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Lateral Overturning Tests of Cement-Bamboo Frame Technology Panels Using ISO 21581 Method II Protocol

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Abstract Sustainable and affordable housing remains a critical challenge in the Philippines, where conventional construction methods contribute to rising environmental impacts, high material costs, and increasing vulnerability to natural hazards. Bamboo, particularly *Bambusa blumeana (Kawayan Tinik),* offers a locally abundant, renewable, and structurally viable alternative material. This study presents the first experimental assessment of the lateral resistance capacity of panels constructed using Cement-Bamboo Frame Technology (CBFT), an engineered bahareque system designed to support disaster-resilient social housing. Following the ISO 22156:2021 recommendations for light-cement bamboo frames (LCBF), eight CBFT panels with similar configurations are subjected to monotonic and cyclic loadings following the ISO 21581:2010(E) loading protocols per Method II boundary conditions. Mechanical parameters are derived in accordance with ISO/TR 21141:2022, while Kolmogorov–Smirnov test verifies the normality of data per ISO 12122-1:2014 recommendation. CBFT panels demonstrate an average maximum lateral resistance of 24.69 kN across all tests, with approximately 12% higher resistance for cyclic tests than monotonic tests. The characteristic values for the 5th percentile are determined using ISO 12122-6:2017 at 8.5 kN. The commonly observed damage modes include cracking of the top timber plates, foundation connection failures, bracing buckling, and cement plaster cracks. Additionally, splitting of bamboo poles and detachment of the cladding from the frame are due to nail connection withdrawals. Overall, the panels maintained structural integrity, with performance consistent with existing literature on similar construction systems. The findings demonstrate that CBFT panels possess adequate capacity for application in sustainable, low-cost, and hazard-resilient housing. The data gathered from this study contributes to standardization efforts and broader structural application of engineered bamboo construction systems.

Keywords Bahareque, Bamboo, Cement-Bamboo Frame Technology, Seismic Loading, Social Housing

1. Introduction

The conventional approach to construction procedures and material usage resulted in environmental hazards and continued depletion of natural resources. In response, sustainable construction practices and the development of potential alternative materials to reduce the usage of conventional methodologies can help counteract these rising environmental issues [1-3]. Although bamboo architecture and engineering are gaining renewed interest in recent years, the use of bamboo in low-cost housing using modern construction methodologies remains relatively new and presents substantial opportunities for further research.

As a developing country, the Philippines faces a significant demand for affordable and disaster-resilient housing. The high energy consumption, pollution and increasing cost associated with conventional building techniques and materials have exacerbated environmental and societal burdens. Bamboo, long embedded in Filipino culture as a source of food, handicrafts, and traditional building components, offers a viable, sustainable alternative. Historically, its structural use can be traced to the native *Bahay Kubo*, an indigenous housing characterized by a bamboo culm framework, rattan walls, and thatched roofing typically made from cogon grass or nipa palm leaves. With a proper engineering approach, the use of bamboo can aid in the growth of alternative and sustainable movement in the construction industry.

1.1. Bamboo in Construction

Bamboo, an evergreen perennial plant of the subfamily *Bambusoideae*, is widely distributed across the globe. Owing to its structural capacities and broad range of potential applications, bamboo is emerging as a viable alternative material in modern construction. Its high tensile strength capacity and excellent weight-to-strength ratio make it a great candidate for sustainable development [4-6]. Bamboo's elasticity also enhances its suitability for housing in earthquake-prone regions, while its low repair and maintenance requirements after natural hazards further support its use. In addition, its high load-bearing capacity has positioned bamboo as a potential material for taller structures, including mid- to high-rise buildings. Although the raw material is naturally susceptible to degradation and insect attack, its durability and service life can be significantly improved through proper treatment processes.

Bambusa blumeana, commonly known as *Kawayan Tinik* (see Figure 1), is one of the most widely used local species in the Philippines, particularly for furniture making and the fabrication of traditional houses. Its rapid growth contributes to high productivity, while its favorable structural properties, combined with environmentally friendly treatment and manufacturing processes, make it a strong candidate for alternative building material applications. It also exhibits competitive strength characteristics relative to other bamboo species [7]. Recent studies on the mechanical properties of *Bambusa blumeana*, including the tensile and compressive characterization [8] and shear strength evaluation [9], further highlight its potential for use in the engineered design of modern bamboo structures.

1.2. Bahareque

In many Latin American countries, people traditionally built houses using variations of the wattle-and-daub technique known as *Bahareque* in Colombia and El Salvador, *Quincha* in Peru, and *Taipa de mão* in Brazil. This typology typically consists of treated timber or bamboo frames filled with a split bamboo matrix and finished with plaster made from cement, mud, or manure (see Figure 2). Lime is also commonly used as a final plaster layer [10]. In Colombia, *Bahareque* often employs *Guadua* canes as the primary structural component, resulting in lightweight and flexible structures capable of withstanding environmental conditions.

