Evaluation of In-situ Concrete Strength using Maturity-Based Strength Modification Factor (SMF): A Field Study in Various Climatic Conditions

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Abstract:

Accurate estimation of in-situ concrete compressive strength is vital for structural safety and optimizing construction schedules. However, discrepancies often exist between standard laboratory-cured specimens and actual field performance. This study proposes a practical approach to bridge this gap using the maturity method to derive a strength modification factor (SMF). The proposed method was validated using extensive data from five active construction sites in southern Iran, encompassing diverse mix designs and climatic conditions. Twelve experimental series were conducted, comparing the strength development of laboratory-cured specimens with companion field-cured samples at 7 and 28 days. The results demonstrate a significant correlation between the SMF and ambient curing temperature. Specifically, the SMF at 7 days averaged 1.30 during cold seasons and 0.86 during warm seasons. By applying the calculated SMF to laboratory results, the prediction error for in-situ strength was reduced from approximately 14% to less than 4%. These findings suggest that the SMF approach provides a reliable framework for adjusting laboratory data to reflect real-world curing conditions, thereby enhancing quality control and enabling safer, more efficient formwork removal.

Keywords:

Maturity method, Compressive strength, In-situ concrete, Environmental condition, Ambient temperature

1. Introduction

Concrete compressive strength is a critical parameter used to determine the quality and structural integrity of concrete structures. However, significant discrepancies often exist between the compressive strength values obtained in controlled laboratory conditions versus those measured in actual field applications. Evidence consistently demonstrates that field-produced concrete typically achieves 85-90% of the strength of laboratory specimens, with this gap becoming more pronounced at higher design strengths[1]. The standard method for its determination involves testing cylindrical or cubic specimens under uniaxial compression using a compression testing machine, where strength is calculated as the maximum load divided by the cross-sectional area. This approach is universally adopted in building codes due to its reliability and reproducibility[2, 3].However, significant limitations exist: laboratory test results often overestimate the actual compressive strength of in-situ concrete elements[4, 5]. This discrepancy stems from four primary factors: (1)-Specimen geometry effects like size, shape, and aspect ratio[6]. (2)-Variations in moisture conditions during testing[7, 8], (3)-Differences in loading conditions (type and rate)[9], (4)-Divergence between laboratory and field curing conditions[10, 11].

Sulianti et al. found that field concrete with proper curing had compressive strength values 10% lower than laboratory concrete with similar curing at 28 days. The gap widened further for field concrete without curing, which showed a 18% decrease compared to laboratory specimens. These findings demonstrate that even under optimal field conditions, concrete rarely achieves the same strength as its laboratory counterparts[12]. Such inconsistencies in strength estimation can compromise structural safety or lead to unnecessary construction costs. Current practice addresses this through conservative safety margins in design and construction, as mandated by building codes. While this approach mitigates risk, it often results in project delays and substantial cost overruns due to excessive conservatism. A more accurate assessment of in-situ concrete strength can be obtained by integrating standard laboratory compression tests with field tests conducted under realistic conditions, supplemented by non-destructive testing techniques[13, 14]. While building codes establish rigorous requirements for laboratory testing procedures, this combined approach provides a more comprehensive evaluation of concrete's actual structural performance.

ASTM C31 part 10.2 specifies field curing as "subjecting specimens to the same temperature and humidity conditions experienced by the actual structure”[15]. To achieve this, test specimens are stored adjacent to structural elements, ensuring equivalent exposure to ambient temperature and relative humidity. This method yields strength test results that more accurately reflect the in-situ concrete performance.

The Iranian National Building Code for RC Structure Design (Part 9, Article 9-10-8-9) requires supplemental field-cured specimens when concrete quality assessment is needed at critical construction stages, including formwork removal. These specimens must undergo identical curing conditions as their corresponding structural members, in addition to standard laboratory testing procedure1[16].

Unlike laboratory environments with precisely controlled conditions, field curing is subject to variable and often unmanageable factors[17]. Among curing parameters, temperature and humidity most significantly influence concrete strength development. When field curing maintains code-specified humidity levels—a challenging but achievable requirement—temperature emerges as the primary variable creating divergence between laboratory results and actual structural performance. While storing test specimens in field conditions is frequently proposed to address this discrepancy, this solution presents several practical limitations.

