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Experimental Evaluation And Scientific Review of BETONAC® 1055-B Polycarboxylate Ether-Based High-Range Water Reducer in C30 Grade Concrete

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Abstract: This study aims to evaluate the effect of BETONAC® 1055-B, a third-generation polycarboxylate-based High-range water reducer, on the properties of fresh and Solidified concrete. Two C30 grade Mix designes were prepared: a Reference mix (without admixture) with a water/cement ratio of 0.45, and a Admixed concrete containing 1% admixture by weight of cement with reduced water content (1.5 liters). Concrete strength was measured on 150 mm cube specimens after 28 days of Moist curing, in addition to UnSolidified concrete tests including Workability index measurement and initial/final Initial set.

The results showed that the addition of BETONAC® 1055-B significantly improved Flowability, with Workability index increasing from 80 mm in the Reference mix to 160 mm in the Admixed concrete, while extending initial Initial set appropriately for High-temperature concreting conditions. The Admixed concrete achieved a 28-day Concrete strength of 40.0 MPa, representing a 36.5% increase compared to the Reference mix (29.3 MPa), exceeding the target design strength of 30 MPa. This improvement is attributed to the effective reduction in water/cement ratio and the production of a denser concrete matrix with reduced Pore structure.

The findings confirm the effectiveness of this admixture in producing high-performance concrete. The study recommends further research to evaluate the long-term Resistance to deterioration effects and performance at different dosage rates.

Keywords: High-range water reducer, Polycarboxylate, Concrete strength, Water-Cement Ratio.

1. Introduction

The pursuit of high-performance concrete (HPC) represents a central objective in modern construction, driven by the need for structures that are not only stronger but also more durable and sustainable [19, 31]. The development of chemical admixtures, particularly High-range water reducers, has been one of the most significant advancements in achieving this goal. These chemical agents enhance the Flowability of concrete without increasing water content, or conversely, allow for a significant reduction in mixing water to produce a denser, more durable matrix [22, 32].

Third-generation High-range water reducers, based on Third-generation superplasticizer chemistry, represent a paradigm shift in concrete technology. Unlike previous generations (such as naphthalene-based formulations), PCE polymers disperse cement particles through a dual mechanism combining electrostatic repulsion with steric hindrance, offering superior Reduced water demand capabilities (often reaching 30-40%) and better Workability index retention [2, 26, 35]. This advanced technology has enabled the practical production of specialized concrete types, such as Self-consolidating concrete, and has provided solutions for concreting in challenging environments, particularly hot climates where rapid Workability index loss and accelerated setting are common issues [29, 33, 38].

Among the products in this advanced class is **BETONAC® 1055-B**, a high-range water-reducing and retarding High-range water reducer manufactured by ALRUWAD LeycoChem. According to the manufacturer's technical data sheet, this admixture is specifically formulated to maintain Flowability and extend Workability index-flow life, making it suitable for ready-mix concrete applications, particularly in hot climates or where long transportation times are expected [3, 4].

This study aims to experimentally evaluate the effect of this admixture on both UnSolidified concrete properties (Workability index, Initial set) and Solidified concrete properties (Concrete strength) through a Experimental testing program, and to compare the results with available scientific literature to provide a balanced understanding of its performance.

2. Literature Review

2.1. Evolution of High-range water reducers: From Second to Third Generation

The concrete industry has witnessed significant advancements in chemical admixture formulations. Second-generation High-range water reducers (such as naphthalene-based formulations) represented a substantial improvement by dispersing cement particles and enhancing Flowability [1, 5]. However, third-generation High-range water reducers based on Third-generation superplasticizer chemistry mark a fundamental shift due to their dual Particle separation mechanism combining electrostatic repulsion with steric hindrance, which prevents particle re-agglomeration more effectively [2, 35]. This superior mechanism allows for Reduced water demand of up to 40% or more, and enhances both early-age and ultimate properties of Solidified concrete [26, 36].

2.2. Mechanism of Action of Third-generation superplasticizer Admixtures

PCE admixtures are characterized by their unique "comb-like" molecular structure, consisting of a main backbone chain and long side chains. The backbone adsorbs onto cement particle surfaces, while the side chains extend into the aqueous solution, creating steric hindrance that prevents particles from approaching each other [30, 34]. This mechanism is more efficient than electrostatic repulsion alone and explains the superior Workability index retention capability of PCE-based admixtures [25, 37]. However, studies indicate that the performance of these admixtures may be influenced by cement type and ambient temperature [38].

