress in Pa, μ_p is plastic viscosity in Pa·s and $\dot{\gamma}$ is shear rate in s⁻¹. The Herschel–Bulkley alternative is $\tau = \tau_0 + K\dot{\gamma}^n$, where K has units Pa·sⁿ and n is dimensionless. Both forms are discussed for cementitious flow by Ferraris and de Larrard (1998). Model choice should consider residual patterns, repeatability and whether the selected measurement segment satisfies the assumed flow condition.

Spread testing should use one apparatus and a fixed filling, lifting and timing procedure. Measure two perpendicular diameters and retain their mean. Fresh density, visible bleeding and segregation should be recorded using a declared procedure and observation interval. Assess flow retention on separate covered portions or companion batches assigned to each age, so that an earlier test does not inadvertently alter the later sample. Record whether each portion is tested after rest or after a fixed remixing step.

Strength measurements at 7 and 28 days should use one declared specimen geometry, curing condition and testing method. Specimens should be traceable to their parent batch. Air content or fresh density should be considered when interpreting strength differences, since comparing differently compacted samples can obscure the effect of composition. A recognised mortar test method suitable for the selected application should be identified before testing; this protocol does not claim compliance with a particular standard without its full procedure being followed.

Table 2

Performance criteria for selecting a candidate mortar

Criterion	Measurement	Decision basis
Initial consistency	Mean spread diameter	Matched target interval established during pilot trials.
Processing resistance	Yield stress and viscosity	Application-specific range supported by repeatable measurements.

Flow retention	Spread at declared ages	Minimum retained flow needed for the intended handling time.
Fresh stability	Bleeding and segregation observations	Declared acceptance limits for the selected application.
Hardened performance	7- and 28-day strength	Required strength and comparison with the matched reference.
Water demand	Effective water at equal initial spread	Lower water is accepted only if the other criteria are met.

4.4 Analysis and reproducibility

For each response, report batch-level observations, the mean, standard deviation and uncertainty associated with the measurement procedure. A two-factor analysis can examine water ratio, dosage and their interaction, with laboratory day handled as a block where justified. Continuous regression should be used only within the tested range. If a nonlinear response is evident, an appropriate response surface can be investigated after adding enough design points; a complex model should not be fitted to a small dataset merely to obtain a high coefficient of determination.

Two derived indices are proposed for transparent reporting. Spread retention is $RD(t) = 100D(t)/D(0)$, where $D(t)$ is spread at the declared age and $D(0)$ is initial spread. Water saving at equal initial spread is $Sw = 100(W_{ref} - W_{test})/W_{ref}$, where both water contents refer to the same binder quantity and consistently corrected effective water. These are reporting definitions proposed here, not results. RD alone does not capture viscosity, and Sw should not be calculated from unmatched consistencies.

Raw data should contain batch identifier, material lot, actual masses, moisture corrections, mixing chronology, temperature and each response. Analysis files should retain units and software versions. Graphs should distinguish individual batch observations from fitted predictions. Validation should compare predicted and measured values in reserved batches, and uncertainty should be reported rather than concealed by averaging. No fitted coefficients or validation scores are supplied in this article.

5 Discussion and research hypotheses

The proposed framework changes the practical meaning of low water demand from an unqualified binder description to a measurable comparison. Its central requirement is a common performance basis. A formulation using less water but failing the intended placement interval cannot be accepted as an improvement for that operation. Likewise, a lower water ratio accompanied by a substantial increase in admixture use needs a separate cost evaluation. Water saving should not be presented as proof of lower total environmental impact without assessing the relevant production inputs.

Three hypotheses follow from the synthesis and require testing. First, the formulation giving the largest initial spread may differ from the formulation giving the best flow retention. Second, changing the admixture introduction sequence may modify the time-dependent response even when nominal composition remains unchanged. Third, selecting a mixture using spread and strength alone may accept a candidate with excessive processing viscosity or unacceptable fresh-state instability. These propositions define comparisons that can fail as well as succeed; they are not reported discoveries.

The approach has important boundaries. Evidence from selected pastes and concretes establishes measurement principles but cannot determine optimum values for a particular local mortar. The narrative source selection may omit relevant studies, and no quantitative pooling was attempted. The proposed starting levels therefore need pilot adjustment. A production recommendation also requires a larger trial under realistic handling conditions, including the intended temperature range and equipment. Demonstrating binder performance on one sand source does not establish performance on all sands.

Conclusion

Mortars based on low water demand cements should be evaluated by combining rheological measurements with practical handling and stability checks. The reviewed evidence supports distinguishing flow initiation from viscosity and considering elapsed time and shear history. The proposed protocol separates equal-water comparisons from equal-spread comparisons, identifies effective water consistently and uses independent batch replication. It also treats strength as an acceptance constraint rather than assuming an improvement from reduced water alone.

The methodological contribution is a staged, reproducible route for selecting candidate formulations and testing specific hypotheses. Actual water saving, optimum dosage and performance gains remain to be established experimentally. Future work should apply the protocol to documented binder–admixture systems and disclose raw measurements, uncertainty and validation results. Until those data exist, the present paper supports evaluation design rather than a numerical recommendation for production.

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