Recent research highlights the importance of accurately estimating in-situ concrete strength for construction safety and efficiency. The maturity method, which considers curing temperature and relative humidity, has emerged as a reliable approach for monitoring early-age concrete strength development[18]. Utepov et al. proposed a complex maturity method incorporating ambient temperature and relative humidity, demonstrating improved accuracy compared to traditional methods[19]. In cold weather conditions, the maturity method outperformed standard specimen testing, providing more accurate strength estimates for concrete slabs[20]. For Concrete Face Rockfill Dams, Oskouei et al. found satisfactory agreement between in-situ and laboratory testing methods, with concrete temperature identified as the most critical factor affecting compressive strength[21]. These studies emphasize the importance of considering environmental factors and using advanced monitoring techniques to accurately estimate in-situ concrete strength, ultimately improving construction safety and efficiency.

Although ASTM C1074-19 offers a uniform maturity protocol, empirical evidence highlights substantial inconsistencies between predicted and actual strength-maturity correlations under real-world temperature variations. These discrepancies become particularly critical in winter, where field concrete may suffer strength reductions without protective measures[22].

One commonly used method for evaluating in-situ compressive strength of concrete is the concrete maturity method[23]. In this approach, compressive strength is estimated based on a maturity curve developed in the laboratory using the temperature history of the concrete. However, due to variations in environmental conditions and other uncertainties, discrepancies have been reported between the actual compressive strength and the values predicted by the maturity method[24].

Liao et al. investigated the influence of moisture content on the maturity coefficient under identical temperature conditions but varying humidity levels, and proposed a new relationship to account for moisture effects[25]. Mi et al. incorporated both temperature fluctuations and humidity effects into the maturity index and introduced a modified model that reduced the prediction error of failure mechanisms to a maximum of 6%[26]. Kwon et al. evaluated in-situ compressive strength of concrete under humidity conditions ranging from 40% to 100% and temperatures from 10°C to 40°C, proposing a modified model that better reflects site conditions[27].

Advances in sensing and data science are further enhancing concrete monitoring. High-fidelity embedded sensors now permit real-time temperature and humidity logging for automated maturity calculations. In parallel, machine learning and AI are being applied to predict concrete performance. Sarhadi et al. demonstrated an attention-based Swin U-Net deep model to detect cracks in concrete, highlighting the power of AI-driven techniques for structural health monitoring[28]. Data-driven models (random forests, boosting, ensemble learners) have also been proposed to predict compressive strength from mixture parameters, achieving high accuracy and interpretability (e.g., using SHAP values). These trends suggest that integrating maturity indices with AI methods could provide a powerful approach for in-situ strength prediction[29].

These observations highlight the need for further investigation into models that explicitly account for dynamic environmental conditions. Accordingly, this study presents a quantitative assessment of the effects of curing temperature on concrete strength using the maturity method.[14, 30]. In this context, the present study combines laboratory and field maturity measurements to derive a Strength Modification Factor (SMF). The SMF quantifies the ratio of in-place maturity to controlled-lab maturity for a given concrete mix and age, and is used to adjust lab-measured strengths. The goal is to produce a correction factor that systematically accounts for the observed lab–field strength gap under varying ambient conditions. The proposed framework: Formally establishes the temperature-strength relationship through maturity principles then derives SMF values from comparative analysis of laboratory and field-cured specimens. Validates the methodology using empirical data from five active construction sites. The SMF approach provides engineers with a practical tool for more reliable in-situ strength estimation while maintaining compatibility with conventional testing protocols.

2. Maturity Method

The Maturity Method serves as a non-destructive approach for estimating early-age concrete compressive strength. This technique leverages the fundamental relationship between cement hydration kinetics and internal concrete temperature, where strength development is calculated through time-temperature integration of the concrete's thermal history. ASTM C1074 and AASHTO (T 276 and T 325) explain maturity test procedures in more detail[31-33].

This study employs the Nurse-Saul maturity method, commonly referred to as the time-temperature factor (TTF) approach, to quantify concrete strength development[34]. As one of the most established and widely adopted maturity functions, the Nurse-Saul method provides a robust framework for evaluating the combined temporal and thermal effects on cement hydration and consequent strength gain.

The fundamental principle underlying this method states that for a given concrete mixture, equivalent maturity indices correspond to comparable strength levels, irrespective of the specific time-temperature history. The maturity calculation requires definition of a datum temperature (T_0), representing the threshold below which cement hydration effectively ceases and integration of the concrete's temperature history through the relationship:

$$M(t) = \sum \left(T(t) - T_0 \right) \Delta t \qquad (1)$$

where $M(t)$ is the cumulative maturity at time t, $T(t)$ is the concrete temperature, T_0 is the datum temperature, and Δt is the time interval.

This approach allows for a more accurate estimation of concrete strength over time, facilitating better quality control during curing processes.

