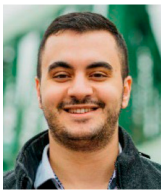
PERFORMANCE OF MECHANICALLY ACTIVATED VOLCANIC TUFF AS A TYPE II ADDITIVE: MECHANICAL EVOLUTION AND DURABILITY IN AGGRESSIVE ENVIRONMENTS



https://doi.org/10.32970/CS.2025.1.1

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The degradation of sewage infrastructure by biogenic sulfuric acid poses a critical challenge for sustainable construction. This study evaluates a mechanically activated volcanic tuff (Cyment L100) as a Type II additive, specifically targeting durability in aggressive wastewater environments. Mechanical evolution and acid resistance (pH 1) were tested for mixtures containing 20% and 40% replacement in CEM I and CEM II systems. Results show that while early strength decreased, CEM I mixtures achieved significant recovery (75 MPa at 56 days). Crucially, acid testing revealed an inversion of the degradation mechanism: while standard Portland cement suffered severe erosion (-1.32% mass loss), the volcanic tuff mixture exhibited mass gain (+1.0%) and retained 100% of its flexural strength. Although frost resistance tests indicated a need for air-entrainment in freeze-thaw zones, the results position this volcanic binder as a specialized, high-durability solution for lining sewage pipelines and wastewater treatment plants (Exposure Class XA3), offering superior resistance to chemical attack compared to standard binders.

Keywords: Volcanic Tuff, Supplementary Cementitious Materials, Concrete Durability, Freeze-Thaw Resistance, Chloride Migration, Acid Resistance

1. INTRODUCTION

Concrete is the most widely used construction material globally, and its production is a major contributor to anthropogenic carbon dioxide emissions, primarily due to the calcination process in clinker manufacturing (Scrivener et al., 2018). To address this, the industry is increasingly adopting Supplementary Cementitious Materials (SCMs) such as fly ash, slag, and natural pozzolans. Volcanic tuffs, abundant in many regions including the Carpathian Basin, possess pozzolanic properties—specifically reactive amorphous silica and alumina—that allow them to react with calcium hydroxide (CH) to form secondary Calcium-Silicate-Hydrate (C-S-H) gels.

Beyond carbon reduction, a critical challenge in modern infrastructure is the rapid deterioration of sewage and wastewater systems due to Biogenic Sulfuric Acid (BSA) corrosion. In these environments, bacteria convert sulfates into sulfuric acid, leading to pH levels as low as 1–2, which rapidly dissolves calcium hydroxide in standard Portland cement. Therefore, developing binders that consume calcium hydroxide through pozzolanic activity is essential for extending the service life of wastewater networks.

This study evaluates “Cyment L100,” a mechanically activated volcanic tuff-based Type II additive. While previous studies have established the general pozzolanic potential of volcanic rocks, this research focuses on the specific trade-offs between chemical durability (acid resistance), transport properties (watertightness), and physical durability (frost resistance) in high-performance concrete. We hypothesize that the pore refinement caused by the pozzolanic reaction enhances chemical resistance but may alter the air-void system, potentially compromising freeze-thaw stability in the absence of air-entraining agents.

The objective is to determine the optimal replacement level (20% vs. 40%) and binder compatibility (CEM I vs. CEM II) to maximize sustainability without sacrificing critical durability metrics required for aggressive exposure classes (XA3, XF4).

2. EXPERIMENTAL PROGRAM

2.1. Materials

Two types of cement supplied by Duna-Dráva Cement Kft. were used:

2.1.1. CEM I 52.5 N

A rapid-hardening Portland cement was selected to provide a binder matrix with high alkalinity and abundant calcium hydroxide (CH). This ensures an optimal environment for the pozzolanic reaction, allowing for the assessment of the intrinsic reactivity of the Cyment L100 additive without the interference of competitive secondary reactions.

2.1.2. CEM II/A-S 42.5 N: A Portland-slag cement containing 6–20% blast furnace slag

A Portland-slag cement was chosen to represent current low-carbon industry standards. This binder allows for the

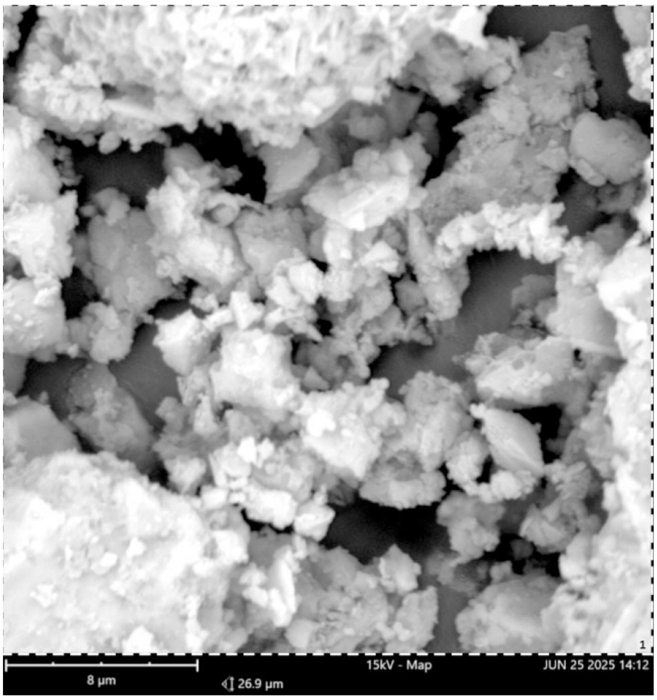


Figure 1: SEM analysis of cyment powder

investigation of 'multi-blend' compatibility; specifically, whether the volcanic tuff can be effectively used in systems where the clinker factor is already reduced by blast furnace slag (Siddique, R. 2012). This combination evaluates the risks of 'clinker dilution' and the competitive demand for calcium hydroxide between the slag and the volcanic tuff.

