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Comparative Experimental Evaluation of Waterproofing Admixtures on the Mechanical and Durability Performance of M20 Concrete

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Abstract

This study evaluates the influence of five waterproofing-admixture categories—naphthalene-, melamine-, lignosulfonate-, polymer- and stearate-based formulations—on the fresh, mechanical and durability properties of M20 concrete. The experimental programme covers slump at water–cement ratios of 0.55, 0.60 and 0.70; 7- and 28-day compressive, split-tensile and flexural strengths; modulus of elasticity; steady-flow water permeability; rapid chloride penetration; accelerated reinforcement-corrosion assessment; 90-day acid and sodium-chloride exposure; and drying shrinkage. Three dosage levels (DI, DII and DIII) were considered for each admixture family. At 28 days, stearate DIII achieved the highest compressive strength (36.11 MPa), flexural strength (4.73 MPa) and modulus of elasticity (2.94×10^4 N/mm²). Ligno DIII produced the highest split-tensile strength (5.54 MPa). Naphthalene DIII had the lowest tabulated 28-day permeability coefficient (5.0140×10^{-11} m/s), representing a 22.85% reduction relative to the control. Polymer DIII exhibited the lowest reported corrosion-related steel mass loss (2.32%). The lowest shrinkage values varied with age: stearate DIII at 28 days and melamine DIII at 60 and 90 days. These results indicate that admixture performance is property-dependent. Interpretation is subject to uncertainties in dosage records, permeability data, RCPT reporting and exposure-test details; the reported findings therefore require confirmation against laboratory records.

Index Terms—Waterproofing admixtures, M20 concrete, compressive strength, permeability, chloride penetration, corrosion, drying shrinkage, concrete durability.

I. INTRODUCTION

Concrete durability depends in part on the transport of water and dissolved aggressive species through connected pores, capillaries and microcracks. Moisture ingress can promote chloride transport, reinforcement corrosion and chemical deterioration. Integral waterproofing admixtures are incorporated during mixing to modify pore connectivity, water repellency or transport properties of the cementitious matrix. Depending on their chemical composition, these materials may act through hydrophobic pore-wall coatings, pore blocking, polymer-film formation or changes in cement-particle dispersion. The effectiveness of an admixture should therefore be assessed using multiple performance indicators. Improvements in slump or compressive strength alone do not establish resistance to pressurised water, chloride ingress or long-term environmental exposure.

This investigation compares five admixture families in a common M20 concrete programme. The objective is to evaluate the response of the tested mixtures across fresh-concrete, mechanical and durability properties rather than to establish a universal ranking for all commercial products. The comparison considers the possibility that an admixture that improves one property may not provide the greatest benefit in other performance measures.

II. OBJECTIVES AND SCOPE

The experimental programme was designed to: (i) compare slump at water–cement ratios of 0.55, 0.60 and 0.70; (ii) determine 7- and 28-day compressive, split-tensile and flexural strengths; (iii) evaluate the modulus of elasticity; (iv) compare steady-flow water permeability and rapid chloride penetration; (v) assess accelerated reinforcement corrosion and 90-day acid and sodium-chloride exposure; and (vi) examine drying shrinkage at 28, 60 and 90 days. The investigation is limited to the M20 mixture and the five admixture families and dosage levels included in the experimental programme.

III. MATERIALS AND EXPERIMENTAL PROGRAMME

The concrete constituents comprised 53-grade ordinary Portland cement, natural river sand (Zone II), crushed coarse aggregate with a nominal maximum size of 20 mm and potable water. The mix proportion was 1:1.55:3.10 (cement:fine aggregate:coarse aggregate). The principal durability comparisons were conducted at a water–cement ratio of 0.55, while slump trials were performed at ratios of 0.55, 0.60 and 0.70. Five admixture families—naphthalene, melamine, ligno, polymer and stearate—were investigated at three dosage levels designated DI, DII and DIII.