Figure 1. Kawayan Tinik (BASE Bahay Foundation, 2024)

Figure 2. 100-year-old traditional bahareque house in Colombia (Kaminski et al., 2024)

Several field studies conducted, including the Armenia 1999 and Muisne, El Salvador 1996 earthquakes, demonstrate the remarkable seismic performance of well-constructed and well-maintained *bahareque* structures. Despite these advantages, traditional *bahareque* requires a reasonable standard of construction, detailing and maintenance to prevent deterioration due to fungal decay or insect attack. Additionally, several studies have highlighted the potential of combining traditional materials with modern construction methodologies. For instance, ref. [11-14] examined the potential of *bahareque*, highlighting its viability as an alternative to conventional techniques. From these developments, *Bahareque Encementado*, a form of engineered *bahareque*, has emerged as an umbrella term for improved vernacular wattle-and-daub construction enhanced through modern engineering principles.

Life cycle assessments of [15,16] on engineered bahareque show that these structures have significantly lower carbon footprint compared to conventional construction materials such as concrete. The low energy required for processing bamboo, combined with the use of alternative plasters, can further reduce the embodied energy of *bahareque* walls. These characteristics make *bahareque* a sustainable housing option for rural and low-income communities, while also ensuring the seismic resilience and potential longevity of the structures.

Notably, the pioneering work of Simón Vélez, a renowned Colombian architect, has played a significant role in demonstrating the architectural and structural potential of bamboo in contemporary *bahareque* and bamboo construction. Vélez's innovative use particularly of *Guadua* canes has opened doors to new possibilities in sustainable architecture. His contributions have been instrumental in elevating bamboo from a vernacular material to one recognized globally for its viability in engineered construction.

Taking inspiration from traditional bahareque systems and as a subsystem of engineered bahareque, Cement-Bamboo Frame Technology (CBFT) is developed. This approach utilizes *Bambusa blumeana* bamboo poles as the primary framing elements, replacing *Guadua angustifolia,* commonly used in Latin American variants, to better align with material availability and housing needs in the Philippines. Designed to support the growing demand for affordable, hazard-resilient, and sustainable social housing, CBFT offers a locally adaptable construction method. As this study presents the first experimental evaluation of the lateral resistance capacity of CBFT wall panels, its findings provide an essential foundation for future research and system refinement.

1.3. Bamboo Standards and Regulatory Codes

One of the main challenges in designing structural elements with bamboo is the difficulty of comparing its physical and mechanical properties, owing to the absence of a universally standardized and codified testing protocol. Although numerous studies on bamboo's material properties have been conducted worldwide, comparing their results remains challenging because testing protocols often follow different criteria and methodologies. In this context, standardizing construction materials and testing procedures helps establish reliable design values and provides a common reference for structural applications. Over the years, global research interest in bamboo has grown substantially, contributing to significant advancements in the field. Despite this progress, further refinement of standardization efforts remains necessary and continues to be pursued.

Countries with abundant bamboo resources have played leading roles in developing bamboo construction codes and standards. The Indian Standard IS 15912:2012 [17] and the 2002 version of the Colombian code [18], Chapter E.7, are among the early notable efforts. Among existing international guidelines, Chapter G.12 of the Colombian NSR-10 remains the most thoroughly developed and widely referenced standard for structural design with bamboo [19]. However, several aspects are still lacking regarding sufficient material properties of various bamboo species and connection design, as it is generally considered the species *Guadua angustifolia Kunth.*

Resulting from the global advancements in standardization efforts and research since the publication of the first version of ISO 22156 in 2004 [20], it became necessary to update the standard to a template adaptable to various localities with indigenous species and construction practices. The revised ISO 22156 in 2021 [21] aligns more closely with the newer ISO bamboo standards, namely the ISO 19624 [22] and ISO 22157 [23]. Nonetheless, the updated standard continues to draw from established timber standards when deriving characteristic values and testing protocols. In many respects, the latest ISO 22156 serves as a continuation of the developments previously introduced in Chapter G.12 of NSR-10.

At present, the standard covers only structures in which the principal load-resisting elements are round bamboo components, including shear panel systems framed with round culms. Its use is restricted to residential and commercial buildings not exceeding 7 m in total height.

Despite these developments, there is still a limited number of tests conducted on engineered bamboo, often applying varied loading protocols and boundary conditions [24-26]. This study aims to address the research gap in establishing design values of bamboo-based construction and to contribute to the ongoing standardization of testing procedures. Under ISO 22156:2021 provisions for in-plane shear capacity of light-cement bamboo frame (LCBF) panels, CBFT panels fabricated using *Bambusa blumeana* poles are tested under monotonic and cyclic loading using Method II boundary conditions specified in ISO 21581:2010 [27].

Furthermore, test panels are to be considered as single-skin matrices evaluated under an unbraced testing set-up. The mechanical properties of the test panels are determined following the recommendations of ISO/TR 21141 [28]. Additionally, the lateral load behavior and corresponding damage modes are observed for each panel. The characteristic values are determined in accordance with ISO 12122-6 [29].

The results of these tests will support the implementation of this innovative construction approach for sustainable, affordable housing in the Philippines.