2.1.3. Cyment L100

Cyment L100 is a multi-component ground volcanic tuff-based additive, produced as a fine powder from pre-dried and mechanically conditioned volcanic tuff, metallurgical slag, and incineration ash. It is primarily used in concrete production, particularly for cast-in-situ and prefabricated structural concrete, where it enhances key properties such as non-permeability, heat reduction, and resistance to environmental aggressiveness.

Designed for use in combination with cements complying with EN 197-1, cyment L is assessed to provide a working life of at least 50 years when used in concrete. The manufacturer specifies its intended use as a type II addition in concrete. The manufacturing process follows conventional grinding techniques without additional treatments that would alter its performance, with further details provided in the manufacturer's documentation (Annex 1).

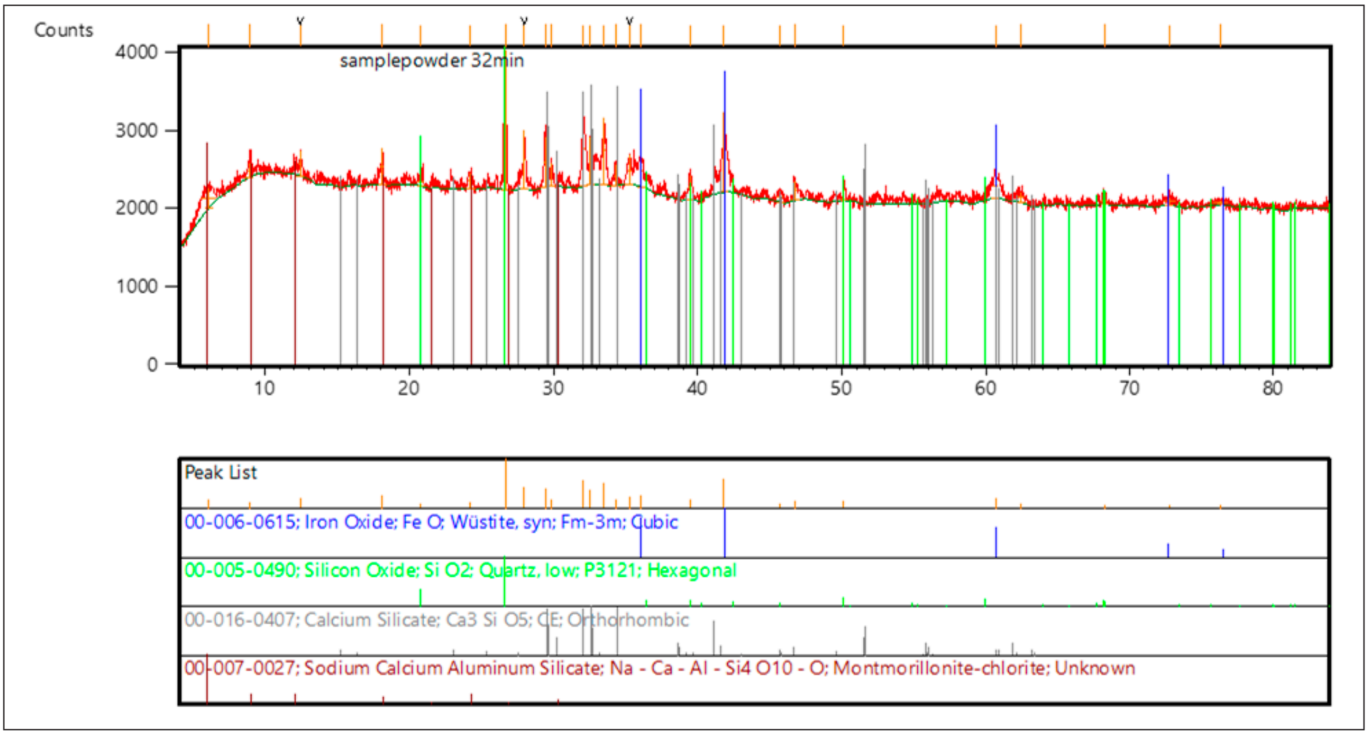
Scanning Electron Microscopy (SEM) analysis was conducted to verify the morphological characteristics of the mechanically activated volcanic tuff (Cyment). Contrary to the initial hypothesis of a spherical morphology typical of fly ash or silica fume, the micrographs reveal that the Cyment particles are predominantly **angular, irregular, and blocky** with sharp fracture edges *(Fig. 1).*

This morphology is consistent with the comminution process of natural rock, confirming its origin as a ground volcanic tuff. The images display a polydisperse particle size distribution, where finer dust-like particles ($< 2 \mu m$) adhere to the surfaces of larger angular fragments ($10–50 \mu m$). While the lack of spherical shape may increase water demand due to higher inter-particle friction, the rough surface texture and wide gradation likely contribute to a dense particle packing effect, enhancing the physical impermeability of the binder matrix.

