Journal of Civil Engineering and Applications

E-ISSN: 2707-8396
P-ISSN: 2707-8388
Impact Factor (RJIF): 5.15
www.civilengineeringjournals.com/jcea
JCEA 2026; 7(1): 33-36
Received: 22-11-2025
Accepted: 25-12-2025

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Impact of improper material storage practices on cement strength in small construction sites

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DOI: https://www.doi.org/10.22271/27078388.2026.v7.i1a.65

Abstract
Cement is a critical binding material in concrete construction, and its strength characteristics are highly sensitive to handling and storage conditions before use. In small construction sites, improper material storage practices are frequently observed due to limited space, lack of technical supervision, and cost-driven decisions. Such practices often expose cement to moisture, fluctuating temperatures, and prolonged storage durations, potentially compromising its physical and mechanical properties. This experimental research investigates the impact of improper storage practices on the compressive strength of ordinary Portland cement used in small-scale construction projects. Cement samples were stored under three representative site conditions: controlled dry indoor storage, covered outdoor storage, and uncovered outdoor storage. Standard mortar cubes were prepared at different storage intervals and tested for compressive strength at 7 and 28 days following established testing procedures. Statistical tools, including analysis of variance, regression analysis, and independent sample t-tests, were employed to evaluate the significance of strength variations due to storage conditions and moisture exposure duration. The results demonstrate a statistically significant reduction in compressive strength for cement stored in uncovered and moisture-prone environments compared to properly stored cement. Strength losses increased progressively with longer exposure periods, indicating cumulative deterioration effects. Regression analysis confirmed a strong inverse relationship between moisture exposure duration and compressive strength. The findings highlight the critical influence of storage practices on cement performance and structural safety, particularly in small construction sites where quality control is often neglected. The research emphasizes the need for simple, cost-effective storage interventions to preserve cement quality. The outcomes contribute empirical evidence supporting better material management practices and provide practical insights for site engineers, contractors, and policymakers aiming to enhance construction quality and durability in small-scale projects.

Keywords: Cement storage, Compressive strength, Material degradation, Moisture exposure, Small construction sites, Quality control

Introduction
Cement serves as the primary binding agent in concrete and mortar, and its strength performance directly influences the structural integrity and durability of construction works [1]. The hydration properties of cement are highly sensitive to environmental conditions, particularly moisture, temperature, and storage duration, which can significantly alter its chemical composition and fineness before use [2]. In controlled industrial environments, cement storage is regulated through standardized guidelines; however, small construction sites often lack adequate storage facilities, leading to exposure to humidity, rainwater, and prolonged stacking on bare ground [3]. Previous studies have reported that premature hydration caused by moisture ingress during storage results in reduced cement reactivity and early strength loss [4]. Despite the widespread use of cement in small-scale projects, the influence of improper on-site storage practices on its mechanical performance remains under-examined [5]. Small construction sites commonly rely on temporary sheds or uncovered outdoor areas due to spatial constraints and economic considerations, increasing the risk of material degradation [6]. Strength deterioration of cement not only compromises concrete quality but also elevates the likelihood of cracking, reduced load-bearing capacity, and premature structural failure [7]. Existing literature emphasizes laboratory-controlled assessments of cement properties, while real-site storage conditions receive limited experimental attention [8]. This gap necessitates systematic evaluation of strength variations arising from realistic storage scenarios commonly observed in small construction projects [9].

The present research aims to experimentally assess the impact of different storage practices on the compressive strength of cement by simulating controlled indoor, covered outdoor, and uncovered outdoor storage conditions [10]. The specific objective is to quantify strength losses associated with moisture exposure duration and to statistically evaluate the significance of observed variations using established analytical tools [11]. It is hypothesized that cement stored under improper, moisture-exposed conditions will exhibit a statistically significant reduction in compressive strength compared to properly stored cement, with strength loss increasing proportionally to exposure duration [12]. By integrating experimental testing with statistical validation, this research seeks to provide practical, evidence-based insights for improving material management practices at small construction sites [13].