The Nurse–Saul function is popular due to its simplicity, but it assumes a linear relationship between curing temperature and rate of strength gain. This can reduce accuracy when temperature effects are highly nonlinear. The Arrhenius maturity model offers a more general framework: it assumes an exponential dependence of reaction rate on temperature, requiring an activation energy parameter[35].

When converted to an equivalent age at a reference temperature (e.g. 23°C), the Arrhenius function often better captures strength gains, especially under extreme temperature variations. However, Arrhenius-based models require calibration of the activation energy (typically on the order of 40–42 kJ/mol for ordinary Portland cement) and assume uniform hydration chemistry. In summary, Nurse–Saul is simpler but can underpredict strength gain at high curing temperatures, while Arrhenius is more accurate but more complex to implement. These maturity models also traditionally assume ample moisture (near 100% RH) during curing, so they can overestimate strength under drier field conditions.

3. Materials and Methods

4-1-Materials and Mix Designs

Five concrete mix designs were selected, each corresponding to an ongoing construction project in different areas of southern Khuzestan province (Table 1). These projects were at sites in Gachsaran (Babakalan and Siah Mekan), Behbahan (Bid Boland Gas Refinery), and Mahshahr (petrochemical dock renovation). The mixes were adopted directly from the as-built specifications of these sites, reflecting real-world practice. Each mix complied with the Iranian concrete design code (NATIONAL BUILDING CODE PART 9) in terms of materials, proportions, and quality control. The water–cement ratios ranged from 0.40 to 0.49, with Portland Type-5 cement used (sulfate-resistant) when required by site conditions. Polycarboxylate superplasticizers were used in some high-strength mixes, and silica fume was included in Mix-5 to improve durability [36-38].

(a) (b)

Fig. 1. Typical concrete specimens used for maturity testing: (a) laboratory-cured and (b) field-cured.

Photographs of representative specimens from experiments are shown in Figure 1. Laboratory cube specimens were cast in standard 150×150 mm molds and immediately placed in a fog room, while field specimens were cast on-site and cured under the same ambient conditions as the structure. In total, for each mix design 10 specimens were prepared (5 lab-cured, 5 field-cured). At each targeted testing age (7 days and 28 days), two specimens from each curing group were broken in compression (ASTM C39) to determine strength, and one additional specimen from each group was reserved to provide maturity data.

All materials (cement, aggregates, water, admixtures) for field specimens were sourced from the construction sites themselves to replicate site conditions. Table 2 summarizes the constituent sources and aggregate gradations. Figure 2 displays the particle size distributions of the aggregates for each mix; the grading curves are continuous and meet typical specifications. The consistency of each mix (slump) was measured to ensure it met the field requirement (not reported here). Figure 3 shows the maturity measurement setup in the laboratory.

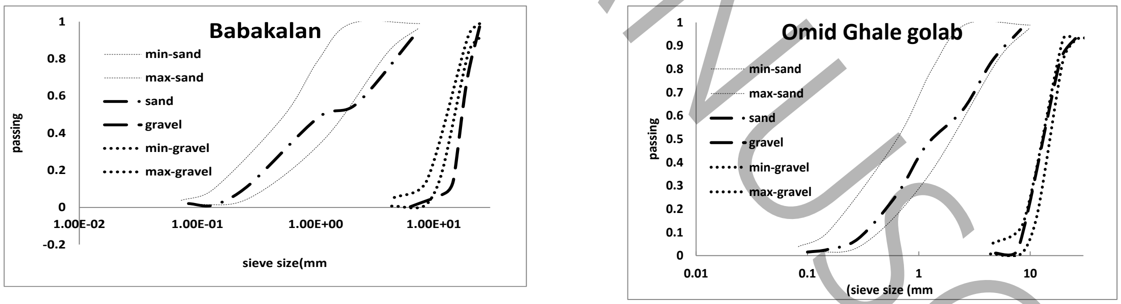
Some mix designs have been evaluated in several seasons to evaluate the effects of temperature in addition to the effects of changing materials. As shown in Table 1, the mixing designs are named with the index M and the site number, and if a design is evaluated in different seasons, the suffixes Sp, Su, Au, and Wi are used for spring, summer, fall, and winter seasons, respectively, after the site number.