Powder X-ray diffraction (XRD) is a powerful analytical technique used primarily for identifying the crystallographic structure, phase composition, and physical properties of a material. It is particularly useful in materials science, chemistry, geology, and engineering for several key applications. The XRD analysis of the cyment L100 indicates the presence of reactive amorphous phases alongside crystalline quartz (SiO_2) and hematite (FeO).

- Iron Oxide (Wüstite, FeO): This phase contributes to the materials overall structure and potentially to its reactivity in cement systems.

Figure 2: X-ray diffraction of cyment powder



- Silicon Oxide (Quartz, SiO_2): A critical component that likely contributes to the pozzolanic reactivity of cyment, particularly in later-stage strength development.
- Calcium Silicate (Ca_3SiO_5): This phase resembles alite, the primary strength-developing component in Portland cement, suggesting cyment contains cementitious properties inherently.
- Sodium Calcium Aluminum Silicate (Montmorillonite-chlorite): A complex aluminosilicate phase that may contribute to the materials reactivity with calcium hydroxide during cement hydration.

These phases suggest the presence of oxides and silicates, commonly found in geological or construction materials like cement or clays. Each phase is indexed with a reference number for verification against known standards. The XRD profile *(figure 2)* provides insights into the sample's mineral composition, as the peak positions and intensities correlate with specific crystal structures. The material analyzed in the document appears to be crystalline rather than amorphous. This conclusion is based on the presence of distinct peaks in the XRD pattern. Crystalline materials produce sharp, well-defined peaks in an XRD analysis due to the orderly arrangement of atoms in their structure. Amorphous materials, on the other hand, lack this long-range order and typically show broad, diffuse humps rather than distinct peaks. The sharp peaks identified, corresponding to specific minerals like quartz and Wüstite, confirm its crystalline nature.

2.2. Concrete mix design

Six concrete mix designs were developed for this study, divided into two series based on cement type. For each cement type, three mixes were prepared: a standard reference mixture without Cyment (designated as A-0 or B-0), a mixture with 20% cement replacement by Cyment (A-20% or B-20%), and a mixture with 40% cement replacement (A-40% or B-40%). The CEM I 52.5 N series was formulated with a cement content of 380 kg/m^3 in the reference mixture, while the CEM II A-S 42.5 N series contained 340 kg/m^3 of cement in its reference mixture.

In the Cyment-containing mixtures, 20% or 40% of the cement weight was replaced with Cyment L100, with all other components remaining consistent within each series. This replacement strategy allowed for direct comparison of the effects of Cyment addition on concrete properties without the influence of other variables.

The concrete mixtures were prepared using a consistent aggregate framework across all mix designs. Sika ViscoCrete 4025 was employed as a plasticizer to achieve the target consistency class (F4) for all mixtures. The water-to-cement ratios were maintained at 0.4 for CEM I mixtures and 0.5 for CEM II mixtures, ensuring comparability within each cement type series while acknowledging the inherent differences between the two cement types.

3. METHODOLOGY

A comprehensive testing program was implemented to evaluate various properties of fresh and hardened concrete. Fresh concrete tests included consistency evaluation through spread tests according to MSZ EN 12350-5:2019 and bulk density measurements following MSZ EN 12350-6:2019. The consistency was adjusted using a plasticizer to achieve the F4 consistency class for all mixtures, ensuring workability comparability across the different compositions. Hardened concrete properties were evaluated through several standardized tests.

Compressive strength was determined on 150 mm cube specimens at ages of 2, 28, and 56 days according to MSZ EN 12390-3:2019, with three specimens tested per mixture and age. Watertightness testing was conducted following MSZ EN 12390-8:2019, providing insights into the permeability characteristics of the different mixtures.

Durability aspects were assessed through frost resistance testing (flange peeling in 3% NaCl medium) according to MSZ CEN/TS 12390-9:2018, chloride ion penetration testing using a migration apparatus and silver nitrate spray indicator, and acid resistance evaluation involving 8-week exposure to pH 1 sulfuric acid.

For the acid resistance test, specimens were prepared as 70 × 70 × 250 mm prisms, with three specimens per mixture subjected to standard conditions (submerged in water) and three to acidic conditions, followed by assessment of mass change and strength properties after the exposure period.

4. RESULTS

4.1. Fresh properties

All mixtures were adjusted to meet the target F4 consistency class (flow diameter 490–550 mm) by varying the superplasticizer dosage. As shown in Table 2 and Table 3, the addition of volcanic tuff (Cyment) had a negligible impact on fresh concrete density, with values remaining within the range of 2,350–2,390 kg/m^3.

Notably, in the CEM I series, the 40% replacement mixture (A-40) required slightly less superplasticizer (2.74 kg/ m^3) than the reference (3.04 kg/m^3) to achieve similar workability (590 mm vs. 570 mm).

