Technologique | 2026, Vol. 7, No.1, 36 – 49 | ISSN Online: 3028-1415 | ISSN Print: 3028-1407
DOI: https://doi.org/10.62718/vmca.tech-gjtdsi.7.1.SC-0226-016

Article History:
Initial submission: 10 February 2026
First decision: 15 February 2026
Revision received: 02 March 2026
Accepted for publication: 08 March 2026
Online release: 11 March 2026

Usage of Concrete Panelized Wall System in Building Construction

Vanessa S. Barcelona
Master of Science in Construction Management, Polytechnic University of the Philippines, Sta. Mesa, Manila, Philippines

Abstract

The growing adoption of industrialized construction methods has positioned concrete panelized wall systems as a viable alternative to conventional building techniques. This study investigates the usage of concrete panelized wall systems in building construction, with particular emphasis on evaluating their structural performance through material strength assessment. The primary objective of the research is to determine the compressive strength characteristics of concrete panels produced under different concrete classifications and to examine the reliability of non-destructive testing methods in assessing in-situ concrete strength. An experimental research design was employed, involving laboratory-based compressive strength tests on concrete specimens representing selected concrete classifications commonly used in panelized wall systems. In parallel, rebound hammer tests were conducted to evaluate surface hardness and estimate compressive strength in a non-destructive manner. The results obtained from the rebound hammer tests were analyzed and compared with laboratory compressive strength values to assess consistency, and practical applicability for quality control purposes. The findings revealed that higher concrete classifications exhibit improved compressive strength performance, confirming their suitability for load-bearing and structural wall applications. The rebound hammer test demonstrated a reasonable comparison with laboratory results, indicating its effectiveness as a rapid assessment and preliminary quality evaluation tool, although limitations in accuracy were observed depending on concrete class and surface conditions. These results highlight the importance of proper calibration and complementary use of destructive and non-destructive testing methods in evaluating concrete panel performance. The study provides practical guidance for engineers and practitioners implementing panelized concrete wall construction systems.

Keywords: concrete panelized wall system, compressive strength test, rebound hammer test, building construction, structural performance

INTRODUCTION

The construction industry's ongoing pursuit of solutions balancing efficiency, sustainability, and structural integrity has positioned concrete panelized wall systems as a transformative alternative to traditional practices (Lavanya, 2024). This study, stemming from prior research on medium-rise residential buildings for urban poor communities, addresses the critical need for safe and affordable housing in rapidly urbanizing areas. By focusing on concrete-based modular systems, the research evaluates methodologies that prioritize structural reliability and social equity, offering a technical response to the persistent housing deficit faced by underserved populations.

These systems represent a significant shift toward off-site prefabrication, where panels are manufactured in controlled factory environments to streamline assembly and enhance quality control (Du et al., 2023; Rahman, 2020). This approach introduces vital efficiencies in labor, cost, and time while minimizing material waste (Yuan et al., 2020; Shahzad et al., 2020). Historically evolving from early modular experiments, modern panelized systems now leverage advanced materials science to provide unparalleled durability against extreme loads and seismic events (Li et al., 2014; Ganiron & Almarwae, 2014; Jaillon & Poon, 2009; Frankl et al., 2011; Zhou et al., 2014). Such resilience is fundamental to the long-term safety and habitability of structures designed for vulnerable urban populations (Fragomeni, 2001).

Beyond structural advantages, panelized systems align with sustainability goals by optimizing resource utilization and minimizing on-site disruptions (Tam et al., 2007; Simpson, 2004). However, their implementation involves complex logistical and architectural challenges that require interdisciplinary collaboration and continuous methodological refinement (Shewchuk & Guo, 2012; Azman et al., 2012; Said et al., 2016). As urbanization and environmental concerns intensify, the demand for technically sound and socially responsive systems becomes paramount (Xue et al., 2017). This thesis utilizes empirical investigation to justify concrete panelized walls as a scalable, cost-efficient solution capable of supporting sustainable building practices and meeting urgent global housing needs (Mlynarczyk & Pessiki, 2003).

This study is significant to the construction industry, engineering practice, housing development, policymaking, and the academic community because it provides material-level evidence on the usage of concrete panelized wall systems in building construction. By experimentally evaluating different concrete classifications through standardized compressive strength and rebound hammer testing, the research strengthens confidence in panelized wall systems as technically viable alternatives to traditional cast-in-place methods. For industry stakeholders, the findings offer empirical guidance for decision-making grounded in material performance rather than assumptions about prefabrication efficiency alone. Structural engineers and design professionals benefit from practical insights into performance-based concrete classification selection, enabling optimized design practices that balance safety, economy, and sustainability.

Contractors and prefabrication manufacturers gain a framework for quality assurance, as the integration of destructive and non-destructive testing methods underscores the importance of standardized testing and quality control in off-site fabrication, reducing risks and ensuring consistency of prefabricated components. Housing developers and policymakers, particularly those engaged in mass housing and urban development programs, can draw on evidence-based support for adopting panelized wall systems as part of sustainable construction strategies that prioritize rapid delivery, cost efficiency, and long-term durability in addressing urban housing demands. Finally, the study contributes to the academic discourse by filling a recognized research gap in material-level evaluation of panelized systems, establishing a foundation for future inquiries into system-level behavior, durability performance, and life-cycle assessment. In doing so, it advances both theoretical understanding and practical application of prefabricated concrete construction in contemporary practice.