Table.1. Materials and Experimental Programme

Parameter	Programme planned
Concrete grade and mix	M20; 1:1.55:3.10 (cement:fine aggregate:coarse aggregate)
Water–cement ratio	0.55, 0.60 and 0.70 for slump; 0.55 for most durability tests
Admixture families	Naphthalene, melamine, ligno, polymer and stearate
Dosage	Three levels (DI, DII, DIII); overall range stated as about 0.12–0.59% by cement mass
Curing ages	7 and 28 days for mechanical properties; 28, 60 and 90 days for shrinkage
Specimens/tests	150 mm cubes; 150×300 mm cylinders; 100×100×500 mm prisms; 102×102×286 mm shrinkage prisms
Durability exposures	Steady-flow permeability, RCPT, accelerated corrosion, 90-day acid and NaCl immersion

Compressive strength was determined using cubes, split-tensile strength using cylinders, flexural strength using prisms and modulus of elasticity using cylindrical specimens. Steady-flow water permeability was evaluated using 150 mm cubes. Rapid chloride penetration specimens were reported as 102 mm in diameter and 51 mm thick. Accelerated corrosion was assessed from the mass loss of embedded steel bars. Chemical resistance was evaluated following 90 days of immersion, and drying-shrinkage readings were recorded at 28, 60 and 90 days. Detailed test conditions and specimen-level records should be reported to enable full replication.

IV. RESULTS AND DISCUSSION

A. Workability of Fresh Concrete

Slump generally increased with admixture addition and, in most cases, with increasing dosage. At a water–cement ratio of 0.55, the control mixture had a slump of 20 mm, while melamine DI reached 68 mm. At a ratio of 0.60, the highest values reported for the melamine, polymer and stearate families were 141, 143 and 156 mm, respectively. These unusually high measurements warrant verification against the original laboratory records. Within the lower water–cement-ratio trials, the melamine-based formulation showed the greatest reported workability improvement. The results should be interpreted cautiously until the high slump readings and corresponding batch details are confirmed.

B. Compressive Strength

The 28-day compressive strength of the control concrete was 25.22 MPa. The tabulated values increased with dosage for each admixture family. Stearate DIII achieved the highest value (36.11 MPa), followed by melamine DIII (34.47 MPa) and naphthalene DIII (32.15 MPa). Ligno DIII and polymer DIII reached 29.89 and 30.22 MPa, respectively. The results indicate that the magnitude of strength enhancement depends on the admixture family and dosage.

Table.2. Compressive Strength values

Mix	DI (MPa)	DII (MPa)	DIII (MPa)
Control	25.22	—	—
Naphthalene	28.95	29.27	32.15
Melamine	31.70	32.36	34.47