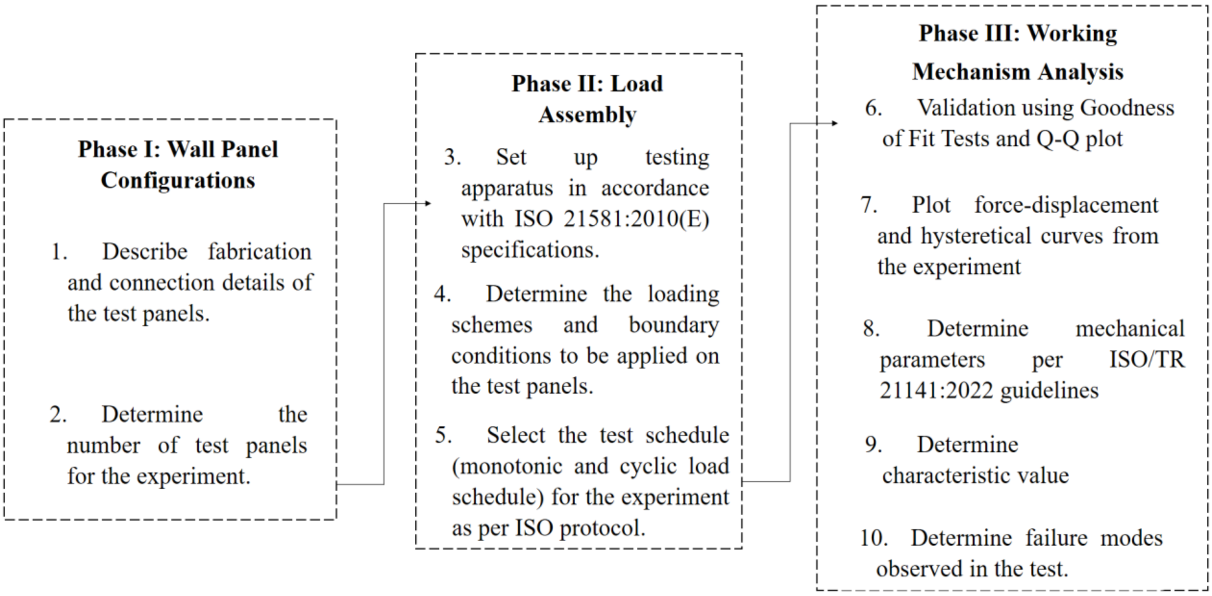
2. Materials and Methodologies

The methodological framework of this study, shown in Figure 3, discusses the data collection, analysis methods, and parameters used in the determination of shear response of CBFT panels. The complete force-displacement and hysteretic response data are plotted and organized for each panel tested. Test reports include a complete description of fabrication details, a diagram of test apparatus set-up and a report of force-displacement and hysteresis data plotted into curves. The damage modes for each panel under monotonic and cyclic loadings are further observed.

The statistical treatment of test data using Kolmogorov-Smirnov goodness-of-fit tests per Annex A of ISO 12122-1 [30] and Q-Q plots serves to validate the applicability of testing protocols used in the study.

2.1. Wall Panel Configurations

The test panels are 2.40 m x 2.40 m in dimension (see Figure 4), 25 mm thick, composed of five *Bambusa blumeana* poles sourced from Nasugbu, Batangas, Philippines. The bamboo poles used for the frame are 80-100 mm in diameter and 2.40 m high. Top and bottom 2' x 4' x 8" timber plates Grade 24 Oregon Pine (Douglas Fir) S4S are used for framing the bamboo poles using 3 pieces of 3-1/2" common wood nails per pole. For bamboo poles 1, 3 and 5, an additional 12mm Ø threaded rod cold-formed into 600mm long J-hooks at the top and 16 mm Ø deformed rebars at the bottom and later injected with mortar infill (1:3 cement-to-sand ratio). The frames are fitted with 600 mm x 2440 mm metallic rib-laths with 100mm vertical overlap fixed with 1-1/2" common wire nails at every 100 mm stiffened with Gauge #18 tie wires. Two pre-painted 3 mm x 25 mm flat bars are used for diagonal bracing of the system connected to rib-laths using tie wires of the same gauge at every 100 mm intersection.



Phase I: Wall Panel Configurations

1. Describe fabrication and connection details of the test panels.
2. Determine the number of test panels for the experiment.

Phase II: Load Assembly

3. Set up testing apparatus in accordance with ISO 21581:2010(E) specifications.
4. Determine the loading schemes and boundary conditions to be applied on the test panels.
5. Select the test schedule (monotonic and cyclic load schedule) for the experiment as per ISO protocol.

Phase III: Working Mechanism Analysis

6. Validation using Goodness of Fit Tests and Q-Q plot
7. Plot force-displacement and hysteretical curves from the experiment
8. Determine mechanical parameters per ISO/TR 21141:2022 guidelines
9. Determine characteristic value
10. Determine failure modes observed in the test.