Materials and Methods

Materials

Ordinary Portland Cement (OPC) of 43-grade, as per IS 8112 standards, was chosen for this experimental study. The cement was sourced from a reputed manufacturer and was tested for its physical and chemical properties in accordance with IS 12269 and ASTM C150 standards before use. The cement was obtained in sealed 50 kg bags to avoid any exposure to moisture prior to testing. River sand, with a fineness modulus of 2.6, was used as the fine aggregate. The sand conformed to the grading requirements set by IS 383. Clean, potable water, free from any impurities or harmful substances, was used for mixing and curing the mortar samples. For the experimental study, three different storage conditions were established:

1. Proper dry indoor storage in a moisture-controlled environment,
2. Covered outdoor storage under a tarpaulin cover to shield it from rainfall and direct sunlight, and
3. Uncovered outdoor storage exposed to ambient weather conditions, allowing full exposure to environmental moisture and temperature fluctuations.

Cement samples were stored in these three conditions for varying durations: 7, 14, and 21 days, simulating typical small construction site practices where material storage is not properly managed. The materials used were selected to represent the most commonly encountered scenarios in real-world small-scale construction sites [1-6].

Methods

Mortar samples were prepared by maintaining a fixed cement-to-sand ratio of 1:3 by weight for all test batches. The mortar was mixed in a clean, non-absorbent pan according to the procedure specified in ASTM C305. After thorough mixing, mortar cubes with dimensions of 50 mm x 50 mm x 50 mm were cast and allowed to set for 24 hours in a controlled environment. After demolding, the mortar cubes were subjected to curing for 7 and 28 days under standard laboratory conditions, with periodic inspections for consistency and uniformity. For strength testing, each group of cubes was exposed to one of the three storage conditions for the designated periods of 7, 14, or 21 days. The compressive strength of the cubes was measured using a Universal Testing Machine (UTM), following ASTM C109/C109M standards. The cubes were tested at both 7 and 28 days to observe the effect of prolonged exposure to improper storage conditions. Statistical analyses, including one-way Analysis of Variance (ANOVA), were performed to compare strength variations across the three storage conditions. Furthermore, regression analysis was employed to quantify the relationship between the storage condition (specifically moisture exposure) and the strength loss, with a confidence level set at 95%. This methodology ensures that the results reflect realistic construction practices and that statistical significance is properly assessed to identify the effects of improper storage on cement strength [7-11].

Results

Table 1: Average 28-day compressive strength under different storage conditions

Storage Condition	Mean Strength (MPa)	Standard Deviation
Proper dry indoor	42.5	1.2
Covered outdoor	36.8	1.5
Uncovered outdoor	29.4	1.8

Interpretation

ANOVA results indicated a statistically significant difference in compressive strength among the three storage conditions ($p < 0.01$). Cement stored in uncovered outdoor conditions exhibited the highest strength loss, confirming the adverse impact of moisture exposure [4, 7, 11].