Ligno	26.07	27.82	29.89
Polymer	27.51	28.11	30.22
Stearate	31.78	32.91	36.11

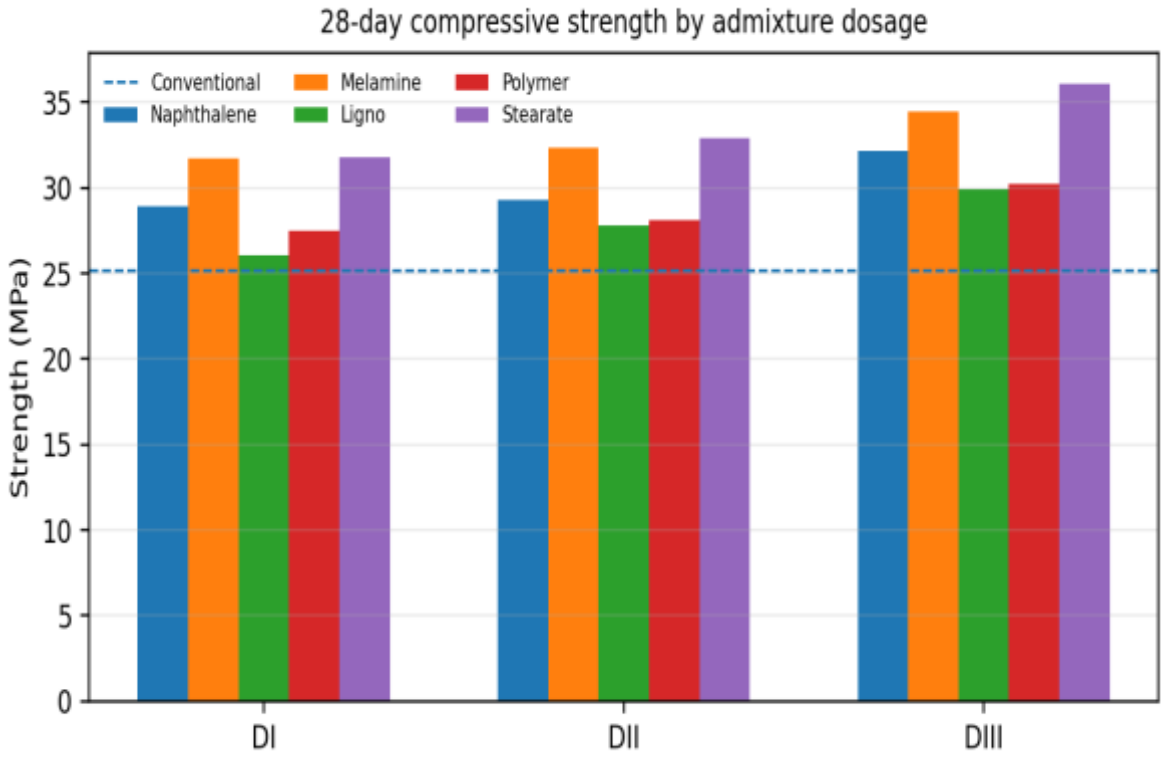


Fig. 1. Reported 28-day compressive strength at three admixture dosage levels.

C. Split Tensile and Flexural Strength

At 28 days, split-tensile strength ranged from 3.27 to 5.54 MPa among the admixture mixtures, compared with 3.11 MPa for the control. Ligno DIII achieved the highest value (5.54 MPa), followed by stearate DIII (5.02 MPa). For flexural strength, the control value was 3.14 MPa, while stearate DIII reached 4.73 MPa and naphthalene DIII reached 4.52 MPa. The admixture producing the highest compressive strength did not produce the highest split-tensile strength, demonstrating that the response varies with the mechanical property considered.

Table.3. Split Tensile and Flexural Strength values

Mix	**28-day split tensile (MPa)**	**28-day flexural (MPa)**
Control	3.11	3.14
Naphthalene DIII	3.87	4.52
Melamine DIII	4.76	4.31
Ligno DIII	5.54	3.67
Polymer DIII	4.60	3.94
Stearate DIII	5.02	4.73