Figure 3. Methodological Framework

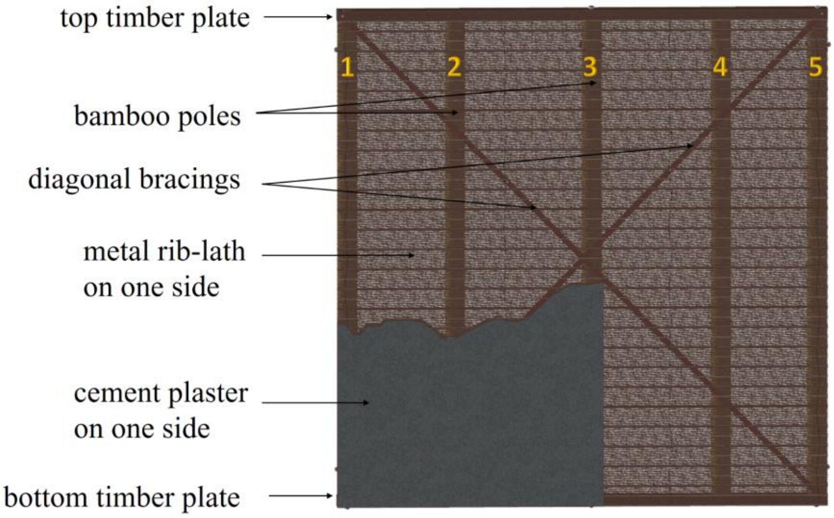


Figure 4. CBFT panel components

The cement plaster is directly applied to the rib-laths in two layers on one side of the panels only. Mortar and cement bamboo infill are cured for 7 days to prepare for testing. The average mortar strength during testing is 16.73 mPa determined per ref [31] and the average moisture content is 13.76% computed per ref [32].

For the identification of test samples, the panel number designation starts with 'CBFT' representing the construction methodology. The character 'M' is adopted for panels tested under monotonic loadings and the character 'C' is used for panels tested under cyclic loadings. The test panel number is presented following the dash line. For example, sample CBFT-M-1 represents the first monotonic test of CBFT panels.

2.2. Test Set-up

All test panels are prepared and tested at the Base Innovation Center, Makati City, Philippines. Four panels are prepared for testing using similar configurations for data accuracy, two panels for monotonic testing and two panels for cyclic testing. A horizontal load, F, is applied to the panels from the top left side by means of the MTS 407 hydraulic actuator and transferred by a loading beam connected to the top timber plate using M16 steel bolts (see Figure 5).

The hydraulic actuator used in the experiments has a built-in detector registering the minimum and maximum force and displacement resisted by the panels. The ALMEMO 710 Data Logger records the test data for each panel. The panels are fixed to the reaction frame through the embedded rebar foundation connections. No hold-down connectors are used to allow for boundary conditions designed to replicate actual site conditions. No vertical loads are considered for the duration of tests to allow for either wall failure or anchorage failure.

2.3. Loading Schemes

Referring to timber loading protocols [33,34] in line with ISO 22156:2021 provisions for in-plane shear capacity of light-cement bamboo frame (LCBF) panels, the loading protocols for monotonic and cyclic testing adopt the ISO 21581:2010 guidelines designed for Method II boundary conditions.

Specifically for monotonic testing, the application of horizontal load, F, is applied in two phases. The pre-loading phase considered the application of 12kN ($0.4F_{max}$), estimating F_{max} at 30 kN, with a loading rate of 2.4 mm per minute. For the main loading phase, the panels are loaded at a rate of 10.02 mm per minute, to allow for a 100 mm displacement in 10 minutes, up to failure ($0.8F_{max}$ after reaching peak load). Figure 6 illustrates the procedure for the application of horizontal load during monotonic testing.

During the cyclic tests, the panels are loaded and pushed to the right (positive) and pulled back to unload (negative). A loading speed of 0.1 Hz is applied, where each cycle lasts up to 10 seconds to achieve ultimate displacement within 1 to 30 minutes. The reference displacement used to determine the amplitude of reversed cycles is 64.47mm. Referring to Table 1, the pattern for the cyclic loadings consists of two displacement schemes: (1) five fully reversed single cycles at amplitudes of 1.25, 2.5, 5, 7.5, and 10% of the reference displacement and (2) phases including three fully reversed cycles of equal amplitude at peak displacements of 20, 40, 60, 80, 100, and, 120% of the reference displacement.