LITERATURE REVIEW

Current Construction Practices and Research Gaps in Panelized Wall Systems. The construction industry has continuously evolved in response to increasing demands for efficiency, cost reduction, and sustainability. Traditional cast-in-place concrete construction has long been the dominant method due to its familiarity, design flexibility, and well-established standards. However, this method is often associated with longer construction durations, higher labor dependency, and increased material waste. As a result, alternative construction approaches such as prefabrication and panelized systems have gained increasing attention.

Bell (2022) traced the historical development of prefabricated housing systems and emphasized their role in addressing large-scale housing shortages, particularly in rapidly urbanizing regions. Prefabrication emerged as a strategic response to limitations of conventional construction, allowing components to be manufactured off-site under controlled conditions. Similarly, Ganiron and Almarwae (2014) discussed the application of prefabricated technology in modular housing, highlighting improved construction speed and quality control.

Recent research has largely focused on process-oriented advantages of prefabricated and panelized construction. Du et al. (2023) demonstrated that lean manufacturing principles significantly improve workflow efficiency and reduce waste in prefabricated construction projects. Yuan et al. (2020) further identified organizational and managerial barriers affecting on-site lean construction for prefabricated buildings, underscoring the importance of coordination and supply chain integration.

Despite the growing body of literature promoting prefabrication, several authors have pointed out a persistent research gap. Li et al. (2014) noted that much of the research on prefabricated construction concentrates on management strategies, logistics, and policy issues, while material-level performance validation remains limited. Jaillon and Poon (2014) similarly emphasized that empirical evaluation of construction materials is often overshadowed by system-level discussions.

This gap is critical because the adoption of concrete panelized wall systems ultimately depends on confidence in material performance. Without experimentally grounded evidence on concrete strength, reliability, and efficiency, stakeholders remain hesitant to deviate from traditional cast-in-place methods. The present study directly responds to this gap by providing material-level experimental data to support the application of concrete panelized wall systems.

Concrete Classification and Material Evaluation in Panelized Construction. Concrete is the most commonly used material in panelized wall systems due to its high compressive strength, durability, fire resistance, and adaptability to prefabrication. The performance of concrete panels, however, is strongly influenced by concrete classification, mix proportion, and curing conditions. Rahman (2020) emphasized that proper mix design and quality control are essential to ensuring the structural integrity of precast concrete walls.

Lavanya (2024) discussed key features of precast concrete panel installation and highlighted that inappropriate concrete mix selection may lead to cracking, reduced strength, and serviceability issues. These observations underscore the importance of selecting suitable concrete classifications based on intended structural function.

Experimental studies have confirmed the relationship between concrete composition and strength behavior. Frankl et al. (2011) investigated precast prestressed concrete sandwich wall panels and found that material properties significantly affect load-bearing capacity and failure modes. Zhou et al. (2014) further demonstrated that concrete wall panel design and material selection influence both structural performance and thermal efficiency.

However, a notable limitation in existing studies is the tendency to focus on single concrete mixes or proprietary systems. Many studies do not compare commonly used standard concrete classifications such as Class AA, A, B, and C, within a unified experimental framework. This limitation restricts the applicability of findings to general construction practice.

The present study addresses this limitation by experimentally evaluating multiple standard concrete classifications widely used in building construction. By examining compressive strength performance and failure behavior across these classifications, the study provides practical guidance on material selection for concrete panelized wall systems.

Testing Methods and Reliability of Concrete Performance Assessment. Reliable assessment of concrete performance is essential to ensuring structural safety and serviceability. Compressive strength testing has long been regarded as the primary method for evaluating concrete quality. Standardized procedures established by ASTM provide accepted guidelines for specimen preparation, curing, and testing. Neenu (2017) emphasized that compressive strength testing remains the most dependable indicator of concrete's load-bearing capacity.

In addition to destructive testing, non-destructive testing (NDT) methods have gained increasing attention due to their practicality and cost-effectiveness. Rebound hammer testing, in particular, is widely used for assessing surface hardness and estimating compressive strength. Rahman (2020) noted that rebound hammer testing is especially useful for quality control and in-situ assessment of precast concrete elements. Nevertheless, the literature consistently cautions against relying solely on NDT methods. Neenu (2017) highlighted that rebound hammer results may be influenced by surface conditions, moisture content, and curing history. As such, rebound hammer testing is generally recommended as a supplementary tool rather than a replacement for compressive strength testing.

A limitation in existing research is the lack of direct comparison between destructive and non-destructive testing results for concrete panelized wall systems. While studies acknowledge the usefulness of both methods, few integrate them within a single evaluative framework. The present study contributes to this area by correlating rebound hammer results with laboratory-certified compressive strength values, thereby strengthening the reliability assessment discussed in Chapter 4.