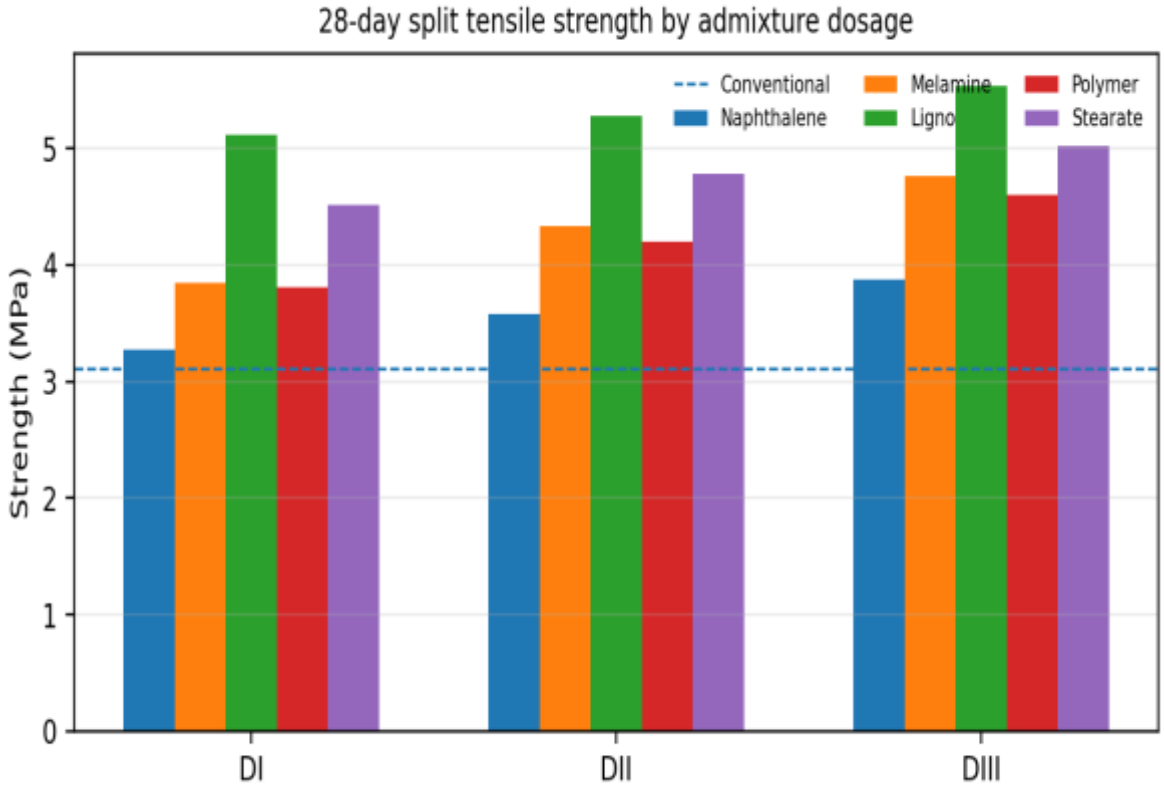


Fig. 2. Reported 28-day split tensile strength by admixture and dosage.

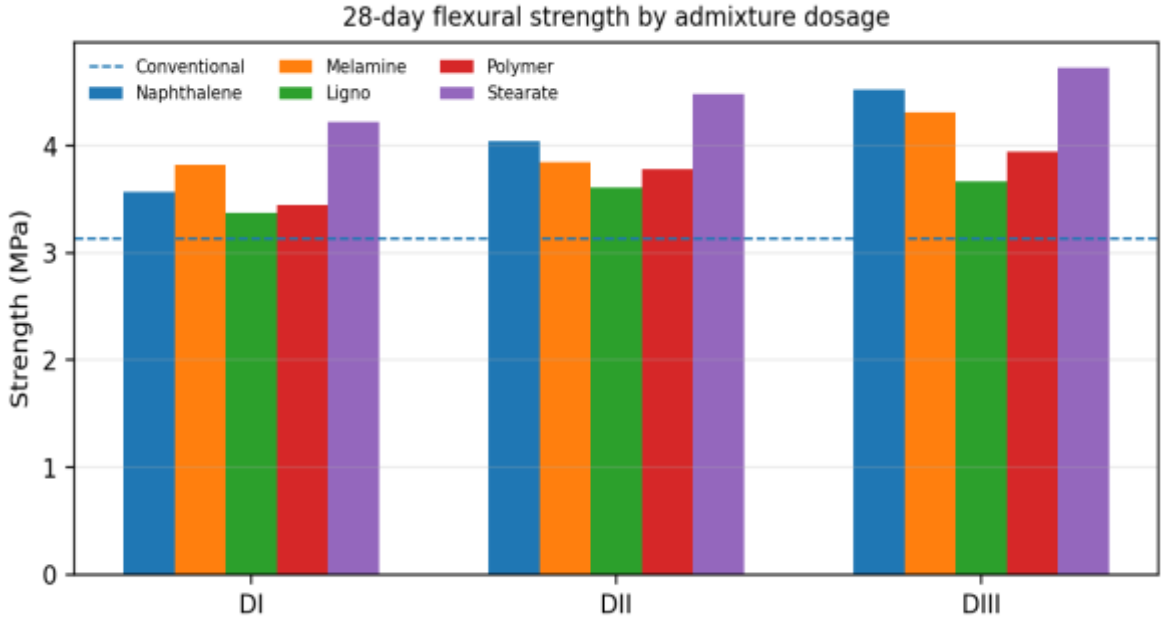


Fig. 3. Reported 28-day flexural strength by admixture and dosage.