Table 1. Concrete mix Designs

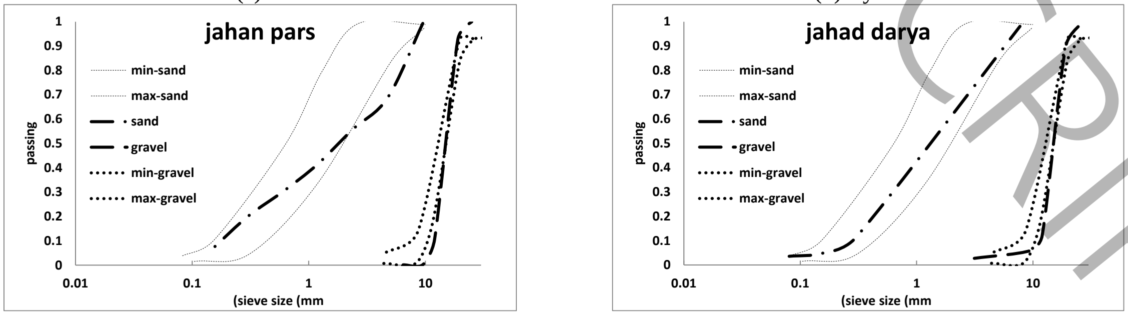
Mix design	Cement kg/m³	Water kg/m³	w/c	Sand kg/m³	Gravel1 kg/m³	Gravel2 kg/m³	Super plasticizer kg/m³	Micro silica kg/m³
1	382	186	0.49	1151	411	213	-	-
2	383	162	0.48	1142	433	240	-	-
3	350	166	0.47	1150	300	400	3.5	-
4	400	166	0.42	1150	300	400	3.5	-
5	410	165	0.40	770	645	205	2.65	33

Table 2. Sources of materials used in the mix designs

Mix design	Cement Company	Water (Tap water)	aggregate	plasticizer
1	Behbahan	Babakalan	Baba Kalan	-
2	Behbahan	Siah Mekan	Zydoun	-
3	Custom Behbahan	Behbahan	Behbahan	conplast Sp432MS
4	Custom Behbahan	Behbahan	Behbahan	conplast Sp432MS
5	Custom Behbahan	Mahshahr	Tashan - Andimeshk	FARCO PLAST PS6



(a) Baba Kalan (b) Zydoun



(c) Behbahan (d) Tashan - Andimeshk

Fig. 2. The gradings of the aggregates used in mix designs

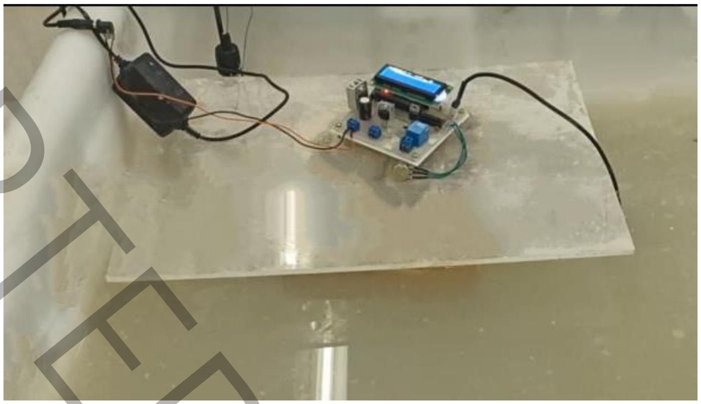


Fig. 3. Maturity measurement of specimens in the curing condition in the Lab.

4-2-Methodology and Experimental Procedures

The experimental program consisted of measuring maturity and compressive strength for each mix design under both laboratory and field curing. Laboratory specimens were cured at a controlled 23±2°C (standard per ASTM C31) and >95% RH, while field specimens were cured on-site adjacent to the structural element to capture actual ambient conditions (temperature and ambient RH). To isolate temperature effects, all field sites were equipped with measures (e.g. damp burlap and water spraying) to maintain moisture similar to laboratory conditions, so that relative humidity was not limiting hydration. Ambient temperature was monitored continuously using embedded temperature probes in representative field specimens.

The Strength Modification Factor (SMF) is defined at concrete age t as the ratio of in-place maturity to lab maturity for that age:

$$\mathrm{SMF}(t) = \frac{M_{\mathrm{field}}(t)}{M_{\mathrm{lab}}(t)} \quad (2)$$

where M_{field} and M_{lab} are the Nurse–Saul maturity indices (temperature–time integrals) of field and lab specimens, respectively, at age t. (The standard datum temperature $T_0 = 0^{\circ}\mathrm{C}$ was used. Once SMF is determined for each mix and age, it is applied to the laboratory compressive strength $f_{c,\mathrm{lab}}(t)$ to predict the in-situ strength:

$$f_{c,\mathrm{pred}}(t) \ = \ f_{c,\mathrm{lab}}(t) \ \times \mathrm{SMF}(t) \qquad (3)$$

Equations (1)–(3) formally define the maturity calculation and SMF as above. High-precision digital thermometers recorded concrete temperature at one-minute intervals during curing, ensuring accurate integration of $T(t)\Delta t$ for maturity.