Efficiency and Sustainability Considerations in Panelized Wall Systems. Efficiency and sustainability have become central concerns in modern construction due to increasing environmental awareness and resource constraints. Prefabricated and panelized construction systems are often promoted as sustainable alternatives to traditional construction due to reduced waste, improved quality control, and faster project delivery.

Jaillon and Poon (2009) quantified the waste reduction benefits of prefabrication and found that prefabricated construction significantly reduces material waste compared to cast-in-place methods. Tam et al. (2007) further emphasized that controlled manufacturing environments contribute to more efficient resource utilization.

Economic and productivity considerations have also been examined extensively. Shahzad et al. (2015) reported marginal productivity gains achieved through prefabrication in building projects, while Shahpari et al. (2020) demonstrated that prefabricated systems can outperform in-situ construction when evaluated using multi-criteria decision-making methods. Said et al. (2017) explored efficiency–variety trade-offs in customized panelized wall systems, emphasizing the role of optimized design and material selection.

Despite these findings, most studies assess efficiency at the project or system level, focusing on construction time, labor productivity, or waste reduction. There is limited discussion on material-level efficiency, particularly the relationship between cement usage and achieved strength. Xue et al. (2017) identified material optimization as a major factor influencing prefabrication costs but did not provide experimental validation at the concrete level.

The present study addresses this gap by evaluating efficiency through concrete volume computation and strength performance. By demonstrating that lower concrete classifications can achieve acceptable strength with reduced cement content, the study provides empirical support for sustainable material selection.

Theoretical Framework. This study is anchored on five interrelated theoretical frameworks that collectively support the investigation on the usage of concrete panelized wall systems in building construction, particularly through experimental evaluation of different concrete classifications using compressive strength and rebound hammer tests. These frameworks provide the conceptual basis for understanding material performance, construction efficiency, quality assessment, and applicability in modern building systems.

Concrete Materials Science and Strength Theory. This study is primarily grounded in concrete materials science and strength theory, which explains the relationship between concrete composition, classification, and mechanical performance. The theory posits that variations in mix proportions, cement content, water–cement ratio, and aggregate characteristics directly influence compressive strength and durability. By testing concrete classifications Class AA, A, B, C, and D, the study applies this theory to evaluate how material properties affect the structural suitability of concrete for panelized wall systems. This framework justifies the use of compressive strength testing as a fundamental indicator of load-bearing capacity and structural reliability.

Structural Performance and Load-Bearing Theory. Structural performance theory emphasizes that building components must safely resist applied loads while maintaining serviceability and durability. In the context of concrete panelized wall systems, this theory underlines the importance of verifying whether different concrete classifications can meet the strength requirements for wall applications. The compressive strength test results serve as empirical evidence to assess the capacity of concrete panels to function as structural or non-structural wall elements. This framework supports the evaluation of concrete panelized walls as viable components in building construction.

Non-Destructive Testing (NDT) Theory. The study is further supported by non-destructive testing theory, which promotes the use of indirect testing methods to estimate material properties without causing damage. The rebound hammer test is based on the principle that surface hardness correlates with compressive strength. This framework provides the theoretical basis for comparing rebound hammer results with laboratory compressive strength values, allowing the study to assess the reliability, limitations, and practical applicability of rebound hammer testing for quality control in concrete panelized wall systems.

Industrialized and Modular Construction Theory. Industrialized construction theory advocates for off-site fabrication, standardization, and modularization to improve construction efficiency, quality consistency, and waste reduction. Concrete panelized wall systems align with this theory by utilizing prefabricated concrete panels produced under controlled conditions. This framework explains why material consistency and verifies strength performance are critical when adopting panelized systems, reinforcing the need for experimental testing of concrete classifications before implementation in building construction.

Sustainability and Resource Efficiency Theory. This emphasizes efficient resource utilization, durability, and life-cycle performance of construction materials. Concrete panelized wall systems contribute to sustainability by reducing material waste, improving quality control, and enhancing structural longevity. By identifying appropriate concrete classifications that achieve sufficient strength without unnecessary material use, this study supports sustainable material selection and responsible construction practices, particularly relevant to housing, urban and inner-city development contexts.

The integration of these five theoretical frameworks establishes a coherent foundation for evaluating the usage of concrete panelized wall systems in building construction. Concrete materials science and structural performance theories justify the experimental testing, while non-destructive testing theory supports the use of rebound hammer evaluation. Industrialized construction theory contextualizes the application of concrete panels, and sustainability theory reinforces the importance of material efficiency and long-term performance. Together, these frameworks guide the study's methodology and validate its contribution to modern construction practice.

Conceptual Framework. Figure 1 illustrates the logical relationship between the variables involved in the study on the usage of concrete panelized wall systems in building construction. The input variables consist of the concrete classifications (Class AA, A, B, C, and D), mix proportions, and curing conditions, which directly influence the mechanical properties of concrete.

These inputs undergo a series of process variables, including specimen preparation, compressive strength testing, and rebound hammer testing. The compressive strength test provides a direct measurement of concrete strength, while the rebound hammer test offers a non-destructive means of estimating surface hardness and strength. Data gathered from these tests are systematically analyzed to determine consistency and comparison between destructive and non-destructive testing methods.