D. Modulus of Elasticity

The 28-day modulus of elasticity of the control concrete was 2.43 × 10^4 N/mm². The corresponding values for naphthalene DI–DIII were 2.65, 2.69 and 2.73 × 10^4 N/mm²; for melamine, 2.62, 2.70 and 2.75 × 10^4 N/mm²; for ligno, 2.59, 2.68 and 2.77 × 10^4 N/mm²; for polymer, 2.63, 2.72 and 2.81 × 10^4 N/mm²; and for stearate, 2.79, 2.88 and 2.94 × 10^4 N/mm². Stearate DIII gave the highest tabulated modulus. The tabulated values are used for comparison because some percentage increases stated elsewhere do not agree with these values.

E. Water Permeability

The control permeability coefficients were 7.0749 × 10^{-11} m/s at 7 days and 6.4989 × 10^{-11} m/s at 28 days. Among the DIII mixtures, polymer had the lowest tabulated 7-day coefficient (5.5634 × 10^{-11} m/s), whereas naphthalene had the lowest 28-day coefficient (5.0140 × 10^{-11} m/s). The 28-day naphthalene value represents a 22.85% reduction relative to the control. The admixture giving the lowest measured permeability therefore depends on the curing age considered. Conflicting values occur in the underlying permeability records and require reconciliation before these comparisons are treated as definitive.

Table.4. Water Permeability

Admixture	**7-day K (×10^{-11} m/s), DIII**	**28-day K (×10^{-11} m/s), DIII**	**28-day reduction vs control**
Naphthalene	5.7689	5.0140	22.85%
Melamine	5.7045	5.0547	22.22%
Ligno	5.7530	5.2115	19.81%
Polymer	5.5634	5.6454	13.13%
Stearate	5.5925	5.7014	12.27%