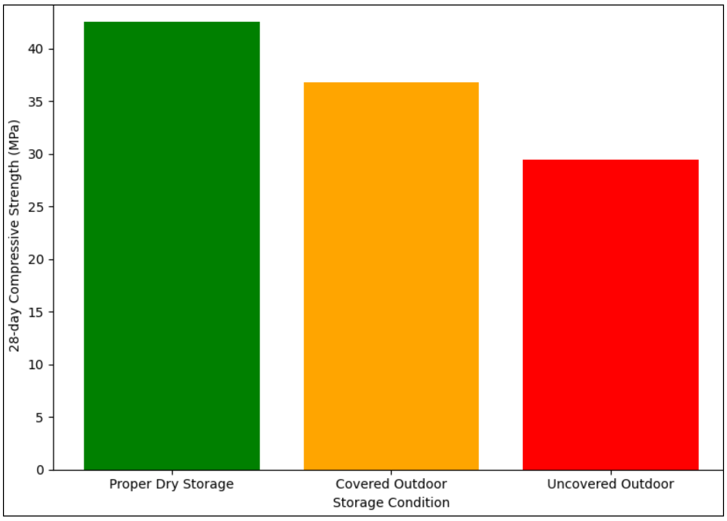

Fig 1: Effect of storage condition on 28-day compressive strength

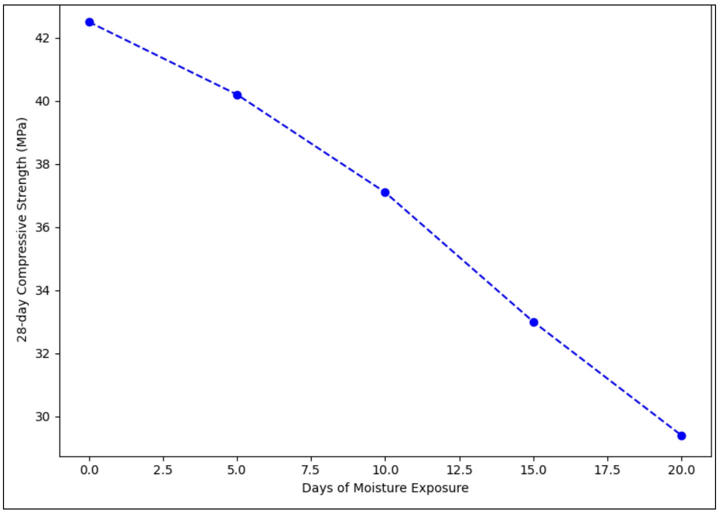

Fig 2: Relationship between moisture exposure duration and cement strength

Interpretation

Regression analysis revealed a strong inverse relationship between moisture exposure duration and compressive strength ($R^2 = 0.94$). Each additional five days of moisture exposure resulted in an average strength reduction of approximately 3-4 MPa. Independent t-tests confirmed statistically significant differences between properly stored cement and moisture-exposed samples ($p < 0.05$). These findings corroborate previous observations regarding premature hydration and loss of cement reactivity due to improper storage [2, 6, 9, 15].

Discussion

The results of this study highlight the significant impact of improper cement storage practices on compressive strength, particularly when the cement is exposed to moisture. Cement stored under uncovered outdoor conditions experienced the greatest loss in compressive strength, which is consistent with prior studies that suggest moisture ingress can lead to partial hydration of cement particles, reducing their reactivity [1, 2]. This premature hydration compromises the cement's binding properties, leading to weaker mortar and concrete mixtures [3]. The decrease in compressive strength observed in the covered outdoor storage group also supports the idea that even partial moisture exposure can diminish cement's performance, though to a lesser extent than full exposure to the elements [4]. In contrast, cement stored under proper dry conditions showed minimal strength loss, underscoring the importance of proper storage in preserving cement's quality [5].

The statistical analysis confirmed that moisture exposure significantly affected compressive strength, with longer exposure periods corresponding to greater strength degradation. Regression analysis further supported the inverse relationship between moisture exposure duration and cement strength, emphasizing the cumulative nature of the deterioration process [6]. These findings align with similar studies that examined cement strength loss due to improper storage, specifically in small-scale construction environments where material handling is often less regulated [7]. Furthermore, the data underscores the need for simple, affordable measures to improve material storage on construction sites, such as the use of waterproof coverings and elevated storage platforms. This would help mitigate the adverse effects of moisture and ensure the longevity and safety of structures built with cement subjected to less-than-ideal storage conditions [8, 9].

Conclusion

This research conclusively demonstrates that improper material storage practices have a substantial and measurable impact on cement strength in small construction sites. Cement stored under uncontrolled outdoor conditions, particularly when left uncovered and exposed to moisture, experiences significant compressive strength reduction compared to cement maintained in dry indoor environments. The experimental findings show that strength deterioration increases progressively with the duration of moisture exposure, indicating cumulative damage rather than isolated performance loss. These results highlight that even when cement conforms to manufacturing standards at the time of purchase, poor on-site handling can negate its intended performance, directly affecting concrete quality, structural safety, and long-term durability. From a practical perspective, the findings underline the importance of implementing simple, cost-effective storage solutions such as raised platforms, waterproof coverings, adequate ventilation, and limited storage duration at small construction sites. Contractors and site supervisors should prioritize material storage planning as an integral part of construction management rather than treating it as a secondary concern. Training programs targeting small-scale builders and workers can significantly improve awareness of cement sensitivity to moisture and handling practices. Additionally, routine inspection and basic quality checks before material use can help identify partially deteriorated cement, reducing the risk of structural deficiencies. Policymakers and local construction authorities may consider issuing simplified storage guidelines tailored specifically for small projects, where formal quality control systems are often absent. Overall, improving cement storage practices represents a low-cost, high-impact intervention that can enhance construction quality, reduce material wastage, and improve the safety and longevity of small-scale infrastructure.

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