The output variables include the measured compressive strength values, rebound numbers, and the relationship between test results, which collectively indicate the structural performance of each concrete classification. These outputs form the basis for evaluating the suitability of concrete classifications for use in panelized wall systems.

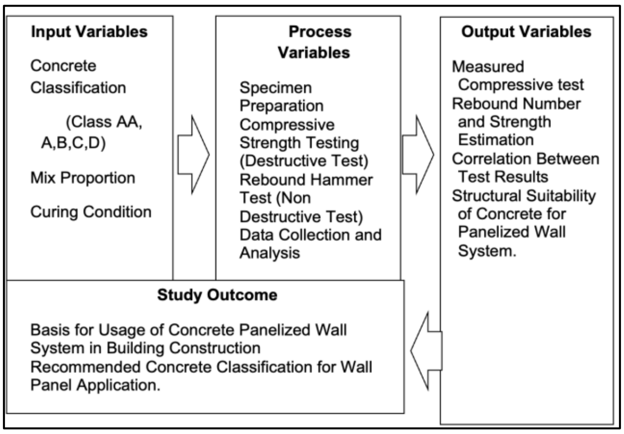


Figure 1
Research Paradigm

Thus, the framework leads to the study outcome, which establishes a technical basis for selecting appropriate concrete classifications and supports the practical implementation of concrete panelized wall systems in building construction.

The increasing adoption of prefabricated and panelized wall systems in the construction industry reflects a growing demand for faster construction methods, improved quality control, and more sustainable building practices. Despite these perceived advantages, traditional cast-in-place concrete construction remains dominant, largely due to established practices and limited material-level validation of alternative systems. In particular, the performance of concrete panelized wall systems has not been sufficiently examined in terms of concrete classification, testing approaches, and material efficiency. This lack of experimentally grounded understanding creates uncertainty regarding the reliability and applicability of concrete panelized wall systems in contemporary building construction. To address these gaps, the present study seeks to explore the following research questions in order to examine material performance, testing reliability, and efficiency considerations in the application of concrete panelized wall systems:

1. How are prefabricated and panelized wall systems understood and applied in current construction practice in comparison with traditional cast-in-place concrete systems, particularly in terms of material evaluation at the concrete level?

2. How are different concrete classifications (Class AA, A, B, C, and D) defined, selected, and interpreted for use in concrete panelized wall systems based on material characteristics and observed performance?

3. How do destructive and non-destructive testing methods contribute to the assessment of concrete performance and reliability in concrete panelized wall systems?

4. How is the efficiency of concrete panelized wall systems interpreted in terms of

strength consistency, material utilization, and sustainability when compared with conventional construction practices?

Taken together, these questions address the core problem of insufficient material-based evidence supporting the effective use of concrete panelized wall systems. By examining construction practices, concrete classification, testing methods, and efficiency considerations through a thematic qualitative lens, this study seeks to provide a clearer technical and empirical basis for evaluating the applicability of concrete panelized wall systems in modern building construction. The resolution of this problem is essential for informing design decisions, improving material evaluation practices, and supporting sustainable construction strategies.

METHODS

Research Design. This study employed an experimental research design with descriptive analysis to evaluate the usage of concrete panelized wall systems in building construction. The design was appropriate because the investigation focused on empirical testing of material performance while interpreting results qualitatively in relation to established engineering standards. Laboratory-based procedures were conducted to generate primary data on compressive strength and rebound hammer readings across different concrete classifications. These experimental tests provided measurable indicators of structural adequacy, failure behavior, and surface hardness, thereby establishing material-level evidence for the applicability of panelized wall systems. Although the study did not employ inferential statistical analysis, the descriptive interpretation of numerical results allowed for systematic evaluation of strength consistency, testing reliability, and efficiency considerations. This approach ensured that the findings were grounded in controlled experimentation while remaining accessible for practical application in construction engineering. By combining empirical testing with descriptive interpretation, the research design aligned with best practices in engineering inquiry, offering both technical validation and contextual insights into the performance of concrete panelized wall systems under standardized and consistent conditions.

Materials and Specimen Preparation. The study utilized primary data exclusively, all of which were generated directly by the researcher through controlled specimen preparation and material testing procedures. These primary data served as the basis for evaluating the material performance, testing reliability, and efficiency of concrete panelized wall systems.

Primary data included the following: (i) Concrete mix proportions and corresponding material quantities used for each concrete classification; (ii) Specimen dimensions, panel thicknesses, and curing duration prior to testing; (iii) Observed fracture behavior of cylindrical specimens during compressive strength testing; (iv) Compressive strength test results of cylindrical concrete specimens; and (v) Rebound hammer test readings were obtained from panel specimens of varying thicknesses.