4.2. Compressive strength

Compressive strength tests were conducted on 150 mm cubic specimens in accordance with MSZ EN 12390-3:2019. Three

Table 1: Mix Proportions ()

Mix ID	Binder	Cement (kg/m^3)	Cyment (kg/m^3)	Water (kg/m^3)	Replacement
A-0 (Ref)	CEM I 52.5 N	380	0	152	0%
A-20		304	76	152	20%
A-40		228	152	152	40%
B-0 (Ref)	CEM II/A-S	340	0	170	0%
B-20		272	68	170	20%
B-40		204	136	170	40%

Table 2: Fresh concrete properties of CEM I 52.5 N mixtures

Mix ID	Cement Replacement	Superplasticizer	Slump Flow	Fresh Density	Temperature
	(%)	(kg/m^3)	(mm)	(kg/m^3)	(°C)
A-0 (Ref)	0%	3.04	570	2,390	21
A-20	20%	3.04	600	2,390	21.2
A-40	40%	2.74	590	2,370	21.4

Table 3: Fresh concrete properties of CEM II/A-S 42.5 N mixtures

Mix ID	Cement Replacement	Superplasticizer	Slump Flow	Fresh Density	Temperature
	(%)	(kg/m^3)	(mm)	(kg/m^3)	(°C)
B-0 (Ref)	0%	1.7	520	2,380	22.1
B-20	20%	2.31	550	2,370	22.3
B-40	40%	2.04	540	2,350	22.4

specimens were tested for each mixture at every testing age (2, 28, and 56 days).

In the case of mixtures made with CEM I 52.5 N cement, the addition of Cyment resulted in a distinct retardation of early-age strength. At 2 days, the mixtures exhibited a 40–50% strength deficit compared to the reference. However, the pozzolanic reaction accelerated significantly thereafter; by 28 days, the strength gap narrowed to 12–22%. At 56 days, the mixtures maintained structural-grade strengths, with the gap stabilizing between 10–20% for both replacement levels *(Figure 3)*.

For the CEM II series, the interaction between the additive and the slag-blended cement varied significantly by dosage. The 20% replacement mixture (B-20) showed excellent compatibility, initially lagging by 15% at 2 days but fully recovering to match (and momentarily exceed) the reference strength by 28 days (101.6%). Conversely, the 40% replacement (B-40) exhibited a sharp drop in early strength (50% deficit at 2 days) and stabilized at approximately 20% lower strength than the reference at later ages *(Figure 3)*.

4.2.1. Results for CEM I 52.5 N Series

Table 4.

4.2.2. Results for CEM II/A-S 42.5 N Series

Table 5.

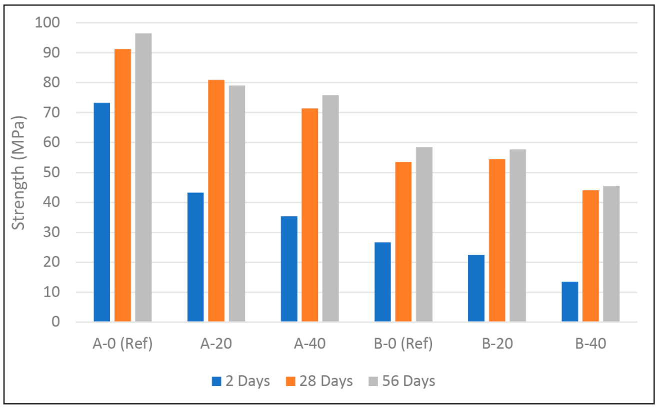


Figure 3: Compressive strengths as a function of age

4.3. Watertightness

The watertightness test of the solidified concrete test specimen was carried out on the basis of the MSZ EN 12390-8:2019 standard.

In the CEM I series, Cyment addition clearly improved watertightness. The average penetration depth decreased from 23.6 mm (Reference) to 19.5 mm (A-20) and 18.3 mm (A-40). This corresponds to a 17–22% improvement in impermeability. However, in the CEM II series, the opposite effect was observed, with penetration depths increasing significantly in the blended cement mixtures.

Table 4: Compressive strength development of mixtures with CEM I 52.5 N

Mix ID	2 Days		28 Days		56 Days	
	Strength (MPa)	Rel. (%)	Strength (MPa)	Rel. (%)	Strength (MPa)	Rel. (%)
A-0 (Ref)	73.29	100	91.19	100	96.5	100
A-20	43.29	59.1	80.89	88.7	79.07	81.9
A-40	35.36	48.2	71.38	78.3	75.85	78.6

Table 5: Compressive strength development of mixtures with CEM II/A-S 42.5 N

Mix ID	2 Days		28 Days		56 Days	
	Strength (MPa)	Rel. (%)	Strength (MPa)	Rel. (%)	Strength (MPa)	Rel. (%)
B-0 (Ref)	26.64	100	53.52	100	58.46	100
B-20	22.45	84.3	54.39	101.6	57.74	98.8
B-40	13.5	50.7	43.99	82.2	45.56	77.9

Table 6: Watertightness results of mixtures

Mix ID	Average Depth (mm)	Relative to Ref. (%)
A-0 (Ref)	23.6	100%
A-20	19.5	83%
A-40	18.3	78%
B-0 (Ref)	15.3	100%
B-20	20.4	133%
B-40	27.4	179%

Table 7: Cumulative scaling mass loss after 56 freeze-thaw cycles

Mix ID	Scaling (g/m^2)	Relative to Ref. (%)	Visual Assessment
A-0 (Ref)	1,399	100%	Slight Scaling (Acceptable)
A-20	4,581	327%	High Scaling (Pass*)
A-40	4,957	354%	High Scaling (Pass*)
B-0 (Ref)	1,825	100%	Slight Scaling (Acceptable)
B-20	7,896	432%	Severe Scaling
B-40	>10,000	--	FAILED (Disintegration)

4.4. Frost resistance (Flange peeling)

The freeze-thaw resistance was evaluated using the slab test method (CEN/TS 12390-9:2018). Specimens were exposed to 56 freeze-thaw cycles in the presence of a 3% NaCl de-icing solution.