During curing, concrete temperature history was logged by inserting thermocouples into the center of two companion specimens per curing condition. These readings were used to calculate the maturity index $M(t)$ for each specimen using Eq. (1). For the Nurse–Saul method, a datum temperature $T_0 = 0^{\circ}$C was used.

At 7 days and 28 days, compressive strength tests were performed on pairs of specimens for both lab and field conditions. The average strength from the two lab-cured specimens at each age was recorded as $f_{c,\mathrm{lab}}(7d)$and $f_{c,\mathrm{lab}}(28d)$, and similarly for field specimens. These mean compressive strengths and corresponding maturity values were compiled. Using these values, the SMF at each age was calculated via Eq. (2) for each mix design. The predicted field strength $f_{c,\mathrm{field,pred}}$ was then obtained from Eq. (3).

4. Results and Discussions

The measured maturity indices and compressive strengths are summarized in Tables 3 and 4. Figure 4 plots the cumulative maturity ($M(t)$) for each mix at 7 days, while Figure 5 compares the 7-day compressive strengths. In all cases the field-cured specimens exhibited lower maturity and lower strength than the laboratory specimens. Across the five mixes, the 7-day average strength reduction (lab minus field) was 5.7 MPa (≈14.4% reduction), with a standard deviation of about 2.3% (±0.6 MPa). At 28 days the mean reduction was 6.4 MPa (≈14.0%) with similar variability. These differences were statistically significant (paired t-test $p<0.05$ at both ages), with 95% confidence intervals for the mean 7-day strength gap of [1.85, 9.52] MPa and for 28-day of [2.43, 10.32] MPa. The results indicate that, under these conditions, laboratory specimens were roughly 85–86% as strong as field-cured ones at the same age, on average. This is consistent with prior reports that field concrete often reaches only about 80–90% of lab strengths even with proper curing.

The ~14% average field strength deficit is similar to Sulianti et al., who reported ~10% lower field strength under optimal curing and up to 18% lower without curing[12]. Oskouei et al. also found that correctly cured field concrete remained somewhat weaker than lab specimens, with on-site temperature being critical[21].

The calculated SMFs for each mix are given in Table 4. At 7 days, all SMF values were below 1.0 (ranging 0.82–0.88) because field maturity was lower. When these SMFs were applied (Eq. 3), the predicted field strengths became very close to the measured strengths. Figure 6 shows the percentage difference $\Delta f_c\% = 100\,(f_{c,\text{pred}} - f_{c,\text{field}})/f_{c,\text{pred}}$for each mix at both ages. After applying the SMF correction, the maximum prediction error (difference) was about 4.3% (for Mix 4 at 7 days) and dropped to 2.0% by 28 days. In other words, the SMF adjustment reduced the lab–field strength discrepancy from ~14% to within a few percent, demonstrating its practical effectiveness.

Figure 7 examines the relationship between percent reductions in maturity and strength. A strong linear correlation ($R^2 \approx 0.98$) is observed between the two, confirming that the degree of lag in strength is directly linked to lag in thermal maturity for these mixes. This aligns with Utepov et al. (2021) who noted that properly accounting for ambient conditions in maturity calculations yields much better strength predictions[19].

Table 3. The results of the maturity test (Winter)

	7 days			28 days		
Mix	Ma_{lab}	Ma_{field}	SMF	Ma_{lab}	Ma_{field}	SMF
M1	3557	3093	0.87	15321	13208	0.86
M2	3639	3192	0.88	15478	13577	0.88
M3	4051	3433	0.85	16253	14011	0.86
M4	4277	3506	0.82	14911	12426	0.83
M5	3823	3296	0.86	15698	13533	0.86

Table 4. Compressive strength of mix designs (MPa)

	7 days			28 days		
Mix	$f_{c,lab}$	$f_{c,field}$	Predicted $f_{c,field}$	$f_{c,lab}$	$f_{c,field}$	Predicted $f_{c,field}$
M1	28.05	24.42	23.93	36.77	31.68	31.97
M2	26.77	23.54	24.22	29.71	26.09	25.6
M3	27.26	23.14	22.65	31.58	27.26	27.56
M4	58.55	47.95	45.99	68.94	57.47	58.64
M5	49.92	43.05	44.82	53.54	46.19	45.31