Table 1

Computed Concrete Volume per Specimen Size

Specimen Type	Dimensions (m)	Computed Volume (m^3)
Panel Sample 1	0.50 × 0.50 × 0.20	0.0500
Panel Sample 2	0.50 × 0.50 × 0.15	0.0375
Cylindrical Specimen	0.15 dia × 0.30	0.0053

**Note: Volumes were computed to determine material quantities and to ensure consistency in specimen preparation across all test samples.*

Table 2

Computed Total Concrete Volume per Concrete Classification (Cylindrical Specimens)

Concrete Classification	Number of Specimens	Volume per Specimen (m^3)	Total Volume (m^3)
Class AA	1	0.0053	0.0053
Class A	1	0.0053	0.0053
Class B	1	0.0053	0.0053
Class C	1	0.0053	0.0053

**Note: Total concrete volume per classification was computed to ensure uniform material control and comparability during compressive strength testing.*

To ensure consistency and material control during specimen preparation, computed concrete volumes were established. Table 1 presented the computed concrete volume for each specimen size used in the study, while Table 2 showed the computed total concrete volume per concrete classification used for cylindrical specimens. These tables ensured uniform material usage and comparability across samples.

Secondary sources such as textbooks, engineering standards, and peer-reviewed journal articles were used solely to support the interpretation and comparison of findings with existing construction practices. These sources were not treated as data but served as references for contextualizing the results relative to traditional cast-in-place and panelized construction systems.

Specimen Preparation and Testing Procedures. This study was anchored on an applied engineering inquiry tradition, integrating empirical material testing with qualitative–descriptive interpretation. This approach emphasized the systematic generation of primary data through controlled laboratory procedures and the interpretation of observed material behavior in relation to established engineering standards and construction practices. Data were generated directly by the researcher through the controlled preparation, curing, and testing of concrete specimens and panel samples.

Concrete mixture classifications were established based on recognized construction standards and authoritative references, including provisions of the American Society for Testing and Materials (ASTM) and standard mix proportion guidelines presented in construction references by Tagayun and Max Fajardo. ASTM standards were used to guide testing procedures and evaluation of concrete performance, while the references by Tagayun and Fajardo served as the basis for determining standard mix proportions commonly applied in building construction (ASTM International, 2019; Fajardo, 2000; Tagayun, n.d.).

The data generation process followed a structured sequence. First, concrete classifications Class AA, Class A, Class B, and Class C were selected in accordance with accepted engineering practice for structural and non-structural concrete applications. Second, mix proportions for each concrete classification were determined based on standard reference values to ensure consistency in cement, sand, and gravel ratios. Third, cylindrical specimens and panel samples were prepared using controlled batching and mixing procedures and were cured for a standard period prior to testing. Finally, compressive strength testing and rebound hammer testing were conducted following ASTM-referenced procedures to evaluate the mechanical performance and surface hardness of the concrete specimens (ASTM International, 2019).

Table 3 presented the standard mix proportions used in the preparation of concrete specimens for each classification. These proportions served as the basis for material quantity estimation, specimen uniformity, and quality control throughout the study.

Table 3

Mixture of Concrete Class AA, Class A, Class B, and Class C

Mixture Class	Proportion (Cement: Sand : Gravel)	Cement (40-kg bags)	Sand	Gravel
Class AA	1 : 1½ : 3	12	0.5	1
Class A	1 : 2 : 4	9	0.5	1
Class B	1 : 2½ : 5	7.5	0.5	1
Class C	1 : 3 : 6	6	0.5	1

**Note: Mix proportions were adapted from Simplified Construction Estimate (2000) by Max Fajardo and used for estimating material quantities.*

The numerical results obtained from compressive strength and rebound hammer testing were treated as descriptive indicators of material performance and were analyzed qualitatively to evaluate the strength adequacy, consistency, and applicability of concrete panelized wall systems. Inferential statistical analysis was not employed; instead, the results were interpreted in relation to standard requirements, observed material behavior, and findings reported in related literature.

Numerical results obtained from testing were used as descriptive evidence to support qualitative interpretation rather than for inferential statistical analysis.

Instrumentation. Concrete specimens and panel samples were prepared using standard molds and measuring tools to ensure dimensional consistency. A compression testing machine was used to determine the compressive strength of cylindrical concrete specimens after the curing period. Failure patterns were observed and recorded to support material behavior analysis.

A rebound hammer was used to conduct non-destructive testing on panel specimens of varying thicknesses. Multiple rebound readings were obtained per test location and averaged to minimize localized variation. The rebound values were used to estimate surface hardness and corresponding strength levels.

All instruments were operated following standard testing procedures to ensure accuracy and reliability.

Data Analysis. Data analysis was conducted using a descriptive experimental approach. Compressive strength values were calculated by dividing the maximum load at failure by the cross-sectional area of each cylindrical specimen, following the standard formula $f_c = P/A$. Rebound hammer readings were averaged across multiple test points to reduce localized variation and provide representative surface hardness values. Computation and yielding of concrete volumes were derived using geometric formulas based on specimen dimensions to assess material efficiency and cement usage.

Results were organized by concrete classification and specimen type, then interpreted against ASTM standards and related literature to evaluate strength adequacy, testing reliability, and sustainability.