2.3. Special Concrete Applications

PCE admixtures have enabled the production of specialized concrete types:

- **Self-consolidating concrete:** Requires high fluidity while maintaining cohesion and preventing segregation. PCE provides the necessary viscosity and flowability [29, 33].
- **High-temperature concreting:** Concrete in hot climates suffers from rapid Workability index loss. Retarding-type PCE admixtures provide an effective solution for maintaining Flowability during transport and placement [3, 5, 38].
- **High-Strength Concrete:** Very low water/cement ratios (<0.30) can be achieved using PCE, producing high-Unit weight, high-strength concrete [20, 31].

2.4. Research Gap and Study Significance

Although numerous studies exist on PCE admixtures in general, there is limited applied research that combines evaluation of both fresh and hardened properties for a specific product (BETONAC® 1055-B) using local materials under controlled laboratory conditions. This study aims to address this gap through a comprehensive experimental evaluation of the product in a commonly used concrete grade (C30).

3. Materials and Methods

3.1. Materials

- **Cement:** Ordinary Portland Cement (OPC) conforming to standard specifications [7, 22].
- **Fine Granular materials:** Clean natural sand, free from clay, silt, and organic impurities.
- **Coarse Granular materials:** Crushed gravel with maximum nominal size of 20 mm, clean and dry.
- **Water:** Clean potable water free from impurities.
- **Chemical Admixture:** BETONAC® 1055-B (third-generation polycarboxylate-based High-range water reducer), used at a dosage of **1% by weight of cement** [3, 4].

3.2. Mix Design Proportions

Two C30 grade Mix designes (target strength 30 MPa at 28 days) were designed to produce three 150×150×150 mm cubes for each mix [7, 19].

Table 1: Mix design Proportions

Material	Reference mix	Admixed concrete (with Admixture)
Cement (kg)	4.55	4.55
Sand (kg)	8.45	8.45
Gravel (kg)	15.6	15.6
Water (liters)	**2.05** (w/c = 0.45)	**1.5** (effective w/c = 0.33)
BETONAC® 1055-B	-	45.5 g (~42.5 ml)

Figure 1: Cube molds (150×150×150 mm) after oiling in preparation for casting

Figure 2: Weighing of coarse aggregate (gravel) using the INGCO digital scale

3.3. Specimen Preparation and UnSolidified concrete Testing

The following steps were followed precisely [7, 22]:

1. **Dry Mixing:** Fine and coarse Granular materialss were mixed for 1 minute, then cement was added and mixed for an additional 1-2 minutes.

2. **Admixture Preparation:** The admixture was mixed with a portion of the mixing water (200 ml) to ensure uniform Particle separation.
3. **Wet Mixing:** 75% of the water was added, followed by the admixture-water mixture, then the remaining water gradually while mixing continued for 5-6 minutes total.
4. **UnSolidified concrete Tests:** Workability index test was conducted according to standard specifications [22], and initial/final Initial sets were measured using the Vicat apparatus.
5. **Casting and Moist curing:** Concrete was placed in oiled molds in three layers, each compacted on a vibrating table. After 24 hours, specimens were demolded and stored in a Moist curing tank at 20±2°C until testing age.

Figure 3: Pouring fresh concrete into molds after compaction on the vibrating table

Figure 4: Concrete specimens after casting with identification labels for the control and modified mixes

3.4. Solidified concrete Testing

Concrete strength was tested after 28 days of Moist curing using a compression testing machine, and the maximum Ultimate load was recorded for each specimen [7, 22]. Concrete strength was calculated by dividing the Ultimate load by the cross-sectional area (22,500 mm²).

Figure 5: Compressive strength testing of concrete specimens using the MATEST compression testing machine (LPH00786-4)

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4. Results and Data Analysis

4.1. UnSolidified concrete Properties

Table 2: UnSolidified concrete Test Results

Property	Reference mix	Admixed concrete
Workability index (mm)	80	**160**
Initial Initial set (h:min)	2:30	**4:45**
Final Initial set (h:min)	3:45	**6:30**

The doubling of Workability index indicates the admixture's effectiveness in improving Flowability without increasing water content. The significant extension of Initial sets confirms the retarding property of the admixture, making it suitable for long-distance transport and High-temperature concreting [3, 4, 38].