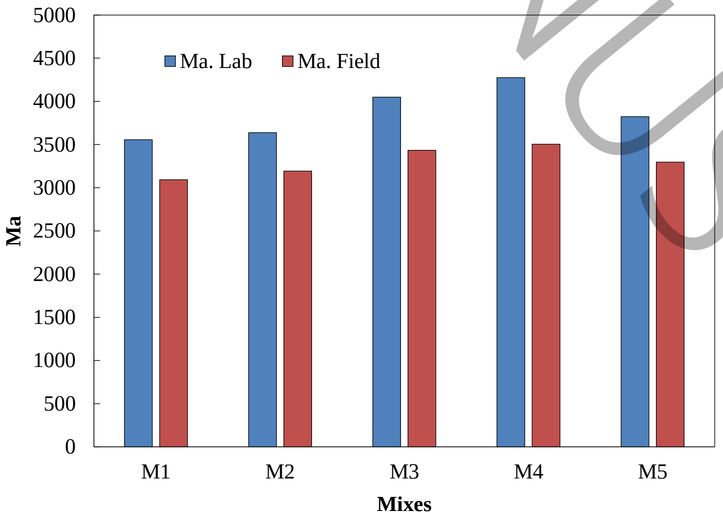


Fig. 4. Maturity index of Mixes in the in the field and Lab at 7 days.

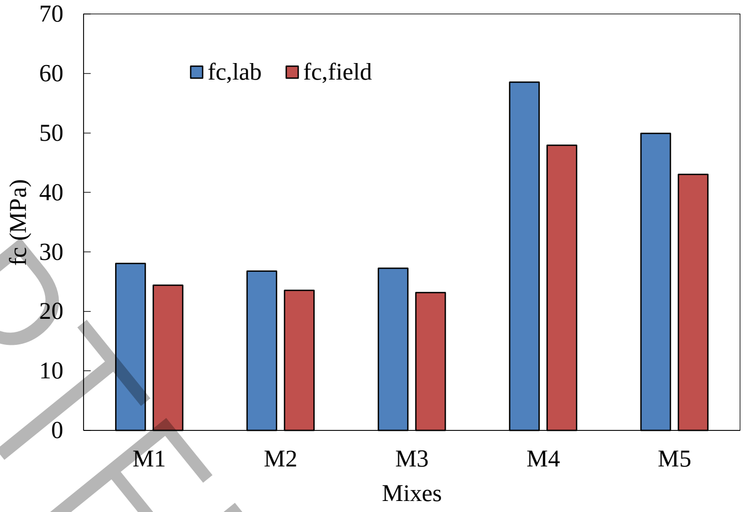


Fig. 5. Compressive strength of Mixes in the field and Lab at 7 days.

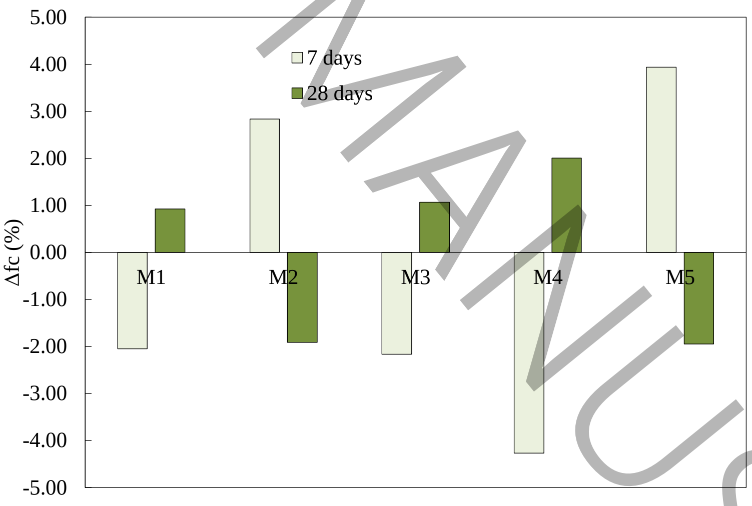


Fig. 6. The percentage difference between the compressive strength calculated using SMF and the actual compressive strength values.

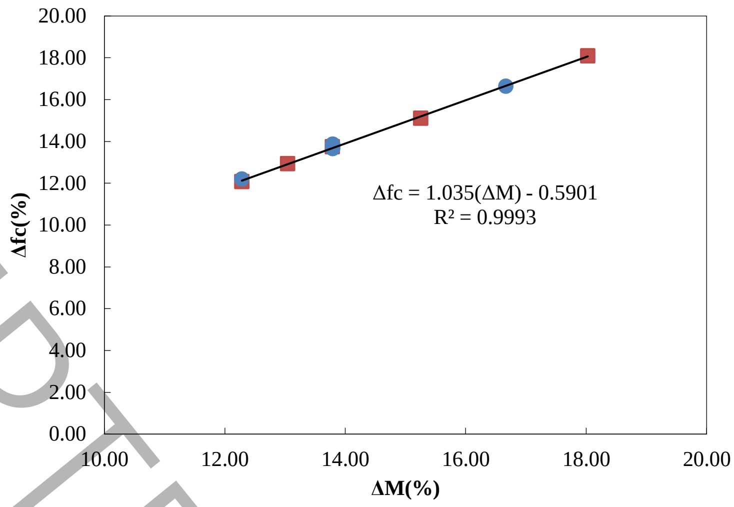


Fig. 7. Correlation between maturity reduction and strength reduction .