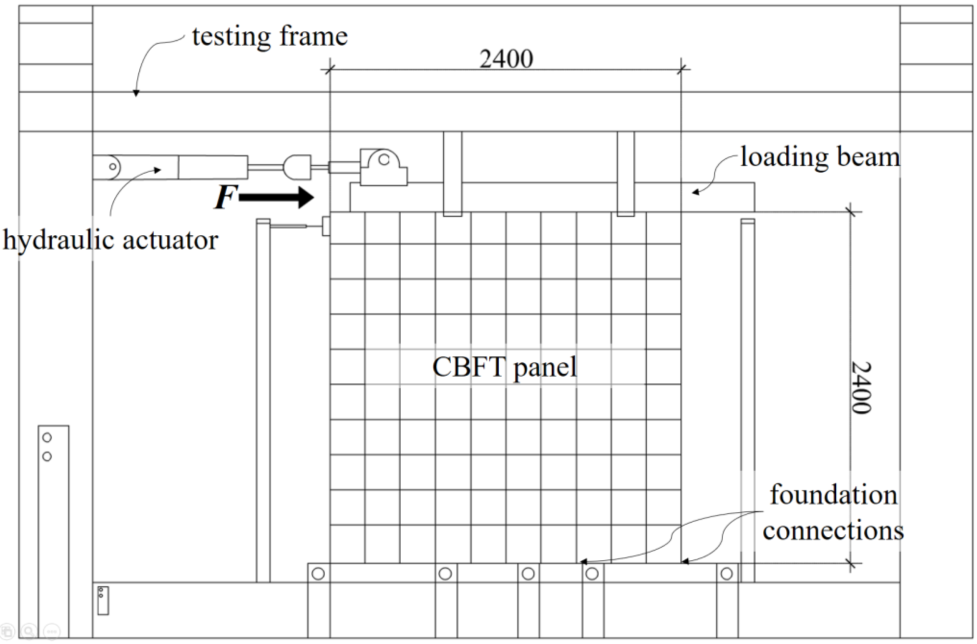


Figure 5. Test set-up details

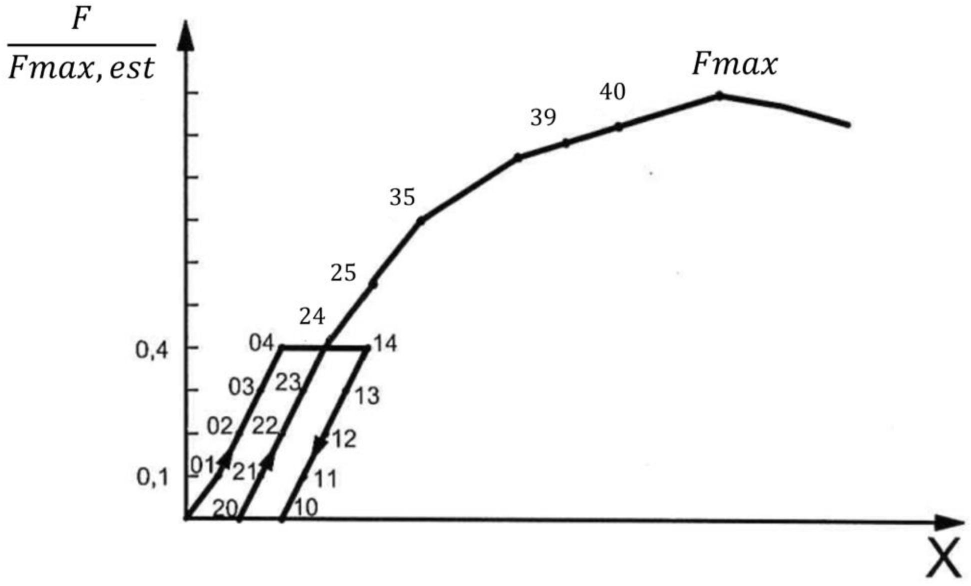


Figure 6. Force vs. time (modified graph from ISO,2010)

Table 1. Amplitudes of Reversed Cycles

Step	No. of Cycles	Amplitude
1	1	0.806
2	1	1.611
3	1	3.224
4	1	4.835
5	1	6.447
6	3	12.894
7	3	25.788
8	3	38.682
9	3	51.576
10	3	64.470
11	3	77.364

3. Results and Discussion

This section presents the analytical results for the experimental tests conducted in the current study. The experimental data considered for the analysis are taken from the results recorded by the actuator. The envelope force-displacement and hysteresis curves are used to illustrate the monotonic and cyclic performance of the panels. For the determination of cyclic response of the panels, the absolute values of the negative envelope curves are taken for consistency.

The normality of the data based on the F_{max} values of the panels is illustrated using a Q-Q plot, where the data points lie approximately along a straight line (see Figure 7). This observation is validated by the Kolmogorov-Smirnov (K-S) test based on fitted distributions as defined in Annex A of ISO 12122-1. At a significance level of α = 0.05, the critical value is determined as 0.375 while the K-S and corresponding p-value are 0.1411. Since the K-S value is less than the critical value, and the p-value exceeds α = 0.05, the data follows a normal distribution.

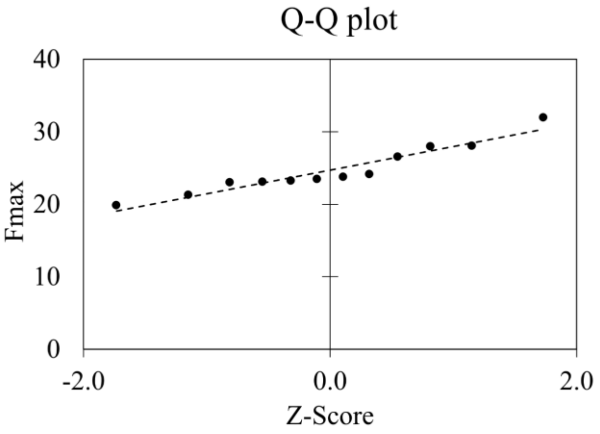


Figure 7. Q-Q plot

All panels are analyzed following the definitions per ref ISO/TR 21141. Following the nomenclature of the guideline, the mechanical parameters are determined, where F_{max} is the point on the curves indicating the maximum force resisted by the panels. The ultimate, F_u is defined as the drop of the resistance by 20% of F_{max} after reaching the peak. The yield capacity, F_y, is defined as the intersection of lines a and f. Line a connects $0.1F_{max}$ and $0.4F_{max}$ and line f is parallel to line e and tangent to the force-displacement curve. Line e connects $0.4F_{max}$ and $0.9F_{max}$. The corresponding displacements of the force parameters are taken as v_{max}, v_u, and v_y. The force-displacement curve of panel CBFT-M-1 is shown in Figure 8 to illustrate the process.