4.5. Chloride migration

The resistance to chloride ingress was evaluated using the non-steady-state migration test (similar to NT BUILD 492). The penetration depth (X_d) was measured at 28 days and 56 days to capture the evolution of the pore structure.

4.6. Acid resistance

The acid resistance testing, involving 8-week exposure to pH 1 sulfuric acid, revealed notable differences in performance between mixtures with and without Cyment. In the CEM I series, the standard mixture experienced a mass loss of approximately 1.5%, corresponding to visible surface deterioration. In contrast, specimens with Cyment addition showed no mass loss during the acid exposure, indicating superior acid resistance.

Six specimens (70 × 70 × 250 mm) were prepared from each mixture. Three reference specimens were stored under water. The acidic medium was adjusted to pH 1. The medium was changed weekly after measuring the specimens masses.

The reference mixture (A-0) *(Figure 4)* was the only formulation to suffer mass loss (-1.32%). In sharp contrast,

Figure 4: CEM I specimens after the acid test

Figure 5: CEM II specimens after the acid test

Table 8: chloride migration depths

Mix ID	28-Day Depth (mm)	56-Day Depth (mm)	Evolution (28d → 56d)	Performance at 56d
A-0 (Ref)	11.9	12.9	+8.4% (Stable)	Reference Baseline
A-20	11.6	11.8	+1.7% (Stable)	Equivalent to Ref
A-40	13.8	9.4	-31.9% (Improvement)	Best Performance
B-0 (Ref)	17.1	18.8	+9.9% (Degradation)	High Permeability
B-20	14.2	14.9	+4.9% (Stable)	Better than Ref
B-40	22.6	15.9	-29.6% (Improvement)	Improved vs 28d

Table 9: Average Mass Change after 8 Weeks (Acid vs. Water)

Mix ID	Water Storage (Control)	Acid Storage (1% H_2SO_4)	Durability Status
A-0 (Ref)	+1.0 g (+0.03%)	-38.7 g (-1.32%)	Surface Erosion (Mass Loss)
A-20	+22.1 g (+0.75%)	+15.2 g (+0.51%)	Intact (Mass Gain)
A-40	+20.4 g (+0.69%)	+31.9 g (+1.09%)	Intact (Mass Gain)
B-0 (Ref)	+10.3 g (+0.36%)	+15.6 g (+0.53%)	Intact (Mass Gain)
B-20	+25.9 g (+0.89%)	+34.4 g (+1.16%)	Intact (Mass Gain)
B-40	+20.6 g (+0.71%)	+36.2 g (+1.25%)	Intact (Mass Gain)

Table 10: Residual Compressive Strength after 8 Weeks in 1%

Mix ID	Standard Strength (MPa)	Post-Acid Strength (MPa)	Retention Index (%)	Performance vs Ref
A-0 (Ref)	89.9	54.6	60.70%	Severe Degradation
A-20	77.2	58.8	76.20%	Moderate Protection
A-40	71.2	64.9	91.20%	High Protection
B-0 (Ref)	60.3	54.8	90.90%	Inherently Resistant
B-20	55.2	48.8	88.40%	Stable
B-40	46.4	43.9	94.60%	Stable (Low Strength)

Table 11: Residual Flexural Strength after 8 Weeks in 1%

Mix ID	Standard Strength (MPa)	Post-Acid Strength (MPa)	Retention Index (%)
A-0 (Ref)	4.76	4.49	94.30%
A-20	4.07	3.69	90.70%
A-40	4.37	4.49	102.7% (No Loss)
B-0 (Ref)	3.51	3.14	89.50%
B-20	3.5	3.43	98.00%
B-40	2.77	2.79	100.70%

the addition of Cyment (A-20 and A-40) completely arrested this erosion. Instead of losing mass, these mixtures gained mass (+0.5% to +1.0%).

The CEM II series (B-0, B-20, B-40) *(Figure 5)* consistently showed mass gain, confirming the inherent acid resistance of slag-based cements. The addition of Cyment further increased this mass gain. While this suggests no immediate erosion, the higher mass accumulation in B-40 (+1.25%) compared to B-0 (+0.53%) could indicate a higher volume of expansive product formation, which might lead to cracking over longer exposure periods (beyond 8 weeks).

4.7. Residual Mechanical Properties after Acid Exposure

The pure Portland cement (A-0) suffered a catastrophic loss of compressive strength, retaining only 60.7% of its capacity. As the replacement level increased, the degradation vanished. The A-40 mixture retained 91.2% of its strength. More importantly, in absolute terms, the A-40 mixture was stronger after acid attack (64.9 MPa) than the reference A-0 (54.6 MPa). Remarkably, the A-40 mixture showed no loss in flexural strength (102.7% retention).

The CEM II series exhibited high retention rates (88–95%) across all mixes, confirming that slag cements are inherently acid-resistant due to their lower calcium hydroxide content. However, the absolute strength of these mixtures remained significantly lower than the Cyment-modified CEM I mixtures (e.g., B-40 Acid Strength: 43.9 MPa vs. A-40 Acid Strength: 64.9 MPa).

5. DISCUSSIONS

The experimental results define Cyment L100 as a chemo-dependent pozzolan whose performance is strictly governed by the alkalinity of the host binder and the specific exposure environment. This section analyzes the mechanisms driving the trade-offs between mechanical recovery (Uzalis, N., et al. 2005), transport properties, and chemical durability.