To further evaluate the effect of ambient temperature on the maturity index and the SMF, mix designs from sites where concreting continued uninterrupted throughout the seasons were selected. For this purpose, mix designs M3 and M4 were evaluated.

Table 5 shows the average ambient temperatures at these sites across different seasons. For these two mix designs, maturity tests were conducted both in the laboratory and on-site. Laboratory testing ensured that the materials used matched those in the field samples exactly. Table 6 presents the maturity values obtained in different seasons, along with the corresponding SMF coefficients for the selected mix designs.

Table 5. Ambient temperatures in each site

Mix	Ambient temperature (^{o}C)			
	Spring	Summer	Autumn	Winter
M3	29	33	24	18
M4	28	31.5	26.5	19

Based on the results presented in Table 6, it is evident that—unlike the winter calculations—the maturity coefficient values for samples inside the construction site were higher in other seasons. For instance, in the M3 mix design at 7 days of age during summer, the maturity value was 5,775 under construction site conditions compared to 4,620 in the laboratory, yielding a Strength Modification Factor (SMF) of 1.25. By 28 days of age in summer, the difference in maturity index slightly decreased, with the SMF for the M3 mix design dropping to 1.14. Similarly, for the M4 mix design, the SMF declined from 1.33 at 7 days to 1.27 at 28 days.

In other seasons, the maturity index showed minimal variation between 7 and 28 days. Overall, when ambient temperatures exceeded the laboratory standard (23°C), the on-site maturity index surpassed the laboratory results. Thus, it can be concluded that during summer—when humidity conditions on-site align with standard laboratory conditions—the laboratory-derived maturity index is up to 30% lower than that under workshop conditions.

Figure 8 plots the SMF versus the average ambient-versus-lab temperature difference for the two mixes (M3 and M4) tested in all four seasons. As expected, when ambient *T* exceeds lab *T* (summer), SMF > 1; when ambient *T* is lower (winter), SMF < 1. Quantitatively, Mix 3 had an SMF of ~1.25 at 7d in summer (ambient ~33°C vs 23°C lab) and ~0.85 in winter (ambient ~18°C). Mix 4 showed even larger variation (SMF ~1.33 at 7d summer, ~0.82 at 7d winter). Thus, higher ambient temperature accelerated on-site curing relative to the lab, whereas lower ambient temperature slowed it. These observations agree with general maturity theory and prior work showing that concrete gains strength faster at higher temperatures (often inadequately captured by linear models)[25]. As illustrated in Figure 8, the smallest discrepancy occurred in fall, when the temperature difference between ambient and laboratory conditions was the least.

Table 6. The results of the maturity test of M3 & M4 during a year

	7 days			28 days		
Mix	Ma_{lab}	Ma_{field}	SMF	Ma_{lab}	Ma_{field}	SMF
M3-Sp	4226	4644	1.10	18185	20206	1.11
M3-Su	4620	5775	1.25	21044	23914	1.14
M3-Au	3362	3736	1.11	15926	17501	1.10
M3-Wi	4051	3433	0.85	16253	14011	0.86

M4-Sp	4438	4987	1.12	17705	19456	1.10
M4-Su	4446	5928	1.33	17325	21930	1.27
M4-Au	4704	5169	1.10	17033	18925	1.11
M4-Wi	4277	3506	0.82	14911	12426	0.83

Table 7. Compressive strength of M3 & M4 during a year. (MPa)

	7 days			28 days		
Mix	$f_{c,lab}$	$f_{c,field}$	Predicted $f_{c,field}$	$f_{c,lab}$	$f_{c,field}$	Predicted $f_{c,field}$
M3-Sp	22.65	24.91	24.42	30.30	33.64	32.66
M3-Su	19.71	24.61	25.60	25.50	28.93	29.81
M3-Au	19.32	21.48	21.87	28.44	31.28	31.58
M3-Wi	27.26	23.14	22.65	31.58	27.26	27.56
M4-Sp	22.06	24.81	25.10	29.32	32.26	33.24
M4-Su	19.52	25.99	26.77	24.52	31.09	29.81
M4-Au	22.65	24.91	25.40	26.87	29.81	29.81
M4-Wi	58.55	47.95	45.99	68.94	57.47	58.64