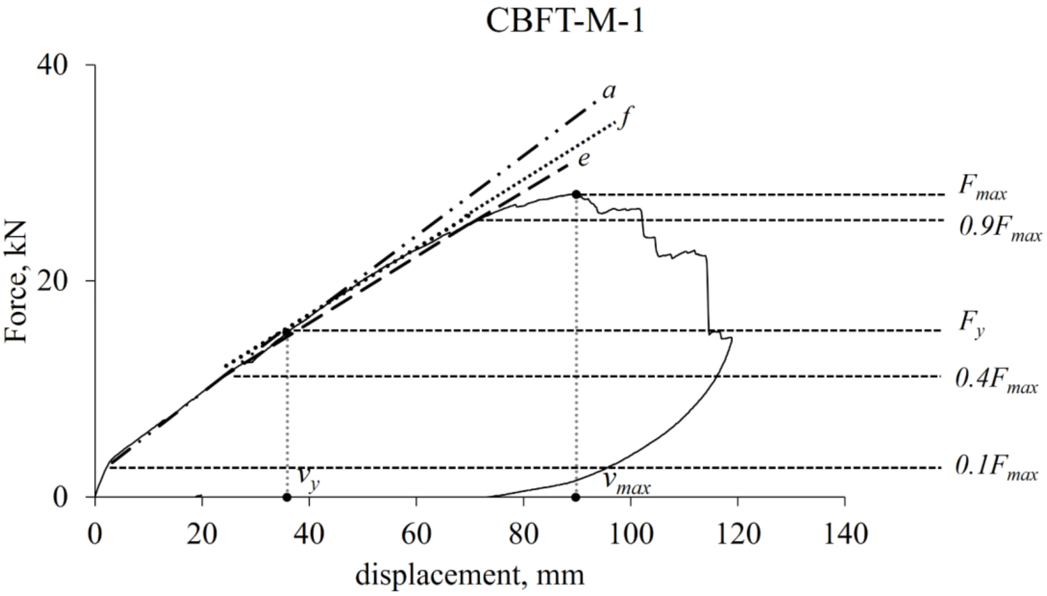


Figure 8. Determination of yielding point for panel CBFT-M-1

Table 2. Mechanical properties of CBFT panels

	Dimension	Loading protocol	F_{max} [kN]	v_{max} [mm]	F_u [kN]	F_y [kN]	v_y [mm]
CBFT-M-1	2.4m x 2.4m	Monotonic	28.01	89.85	22.41	15.20	34.46
CBFT-M-2	2.4m x 2.4m	Monotonic	19.68	62.58	15.74	10.69	17.47
CBFT-M-3	2.4m x 2.4m	Monotonic	26.58	59.58	21.26	20.34	34.48
CBFT-M-4	2.4m x 2.4m	Monotonic	21.25	89.08	17.00	17.84	56.99
CBFT-C-1 (+)	2.4m x 2.4m	Cyclic	24.17	62.18	19.34	12.68	22.18
CBFT-C-1 (-)	2.4m x 2.4m	Cyclic	23.01	72.98	18.41	12.86	39.29
CBFT-C-2 (+)	2.4m x 2.4m	Cyclic	28.08	59.15	22.46	11.67	20.32
CBFT-C-2 (-)	2.4m x 2.4m	Cyclic	32.00	63.73	25.60	12.72	19.76
CBFT-C-3 (+)	2.4m x 2.4m	Cyclic	23.22	54.93	18.58	13.09	23.32
CBFT-C-3 (-)	2.4m x 2.4m	Cyclic	23.46	42.40	18.77	13.91	21.09
CBFT-C-4 (+)	2.4m x 2.4m	Cyclic	23.73	55.45	18.98	11.50	22.50
CBFT-C-4 (-)	2.4m x 2.4m	Cyclic	23.07	59.80	18.46	10.79	24.12
Mean (Mono)	2.4m x 2.4m	Monotonic	23.88	75.27	19.10	16.02	35.85
Mean (Cyclic +)	2.4m x 2.4m	Cyclic	24.80	57.93	19.84	12.24	22.08
Mean (Cyclic -)	2.4m x 2.4m	Cyclic	23.39	59.73	20.31	12.57	26.07

3.1. Mechanical Parameters and Characteristic Values

Table 2 summarizes the mechanical performance of the CBFT panels. Figure 9a presents the force-displacement curves of the monotonic tests, while Figure 9b shows the hysteresis and envelope curves from cyclic tests. Insights into the mechanical capacities of the panels can be gained by analyzing the average values of maximum resistance of the panels and yielding points.