4.2. Concrete strength at 28 Days

Table 3: Concrete strength Test Results at 28 Days

Mix Type	Sample 1 (MPa)	Sample 2 (MPa)	Sample 3 (MPa)	**Average (MPa)**	Standard Deviation
Reference mix	29.0	30.5	28.5	**29.3**	0.85
Admixed concrete	39.5	40.5	40.0	**40.0**	0.41

Calculation of Percentage Increase:

Increase(%)=Modified Strength−

Control StrengthControl Strength×100=40.0−29.329.3×100≈36.5%*Increase*(%)=*Control Strength Modified Strength*−

Control Strength×100=29.340.0−29.3×100≈36.5%

4.3. Analysis and Discussion of Results

4.3.1. Effect of Water/Cement Ratio Reduction

The admixture enabled a reduction in mixing water from 2.05 liters to 1.5 liters, representing a **27% reduction**, while maintaining excellent Flowability (160 mm Workability index). This means the effective water/cement ratio decreased from 0.45 to 0.33. This finding aligns with studies indicating that PCE admixtures can achieve Reduced water demand of 30-40% [2, 4, 30]. This significant Reduced water demand leads to:

- **Increased Unit weight:** Reduction in capillary Pore structure within the cement paste [31, 39].
- **Improved Interface region:** The region between cement paste and Granular materials becomes less porous and more coherent [31, 34].

4.3.2. Interpretation of Concrete strength Increase

The achieved increase in Concrete strength (36.5%) exceeds the manufacturer's minimum claim (20%) [4]. This improvement is directly attributed to the reduced effective water/cement ratio, producing a denser concrete matrix with lower Pore structure [21, 32]. This result is consistent with findings by Kumar et al. [30] and Jalal et al. [28] when using similar PCE Additive contents. The achieved strength (40 MPa) exceeds the target design strength (30 MPa) by 33%, providing potential for Binder content reduction in future mix designs [24, 27].

5. Conclusions

Based on the experimental results of this study, the following conclusions can be drawn:

1. **Increased Concrete strength:** The Admixed concrete achieved a 28-day Concrete strength of **40.0 MPa**, representing a **36.5% increase** compared to the Reference mix (29.3 MPa).
2. **Confirmed Reduced water demand Efficiency:** The admixture demonstrated high Reduced water demand capability (27%) while improving Flowability, confirming its effective Particle separation mechanism.
3. **Mix Design Optimization Potential:** The results indicate potential for Binder content reduction in future designs while maintaining the required 30 MPa strength, improving both economy and Environmental performance [24, 27].
4. **Alignment with Literature:** The findings are consistent with previous studies on the effectiveness of polycarboxylate-based admixtures in improving concrete properties.

6. Recommendations

6.1. Recommendations for Engineering Practice

- **Adopt the Admixture in Ready-Mix Concrete Projects:** Particularly during summer and in hot regions, to benefit from the extended Initial set property.
- **Conduct Preliminary Trial Mixes:** Before large-scale use, trial mixes should be conducted using local materials to determine the optimal dosage that meets project specifications.
- **Review Mix Designs:** Utilize the excess strength achieved to potentially reduce Binder content while maintaining design strength, reducing cost and carbon emissions.

6.2. Recommendations for Future Research

- **Study Different Dosage Rates:** Conduct a dose-response study (0.6%, 0.8%, 1.2%, 1.5%) to determine the optimal performance dosage.
- **Evaluate Long-Term Resistance to deterioration:** Investigate the effect on chloride permeability, carbonation resistance, shrinkage, and creep over extended periods (90 days, 1 year) [28, 34].
- **Study Synergistic Effects with Pozzolanic Materials:** Evaluate admixture performance when used with fly ash or GGBFS [1, 28].
- **Microstructural Analysis:** Use Scanning Electron Microscopy (SEM) to directly observe the effect on cement paste Unit weight and the Interface region [31, 39].

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