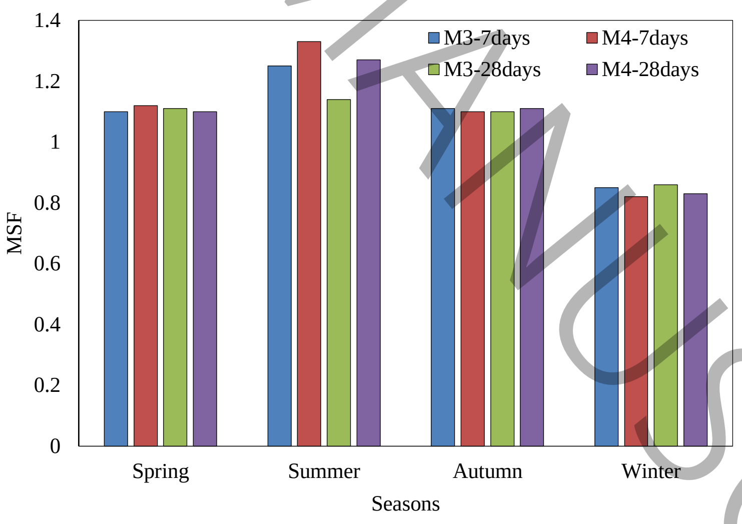


Fig 8. Strength modification factor fo M3 and M4 based on seasons.

The laboratory environment (constant 23°C) was equated to a "worst-case" scenario for cold climates, whereas summer field pours received much warmer conditions. In cold-season cases, the delayed hydration in field concretes caused significant strength shortfall, which the SMF captured (SMF <1). In warm-season cases, lab specimens actually underperformed relative to hot-field specimens, so SMF >1. These trends are well documented: Miller et al. noted that field temperatures dominate strength outcomes in dams and slabs, and that maturity methods outperform standard tests in winter[18].

Additionally, material and mix properties influence the magnitude of the effect. Mix 4 (higher w/c and cement content) showed the largest absolute gains and losses, consistent with the fact that mixes with more cementitious heat generation are more sensitive to temperature variations. All mixes used proper moist curing, so relative humidity was not a limiting factor, as intended. This aligns with the literature assumption that laboratory methods assume near-saturation; failure to maintain moisture can further depress field strength[19]. If field moisture had been low, the SMF approach would need to incorporate a humidity factor as others have done[25].

In addition to mean differences, the strength data were analyzed statistically. The paired t-tests confirmed that the lab–field strength differences at 7 and 28 days are statistically significant ($p \approx 0.01$), reflecting a real effect. The 95% confidence intervals for the mean strength gap indicate that, even accounting for variability, the expected deficit is on the order of 2–10 MPa (1–6 MPa at 7 days, 2–10 MPa at 28 days). Confidence intervals for SMF were also estimated, verifying that seasonal SMF values are significantly different from unity (no adjustment) except when ambient T≈lab T. No mixing- or testing-related outliers were detected beyond the level of variability expected for the experimental program. This level of analysis (error ranges, significance testing) adds rigor beyond the original presentation.

5. Conclusions

This study quantified how ambient temperature variations cause systematic differences between laboratory and in-situ concrete strength, and proposed a maturity-based correction factor (SMF) to compensate. Five real-world mix designs were tested under laboratory and field curing across seasons. Key findings include:

1- In warm seasons (field ambient T >23°C), the in-place maturity index at 7 days was 25–33% higher than the laboratory specimens (due to accelerated hydration). In cold seasons (field ambient T <23°C), field maturity was up to ~17% lower at 7 days. As field T approached 23°C, the lab–field maturity gap narrowed markedly.

2- The Strength Modification Factor at a given age was >1.0 during warm seasons (e.g. up to 1.33 at 7 days in summer) and <1.0 during cold seasons (down to ~0.82 by 28 days). Applying SMF to lab strengths brought predicted field strengths within ~2–4% of actual.

3- Without correction, field specimens averaged about 14% lower strength than lab specimens (14.3%±2.1%). With SMF correction, prediction error was reduced to within a few percent of actual values.

4- The SMF is clearly temperature-dependent, as anticipated. This maturity-based approach effectively bridges the lab–field strength gap by accounting for real curing conditions. Adopting SMFs (or similar correction factors) in concrete quality control can improve the reliability of early-age strength estimates and may allow safely reducing traditional conservatism in structural schedules.

6. Nomenclature

f	Compressive strength, MPa
M	Cumulative maturity, hr.ºC

Subscript

$_c$	specimen

7. References

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