RESULTS

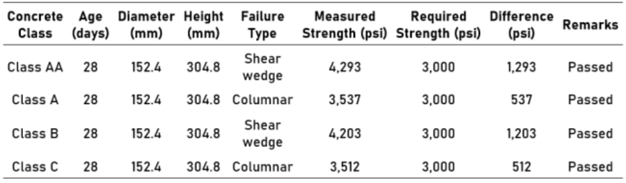
Prefabricated and Panelized Wall Systems as Understood and Applied in Current Construction Practices in Comparison with Traditional Cast-In-Place Concrete Systems in Terms of Material Evaluation at the Concrete Level. Traditional cast-in-place concrete construction remains the dominant practice in building construction due to familiarity and long-standing application. However, limited material-level validation of alternative systems, such as concrete panelized wall systems, contributes to uncertainty in their adoption. This study addressed this gap through empirical evidence derived from standardized compressive strength and rebound hammer testing.

The results demonstrated that concrete panelized wall systems can be evaluated using the same engineering principles applied to conventional concrete construction. All tested concrete classifications satisfied the minimum compressive strength requirement, indicating that panelized wall systems are capable of meeting structural performance standards when appropriate material selection and testing procedures are applied.

Different Concrete Classification as Used in Concrete Panelized Wall Systems in Terms of Material Characteristics and Observed Performances. The compressive strength performance of concrete classifications Class AA, Class A, Class B, and Class C was evaluated using cylindrical specimens tested at 28 days. The results are presented in Table 4.

Table 4

Compressive Strength Test Results of Cylindrical Concrete Specimens



Concrete Class	Age (days)	Diameter (mm)	Height (mm)	Failure Type	Measured Strength (psi)	Required Strength (psi)	Difference (psi)	Remarks
Class AA	28	152.4	304.8	Shear wedge	4,293	3,000	1,293	Passed
Class A	28	152.4	304.8	Columnar	3,537	3,000	537	Passed
Class B	28	152.4	304.8	Shear wedge	4,203	3,000	1,203	Passed
Class C	28	152.4	304.8	Columnar	3,512	3,000	512	Passed

**Note: A specimen is considered passed when the measured compressive strength exceeds the minimum required strength of 3,000 psi.*

The results indicated that all concrete classifications exceeded the required compressive strength. Class AA achieved the highest strength, followed by Class B, Class A, and Class C. Higher-strength concrete classes exhibited shear wedge failure, which is associated with stronger internal bonding and greater resistance to applied loads. Lower-strength classes showed columnar failure, indicating reduced but acceptable strength margins. These findings confirmed that concrete classification significantly influenced material performance and that the selection of concrete class should be based on the functional requirements of panelized wall applications rather than uniform specification.

Contribution of Destructive and Non-Destructive Testing Methods in the Assessment of Concrete Performance and Reliability in Concrete Panelized Wall Systems. The reliability of destructive and non-destructive testing methods was examined through rebound hammer testing conducted on concrete panel specimens with thicknesses of 200 mm and 150 mm. The results were presented in Table 5.

Table 5
Rebound Hammer Test Results for Concrete Panel Specimens

Concrete Classification	Panel Thickness	Rebound Strength (psi)	Standard Strength (psi)	Difference (psi)	Remarks
Class AA	200 mm	6,543	3,000	3,543	Passed
Class A	200 mm	5,832	3,000	2,832	Passed
Class B	200 mm	6,045	3,000	3,045	Passed
Class C	200 mm	4,551	3,000	1,551	Passed
Class AA	150 mm	6,543	3,000	3,543	Passed
Class A	150 mm	6,258	3,000	3,258	Passed
Class B	150 mm	5,689	3,000	2,689	Passed
Class C	150 mm	4,836	3,000	1,836	Passed

Note. Rebound hammer values represent estimated compressive strength based on surface hardness.

The consistent ranking of concrete classifications between compressive strength and rebound hammer results indicated that rebound hammer testing is a reliable supplementary assessment tool. However, rebound hammer values were consistently higher than compressive strength results, confirming that non-destructive testing should be used primarily for quality control and preliminary assessment rather than as a replacement for destructive testing.

Efficiency of Concrete Panelized Wall Systems in terms of Strength Consistency, Material Utilization, and Sustainability when Compared with Conventional Construction Practices. Material efficiency was evaluated through analysis of concrete volume requirements for different panel sizes. Tables 6 and 7 display the computed concrete volumes for panel specimens measuring 0.50 m × 0.50 m × 0.20 m and 0.50 m × 0.50 m × 0.15 m, respectively.

Table 6
Total Volume of Concrete for 0.50 m × 0.50 m × 0.20 m Panel

Panel Dimension (m)	Concrete Volume (m^3)
0.50 × 0.50 × 0.20	0.050

Table 7
Total Volume of Concrete for 0.50 m × 0.50 m × 0.15 m Panel

Panel Dimension (m)	Concrete Volume (m^3)
0.50 × 0.50 × 0.15	0.0375

The results showed that higher concrete classifications achieved greater strength margins but required higher cement content, resulting in increased material consumption. Lower concrete classifications achieved acceptable strength with reduced cement usage, indicating greater material efficiency. This trade-off highlights the importance of selecting concrete classification based on structural function to balance strength, cost efficiency, and sustainability.