5.1. Fresh State and Early-Age Behavior

Unlike many natural pozzolans that increase water demand due to high specific surface area, Cyment L100 exhibited a neutral-to-positive effect on workability. In the CEM I series, the 40% replacement mixture (A-40) achieved the target F4 consistency (590 mm flow) with slightly lower superplasticizer dosage than the reference. This suggests that the mechanical activation process may optimize particle morphology, allowing the tuff to act as a lubricant or “ball bearing” in the fresh paste contrary to the typical water-demand increase observed with some natural pozzolans.

However, the “Dilution Effect” was evident at early ages. By replacing rapid-hardening clinker with slower-reacting volcanic tuff, the initial volume of hydration products was reduced, leading to a 40–50% strength deficit at 2 days across all mixtures. At this stage, the volcanic tuff acts primarily as an inert filler, as the alkalinity of the pore solution is not yet sufficient to trigger the dissolution of amorphous silica.

5.2. Mechanical Evolution and Activator Starvation

The subsequent strength development highlights the “Critical Clinker Factor”.

The experimental data defines Cyment L100 as a chemo-dependent pozzolan whose mechanical efficiency is strictly governed by the alkalinity of the host binder.

- In High-Alkalinity Environments (CEM I): Cyment transitions from a filler to a binder. The abundance of calcium hydroxide (CH) provided by the pure Portland clinker drives the pozzolanic reaction, allowing the A-40 mixture to recover from 35 MPa (2 days) to 75 MPa (56 days).
- In Competitive Environments (CEM II): The B-40 mixture (CEM II + 40% Cyment) revealed a phenomenon of “Activator Starvation.” The simultaneous demand for alkalis by both the slag (inherent in CEM II) and the high volume of Cyment exceeded the system’s capacity. This “Double Negative” effect arrested hydration, leaving the Cyment largely unreacted and resulting in a permanent strength deficit (Turk, k., et al. 2007).

5.3. Transport Properties: The “Late-Blocking” Effect

The impact of Cyment on fluid transport revealed a strong time-dependency, confirming its slow reaction kinetics.

In the Chloride Migration test, the A-40 mixture initially performed worse than the reference at 28 days (13.8 mm vs. 11.9 mm), behaving as a porous matrix. However, a dramatic transformation occurred between 28 and 56 days, where the penetration depth dropped by 32% to just 9.4 mm. This “Late-Blocking” effect confirms that once the volcanic tuff dissolves and reacts with calcium hydroxide, the secondary C-S-H products effectively precipitate within the capillary network (Massazza, F. 2022). This mechanism correlates directly with the watertightness results, where the A-40 mixture achieved the densest microstructure among all mixes, but only after sufficient curing time.

Conversely, in the CEM II series, this blocking mechanism failed. The B-40 mixture exhibited increased permeability, further evidence that without sufficient CH to activate the tuff, the particles serve only to disrupt the binder matrix rather than refine it (Khan, M. I. 2012).

5.4. The Durability Paradox: Frost vs. Chemical Resistance

The most significant finding of this study is the sharp divergence between physical and chemical durability performance.

5.4.1. Freeze-Thaw Vulnerability (Physical Failure)

While Cyment improved impermeability in CEM I, it drastically reduced frost resistance. The failure mechanism appears to be twofold:

1. Air-Void Destabilization: Frost resistance relies on a network of microscopic air bubbles to relieve hydraulic pressure (Valcuende, M., & Parra, C. 2010). The high volume of fine volcanic tuff particles (76–152 kg/m^3) likely filled these voids or destabilized the entrained air during mixing.
2. Pore Connectivity: Although Cyment refined the chemical porosity (blocking chloride ions), it appears to have created a capillary network that, while finer, remains saturable. When this refined system freezes, the hydraulic pressure cannot escape, leading to surface scaling.

The catastrophic failure of the B-40 mixture serves as a warning against using high-volume pozzolans in low-clinker systems without air entrainment; the weak binder matrix simply disintegrated under expansive ice forces.

The experimental data reveals a critical vulnerability in the use of volcanic tuff without air-entrainment adjustments. cyment L100 significantly increases the scaling potential of concrete. While it acts as a pore-blocker for fluids (improving watertightness), it does not provide freeze-thaw protection. Consequently, for applications exposed to de-icing salts (Exposure Class XF4), Cyment mixtures must be air-entrained or limited to lower replacement levels (<20%) to prevent surface degradation.

5.4.2. Acid Resistance (Chemical Shield)

In contrast to the physical failure under frost, Cyment provided a decisive advantage against chemical attack. In the sulfuric acid exposure test, the pure CEM I reference suffered severe degradation, losing mass and 40% of its compressive strength due to the rapid dissolution of calcium hydroxide.

Cyment effectively reversed this degradation. The A-40 mixture not only prevented mass loss but retained 91% of its compressive strength and 100% of its flexural strength. By consuming the soluble calcium hydroxide; the primary target for acid attack in **sewage environments**; cyment effectively mitigates the risk of **biogenic corrosion**. The formation of a dense, chemically stable matrix suggests that Cyment-modified concrete is particularly suitable for **Exposure Class XA3** (highly aggressive chemical environments), common in industrial and municipal wastewater facilities.