Among the monotonic tests, Panel CBFT-M-1 exhibits the highest maximum force F_{max} at 28.01 kN, whereas Panel CBFT-M-2 reached the least at 19.68 kN. The average F_{max} for panels subjected to monotonic loadings is 23.88 kN. Panel CBFT-M-1 also records the highest ultimate force at 22.41 kN and the highest ultimate displacement value at 112.67 mm, as clearly defined from the force-displacement curves. For the cyclic tests, Panel CBFT-C-2 reached the highest F_{max} for both positive and negative envelopes at 28.08 kN and 32 kN, respectively.

The average F_{max} values are 24.80 kN for the positive envelope curves and 23.39 kN for the negative envelope curves. Overall, the average maximum force across all panels is 24.69 kN.

On average, the maximum and ultimate forces of the positive cycles are approximately 5% higher than those of the negative cycles. When comparing monotonic and cyclic responses, the cyclic panels exhibited approximately 12% higher maximum and ultimate force capacities. Relative to previously reported CBSW subsystem performance, the CBFT panels, tested without external hold-down connectors, demonstrate maximum resistance capacities comparable to those of CBSW panels of similar configuration with a 1:2 matrix-to-frame ratio [35].

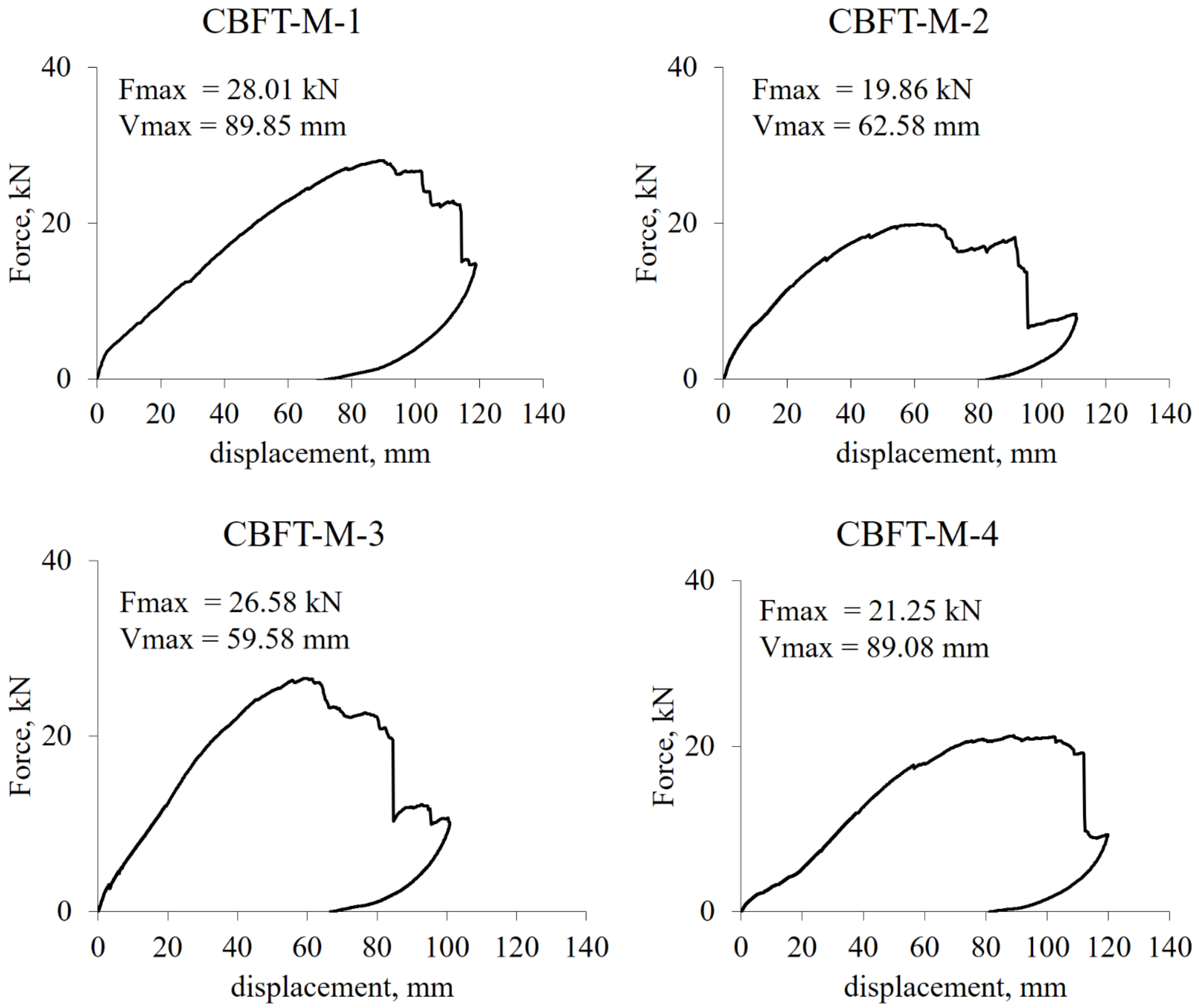
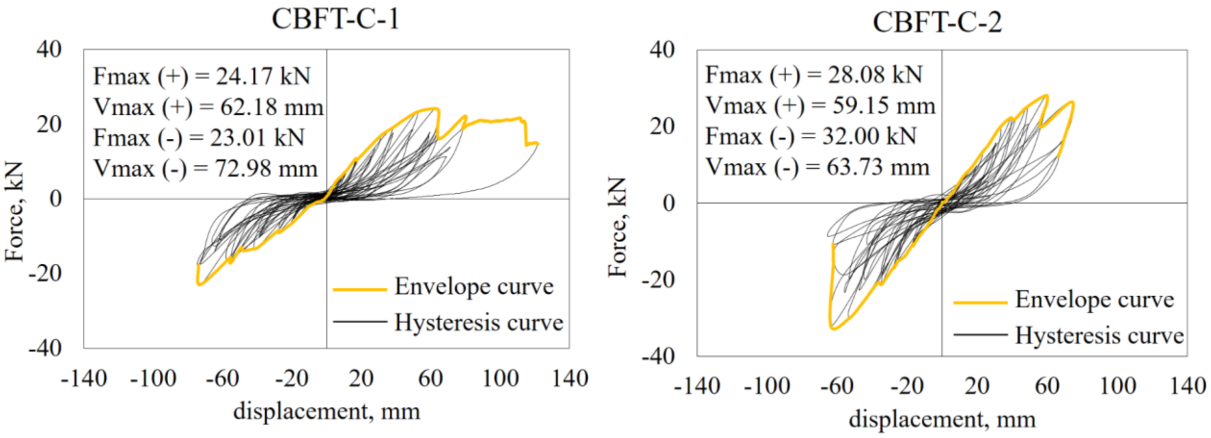