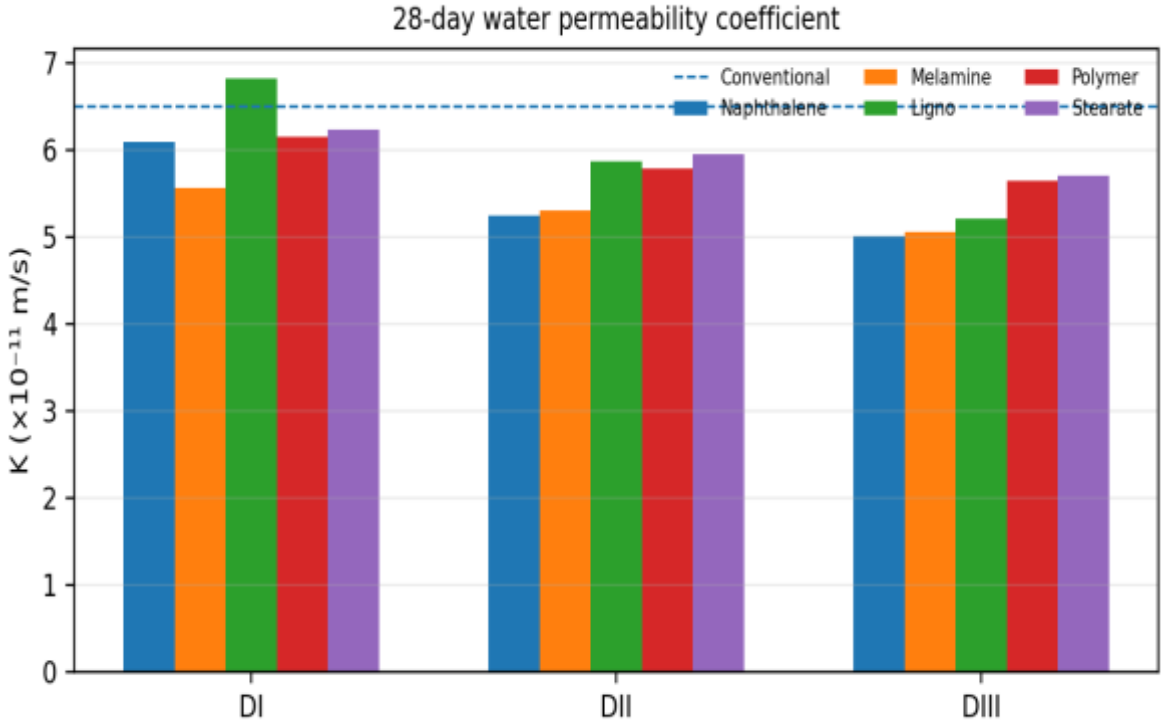


Fig. 4. Reported 28-day water permeability coefficient; lower values indicate lower measured permeability.

F. Rapid Chloride Penetration and Corrosion

The control mixture was reported to have a charge passed of 2349 C. Naphthalene mixtures were reported in the range of 1515–1437 C, while stearate was described as providing the best overall rapid-chloride-penetration performance. The reported interpretation suggests a reduction in charge passed by approximately 1.5–2.7 times. However, the available results include a table labelled as specimen weight change alongside narrative values expressed in coulombs. The complete charge-passed dataset, specimen dimensions and calculation records must be reconciled before a

quantitative comparison can be established. In the accelerated-corrosion assessment, the control concrete had an average embedded-bar mass loss of 3.30%. The corresponding reported averages were 2.32% for polymer DIII, 2.35% for naphthalene DIII, 2.41% for stearate DIII, 2.51% for ligno DIII and 2.61% for melamine DIII. Polymer DIII therefore had the lowest reported steel mass loss in this test.

G. Acid and Chloride Exposure

After 90 days of acid immersion, the control specimen exhibited 0.74% mass loss and a 12.29% reduction in compressive strength relative to its water-immersed counterpart. Stearate DIII exhibited 0.47% mass loss and a reported strength reduction of 1.14%. Following 90 days of sodium-chloride immersion, the control mass loss was 0.69%, compared with 0.42% for stearate DIII; the reported strength loss for stearate DIII was 1.27%. These results indicate lower measured mass and strength losses for stearate DIII under the stated laboratory exposures. The acid identity and concentration, sodium-chloride concentration and solution-management procedure must be specified before broader conclusions about chemical resistance can be drawn.

H. Drying Shrinkage

The control drying-shrinkage values were 240, 270 and 300 × 10^{-6} at 28, 60 and 90 days, respectively. The lowest 28-day value was 150 × 10^{-6} for stearate DIII, corresponding to a 37.5% reduction relative to the control. At 60 and 90 days, melamine DIII gave the lowest values, 200 × 10^{-6} and 230 × 10^{-6}, representing reductions of 25.93% and 23.02%, respectively. Thus, stearate DIII showed the lowest reported shrinkage at 28 days, whereas melamine DIII showed the lowest values at the later measurement ages. The age labels and measurement protocol should be confirmed.