6. FINDINGS

The most distinct advantage of the Cyment-modified binder is its exceptional resistance to sulfuric acid (pH 1), identifying it as a premium material for **sewage infrastructure**. While standard CEM I concrete suffered severe surface erosion (-1.32% mass loss), the volcanic tuff mixture inverted this mechanism, leading to mass gain (+1.0%) and the retention of **100% of flexural strength**. This confirms that Cyment acts as an effective chemical shield against biogenic acid corrosion in wastewater treatment tanks and pipes.

The study establishes a definitive boundary for usage. Cyment acts as a “chemo-dependent” additive that requires a high-alkalinity host. In **CEM I systems**, it contributes to strength recovery (75 MPa at 56 days); however, in low-clinker **CEM II systems**, it induces “activator starvation,” leading to arrested hydration.

A critical divergence was identified between chemical and physical durability. The same pore refinement that blocked chloride ingress (-32% depth) created a capillary structure vulnerable to freezing pressure. Therefore, this study mandates that for **Exposure Class XF4**, Cyment usage must be coupled with air-entrainment or limited to <20% replacement to prevent scaling failure.

At 40% replacement in CEM I, the material offers a viable strategy for reducing embodied carbon by **roughly 33%** without compromising long-term mechanical performance, provided the curing duration is sufficient to overcome the early-age dilution effect.

7. REFERENCES

Cyment: Fewer emissions, more sustainability: (n.d.). Retrieved from https://www.cyment.eu/en/

MSZ EN 197-1:2011. Cement – Part 1: Composition, specifications and conformity criteria for common cements. European Committee for Standardization.

MSZ EN 12390-3:2019. Testing hardened concrete – Part 3: Compressive strength of test specimens. European Committee for Standardization.

MSZ EN 12390-8:2019. Testing hardened concrete – Part 8: Depth of penetration of water under pressure. European Committee for Standardization.

CEN/TS 12390-9:2016. Testing hardened concrete – Part 9: Freeze-thaw resistance - Scaling. European Committee for Standardization.

Scrivener, K. L., John, V. M., & Gartner, E. M. (2018). Eco-efficient cements: Potential economically viable solutions for a low-CO2 cement-based materials industry. Cement and Concrete Research, 114, 2–26.

Siddique, R. (2012). Effect of volcanic ash on the properties of cement paste and mortar. Resources, Conservation and Recycling, 56, 66–70.

Massazza, F. (2002). Pozzolana and pozzolanic cements. In Lea's Chemistry of Cement and Concrete (4th ed., pp. 471–631). Butterworth-Heinemann.

Uzalis, N., et al. (2005). The effect of volcanic tuff on the strength and durability of concrete. Cement and Concrete Research, 35(9), 1785-1793.

Khan, M. I. (2012). Permeability and chloride penetration resistance of concrete containing natural pozzolan. Journal of Materials in Civil Engineering, 24(11).

Valcuende, M., & Parra, C. (2010). Natural products as a substitute for microsilica in high-performance concrete: Frost resistance. Construction and Building Materials, 24(12).

Allahverdi, A., & Škvára, F. (2000). Acidic corrosion of hydrated cement-based materials. Ceramics – Silikáty, 44(3), 114–120.

Turk, K., et al. (2007). Sulfate resistance of blended cements containing natural pozzolan and fly ash. Construction.

Massazza, F. (2002). Pozzolana and pozzolanic cements. In Lea's Chemistry of Cement and Concrete (4th ed., pp. 471–631). Butterworth-Heinemann.