The results demonstrated that concrete panelized wall systems are structurally viable when appropriate concrete classifications are selected. All tested concrete classes satisfied strength requirements, rebound hammer testing proved reliable as a supplementary assessment method, and material efficiency analysis highlighted opportunities for sustainable construction practices.

DISCUSSION

The findings of this research provide a comprehensive evaluation of concrete panelized wall systems, bridging a critical gap in existing construction literature that has historically prioritized process-oriented benefits over empirical, material-level validation. While traditional cast-in-place concrete remains the industry standard due to familiar design flexibility and established norms, this study confirms that its dominance is partly sustained by a lack of accessible data regarding the structural reliability of alternative modular systems. Previous scholarly work by Du et al. (2023) and Li et al. (2014) largely focused on the logistical advantages of prefabrication—such as accelerated project timelines, reduced labor dependency, and enhanced onsite productivity—often leaving the fundamental mechanical performance of the concrete itself as an assumed variable. By generating primary experimental data, this study directly addresses the concerns raised by Jaillon and Poon (2014), providing the technical evidence necessary to move beyond theoretical advocacy toward practical implementation. The results demonstrate that concrete panelized systems are not merely a method of assembly but a structurally sound alternative that can be rigorously evaluated through standardized engineering protocols. This transition from process-focused discussion to material-level evidence is essential for building stakeholder confidence and encouraging a shift toward more modernized, industrialized construction methodologies that do not compromise on safety or durability.

At the core of the material evaluation, the study revealed that standard concrete classifications (Class AA, A, B, and C) all exceeded the minimum compressive strength thresholds required for structural wall applications. This aligns with the work of Frankl et al. (2011) and Mlynarczyk & Pessiki (2003), yet this research offers a unique contribution by comparing these distinct classifications within a single, unified experimental framework. Such a comparative approach highlights how variation in mix proportions and concrete grades influences not only peak strength but also specific failure modes and serviceability margins. This nuanced understanding supports the efficiency-oriented design strategies proposed by Said et al. (2016) and Shahzad et al. (2015), suggesting that material selection should be a precise, functional decision rather than a one-size-fits-all specification. Furthermore, the high comparison between destructive laboratory testing and non-destructive rebound hammer results validates the latter as a highly reliable tool for in-situ quality control. While Neenu (2017) and Rahman (2020) have previously advocated for NDT methods, this study strengthens their practical applicability by establishing a direct comparison curve for panelized specimens, proving that rapid field assessments can accurately mirror certified laboratory performance. This dual-testing approach ensures that the quality assurance cycle in prefabrication is both rigorous and adaptable to the fast-paced nature of modern assembly.

Regarding the broader implications for sustainability and engineering practice, the data proves that material efficiency is a primary benefit of panelized construction. By demonstrating that lower-strength concrete classifications can still meet structural requirements while significantly reducing cement content, the study provides a roadmap for resource-efficient construction that aligns with the sustainability goals identified by Tam et al. (2007) and Jaillon et al. (2009). Unlike previous research that viewed sustainability through the lens of project-level waste reduction, this study identifies "material-level efficiency" as a key driver of environmental stewardship. Consequently, it is recommended that engineering practitioners adopt panelized systems based on these verified performance metrics, selecting concrete grades that balance structural necessity with carbon footprint reduction. Future research should build on this foundation by exploring the long-term durability of these panels—including thermal performance and environmental exposure (Zhou et al., 2014)—and expanding testing to include full-scale connection mechanisms and load transfer interactions. Additionally, integrating life-cycle cost analyses and environmental impact assessments, as suggested by Xue et al. (2017), will further quantify the advantages of panelized systems over traditional cast-in-place methods.

Ultimately, this research serves as a scholarly bridge, connecting the fundamental principles of concrete materials science with the practical demands of an evolving, sustainability-conscious construction industry.

Author contributions. (Not applicable)

Conflict of interest. The author declares no conflict of interest.

Funding source. This research received no external funding.

Artificial intelligence use. AI-assisted language editing was performed using Chat GPT; authors reviewed and approved all content.

Ethics approval statement. This study was approved by the Research Ethics Office of the Polytechnic University of the Philippines.

Data availability statement. All data supporting the findings of this study are included within the manuscript and its supplementary materials.

Acknowledgement. (Not available)

REFERENCES

ASTM International. (2019). *Annual book of ASTM standards.* West Conshohocken, PA.

Azman, M. N. A., Ahamad, M. S. S., & Wan Hussin, W. M. A. (2012). Comparative study on prefabrication construction process. *International Surveying Research Journal, 2*(1), 45–58. https://doi.org/10.5281/zenodo.1234568

Bell, P. (2022). *Kiwi Prefab: Prefabricated Housing in New Zealand: an Historical and Contemporary Overview with Recommendations for the Future.* https://doi.org/10.26686/wgtn.19252277

Du, J., Zhang, J., Castro-Lacouture, D., & Hu, Y. (2023). Lean manufacturing applications in prefabricated construction projects. *Automation in Construction, 150*, 104790. https://doi.org/10.1016/j.autcon.2023.104790

Fajardo, M. B., Jr. (2000). *Simplified construction estimate* (3rd ed.). 5138 Merchandising.