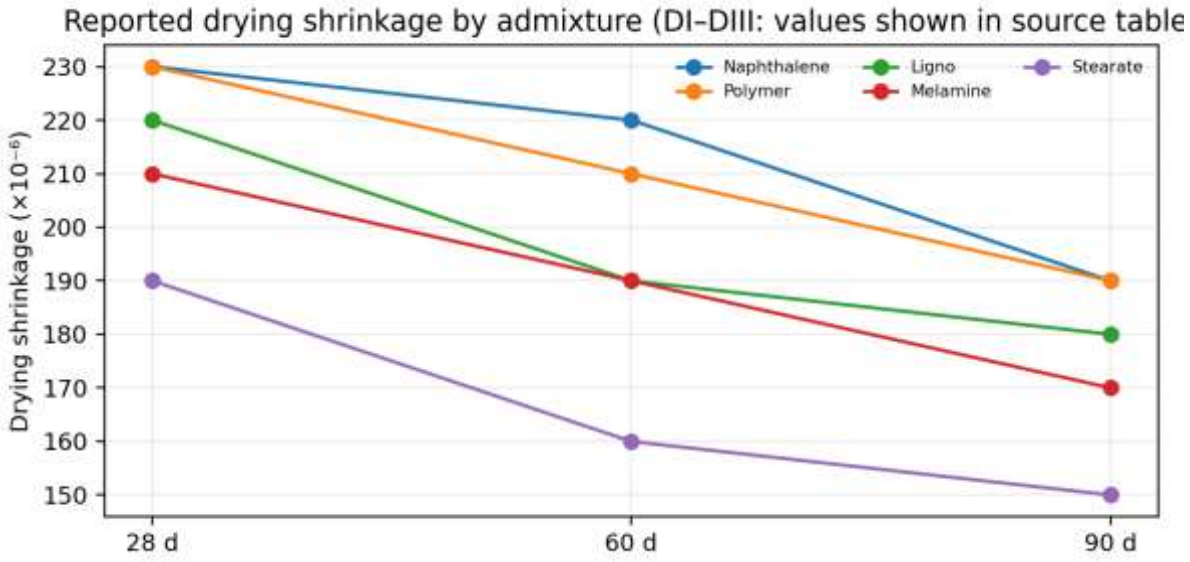


Fig. 5. Drying-shrinkage values at 28, 60 and 90 days for the DIII dosage series.

V. COMPARATIVE INTERPRETATION

The results demonstrate that no single admixture family provides the best response across all measured properties. Melamine-based admixture produced the greatest reported workability at the lower water–cement ratio. Stearate DIII achieved the highest 28-day compressive strength, flexural strength and modulus of elasticity. Ligno DIII produced the highest split-tensile strength. Naphthalene DIII had the lowest tabulated 28-day water-permeability coefficient, while polymer DIII gave the lowest reported corrosion-related steel mass loss. Melamine DIII produced the lowest reported shrinkage at 60 and 90 days, whereas stearate DIII was lowest at 28 days. Admixture selection should therefore be based on the governing performance requirement and exposure condition, subject to verification of the test records.

VI. CONCLUSIONS

The experimental comparison of five waterproofing-admixture families in M20 concrete demonstrates that their influence varies across fresh, mechanical and durability properties. Within the limits of the reported test programme, the following conclusions are drawn:

1. Slump generally increased with admixture dosage. Melamine-based admixture showed the greatest reported workability at the lower water–cement ratio, although unusually high slump readings require verification.
2. Stearate DIII achieved the highest reported 28-day compressive strength (36.11 MPa), flexural strength (4.73 MPa) and modulus of elasticity (2.94×10^4 N/mm²).
3. Ligno DIII produced the highest reported 28-day split-tensile strength (5.54 MPa), confirming that the optimum admixture varied with the mechanical property considered.
4. Naphthalene DIII had the lowest tabulated 28-day water-permeability coefficient (5.0140×10^{-11} m/s), approximately 22.85% below the control value. This result should be interpreted after reconciling the conflicting permeability records.
5. Polymer DIII produced the lowest reported embedded-steel mass loss (2.32%) in the accelerated-corrosion comparison, compared with 3.30% for the control concrete.
6. Stearate DIII showed the lowest reported mass loss during acid and sodium-chloride exposure. Melamine DIII had the lowest reported shrinkage at 60 and 90 days, while stearate DIII had the lowest value at 28 days.
7. The results support property-specific admixture selection rather than a universal ranking. Confirmation of dosage, permeability, RCPT and chemical-exposure records, together with independent replication, is necessary before the findings are used in specifications or design.

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