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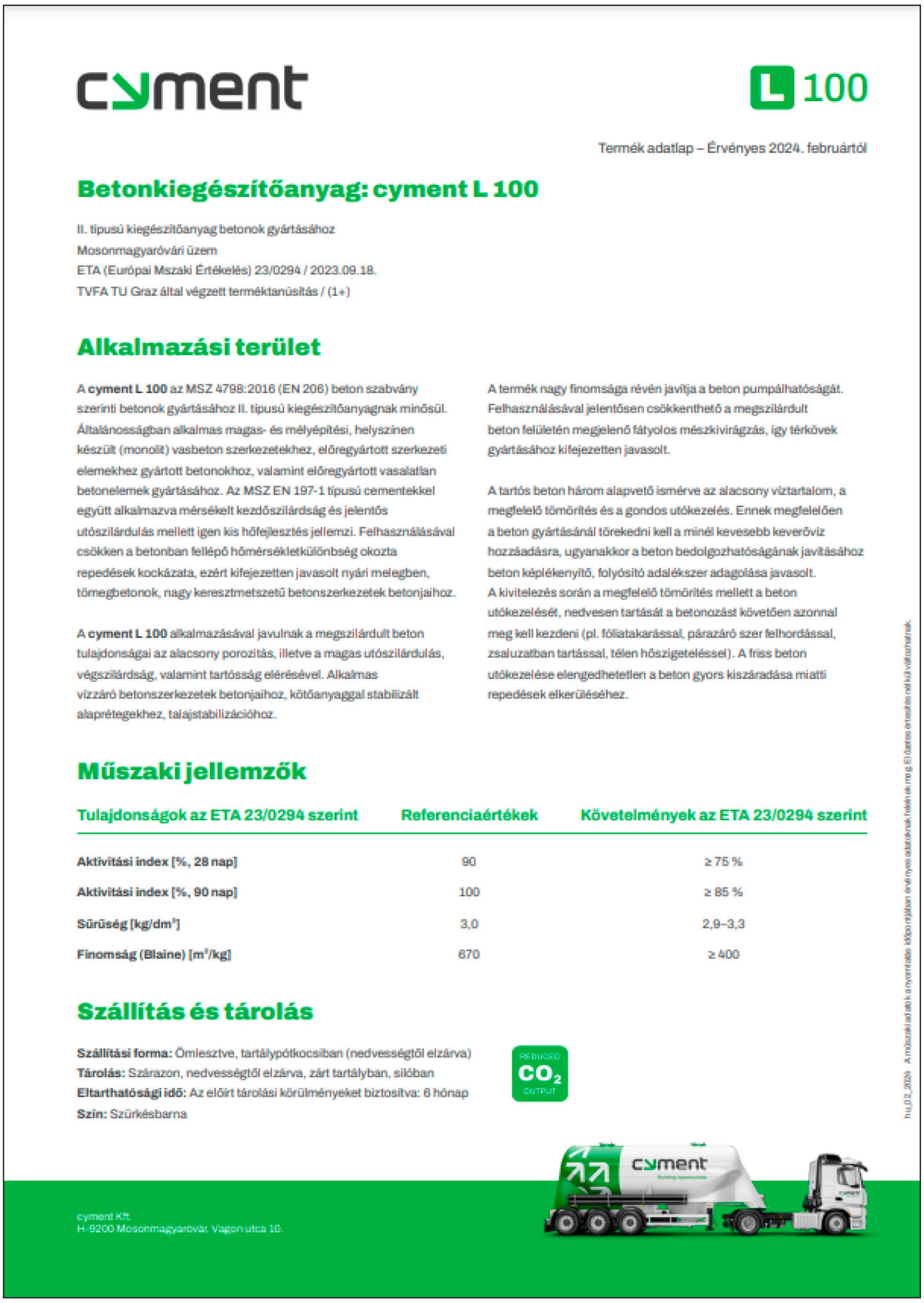
cyment

L 100

Termék adatlap – Érvényes 2024. februártól

Betonkiegészítőanyag: cyment L 100

II. típusú kiegészítőanyag betonok gyártásához
Mosonmagyaróvári üzem
ETA (Európai Mszaki Értékelés) 23/0294 / 2023.09.18.
TVFA TU Graz által végzett terméktanúsítás / (1+)

Alkalmazási terület

A **cyment L 100** az MSZ 4798:2016 (EN 206) beton szabvány szerinti betonok gyártásához II. típusú kiegészítőanyagnak minősül. Általánosságban alkalmas magas- és mélyépítési, helyszínen készült (monolit) vasbeton szerkezetekhez, előregyártott szerkezeti elemekhez gyártott betonokhoz, valamint előregyártott vasalatlan betonelemek gyártásához. Az MSZ EN 197-1 típusú cementekkel együtt alkalmazva mérsékelt kezdőszilárdság és jelentős utószilárdulás mellett igen kis hőfejlesztés jellemzi. Felhasználásával csökken a betonban fellépő hőmérsékletkülönbség okozta repedések kockázata, ezért kifejezetten javasolt nyári melegben, tömegbetonok, nagy keresztmetszetű betonszerkezetek betonjaihoz.

A **cyment L 100** alkalmazásával javulnak a megszilárdult beton tulajdonságai az alacsony porozitás, illetve a magas utószilárdulás, végszilárdság, valamint tartósság elérésével. Alkalmas vízzáró betonszerkezetek betonjaihoz, kötőanyaggal stabilizált alaprétegekhez, talajstabilizációhoz.

A termék nagy finomsága révén javítja a beton pumpálhatóságát. Felhasználásával jelentősen csökkenthető a megszilárdult beton felületén megjelenő fátyolos mészkivirágzás, így térkövek gyártásához kifejezetten javasolt.

A tartós beton három alapvető ismérve az alacsony víztartalom, a megfelelő tömörítés és a gondos utókezelés. Ennek megfelelően a beton gyártásánál törekedni kell a minél kevesebb keverővíz hozzáadásra, ugyanakkor a beton bedolgozhatóságának javításához beton képlékenyítő, folyósító adalékszer adagolása javasolt. A kivitelezés során a megfelelő tömörítés mellett a beton utókezelését, nedvesen tartását a betonozást követően azonnal meg kell kezdeni (pl. fóliatakarással, párazáró szer felhordással, zsaluzatban tartással, télen hőszigeteléssel). A friss beton utókezelése elengedhetetlen a beton gyors kiszáradása miatti repedések elkerüléséhez.

Műszaki jellemzők

Tulajdonságok az ETA 23/0294 szerint	Referenciaértékek	Követelmények az ETA 23/0294 szerint
Aktivitási index [%, 28 nap]	90	≥ 75 %
Aktivitási index [%, 90 nap]	100	≥ 85 %
Sűrűség [kg/dm^3]	3,0	2,9–3,3
Finomság (Blaine) [m^2/kg]	670	≥ 400

Szállítás és tárolás

Szállítási forma: Ömlesztve, tartálypótkocsiban (nedvességtől elzárva)
Tárolás: Szárazon, nedvességtől elzárva, zárt tartályban, silóban
Eltarthatósági idő: Az előírt tárolási körülményeket biztosítva: 6 hónap
Szín: Szürkésbarna

REDUCED CO₂ OUTPUT

cyment Kft.
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