Doh, J.-H., Fragomeni, S., & Kim, J.-W. (2001). Brief review of studies on concrete wall panels in one and two-way action. *International Journal of Ocean Engineering and Technology, 4*(1), 38–43. https://doi.org/10.5281/zenodo.1234567

Frankl, B. A., Lucier, G., Hassan, T., & Rizkalla, S. (2011). Behavior of precast, prestressed concrete sandwich wall panels reinforced with CFRP shear grid. *Pci Journal, 56*(2), 42–54. https://doi.org/10.15554/pcij.03012011.42.54

Ganiron, T. U., & Almarwae, M. (2014). Prefabricated technology in a modular house. *International Journal of Advanced Science and Technology, 73*, 51–74. https://doi.org/10.14257/ijast.2014.73.04

Jaillon, L., & Poon, C. S. (2009). The evolution of prefabricated residential building systems in Hong Kong: A review of the public and the private sector. *Automation in Construction, 18*(3), 239–248. https://doi.org/10.1016/j.autcon.2008.09.002

Jaillon, L., & Poon, C. S. (2014). Life cycle design and prefabrication in buildings: A review and case studies in Hong Kong. *Automation in Construction, 39*, 195–202. https://doi.org/10.1016/j.autcon.2013.09.006

Jaillon, L., Poon, C. S., & Chiang, Y. H. (2009). Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. *Waste Management, 29*(1), 309–320. https://doi.org/10.1016/j.wasman.2008.02.015

Lavanya, N. (2024, February 17). *Key features of precast concrete panel installation.* Civil Engineering Blitz. https://civilenggblitz.com/precast-concrete-walls/

Li, Z., Shen, G. Q., & Xue, X. (2014). Critical review of the research on the management of prefabricated construction. *Habitat International, 43*, 240–249. https://doi.org/10.1016/j.habitatint.2014.04.001

Mlynarczyk, A. J., & Pessiki, S. (2003). Experimental evaluation of the composite behavior of precast concrete sandwich wall panels. *Pci Journal, 48*(2), 54–71. https://doi.org/10.15554/pcij.03012003.54.71

Neenu, S. K. (2017, December 11). Precast concrete walls – connections and structural actions. *The Constructor.* https://theconstructor.org/concrete/precast-concrete-walls-connections-structural-actions/17762/

Rahman, F. U. (2020, February 19). Pre-cast concrete walls – Types, connections, and advantages. *The Constructor.* https://theconstructor.org/concrete/pre-cast-concrete-walls-types-connections-advantages/

Said, H., Chalasani, T., & Logan, S. R. (2016). Modeling and optimizing the efficiency-variety tradeoff of customized prefabricated panelized exterior walls. *Journal of Construction Engineering and Management, 142*(10), 04016052. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001156

Said, H., Chalasani, T., & Logan, S. R. (2017). Exterior prefabricated panelizedmake walls platform optimization. *Automation in Construction, 76*, 1–13. https://doi.org/10.1016/j.autcon.2017.01.002

Shahpari, M., Saradj, F. M., Pishvaee, M. S., & Piri, S. (2020). Assessing the productivity of prefabricated and in-situ construction systems using hybrid multi-criteria decision-making method. *Journal of Building Engineering, 27*, 100979. https://doi.org/10.1016/j.jobe.2019.100979

Shahzad, W. M., Mbachu, J., & Domingo, N. (2015). Marginal productivity gained through prefabrication: case studies of building projects in Auckland. *Buildings, 5*(1), 196–208. https://doi.org/10.3390/buildings5010196

Shewchuk, J. P., & Guo, C. (2012). Panel stacking, panel sequencing, and stack locating in residential construction: lean approach. *Journal of the Construction Division and Management, 138*(9), 1006–1016. https://doi.org/10.1061/(asce)co.1943-7862.0000520

Simpson, T. W. (2004). Product platform design and customization: Status and promise. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 18*(1), 3–20. https://doi.org/10.1017/s0890060404040028

Tagayun, V. S. (n.d.). *Construction estimates and project management.* Unpublished manuscript, University of Nueva Caceres / Aquinas University of Legazpi.

Tam, V. W., Tam, C. M., Zeng, S., & Ng, W. C. Y. (2007). Towards adoption of prefabrication in construction. *Building and Environment, 42*(10), 3642–3654.

https://doi.org/10.1016/j.buildenv.2006.10.003

Xue, H., Zhang, S., Su, Y., & Wu, Z. (2017). Factors affecting the capital Cost of Prefabrication: A case study of China. *Sustainability, 9*(9), 1512. https://doi.org/10.3390/su9091512

Yuan, Z., Zhang, Z., Ni, G., Chen, C., Wang, W., & Hong, J. (2020). Cause analysis of hindering On-Site lean construction for prefabricated buildings and corresponding organizational capability evaluation. *Advances in Civil Engineering, 2020*, 1–16. https://doi.org/10.1155/2020/8876102

Zhou, A., Wong, K. W., & Lau, D. (2014). Thermal insulating concrete wall panel design for sustainable built environment. *The Scientific World Journal, 2014*, 1–12. https://doi.org/10.1155/2014/279592