Figure 9(a). Force-displacement monotonic curves



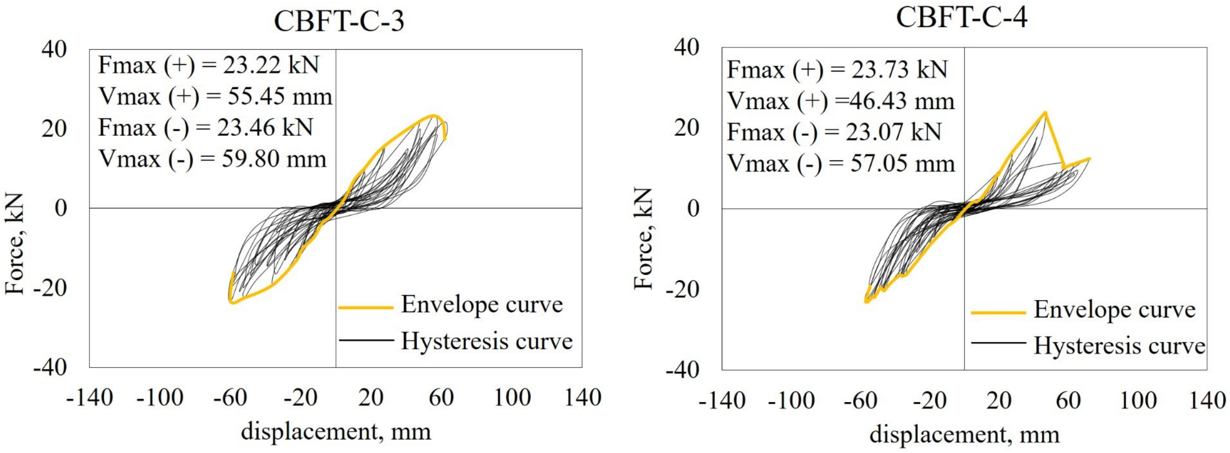


Figure 9(b). Hysteresis and envelope curves

The average F_{max} of the CBFT panels is comparable to CBSW subsystems with rib-lath matrices, and approximately 80% higher than panels constructed with flattened bamboo mat matrices. From the F_y values, the maximum capacities are determined for panel CBFT-M-3 and the negative envelope of panel CBFT-C-3.

In general, the test panels exhibit elastic behavior during monotonic loading, followed by a gradual reduction in resistance. The hysteresis behavior for cyclic tests shows a decrease in force resistance for each cycle.

The characteristic values of the CBFT panels are determined from their maximum force capacities in accordance with ISO 12122-6. For the 5th percentile at 75% confidence and a sample size of n = 12, a sampling factor, k_n = 1.76, is applied, yielding a characteristic value of 8.5 kN.

3.2. Damage Modes

This section presents the observed damage modes for both monotonic and cyclic tests.

In general, the lateral behavior of CBFT panels includes: (a) cracking of the top timber plates, (b) foundation connection failure, (c) splitting of bamboo poles, (d) detachment of the cladding from bamboo-timber frame, (e) buckling of flat-bar bracing, and (f) cracking of cement plaster. Overall yielding of CBFT panels is characterized by a combined buckling failures and connection impairments.

Although panels CBFT-C-3 and CBFT-C-4 did not exhibit bamboo pole splitting, cladding detachment, or anchor bolt and nail connection failures, these are the only panels to exhibit foundation connection damage resulting in uplift and indicating the onset of overturning (Figure 10b). Notably, CBFT-C-4 is the only panel to exhibit uplift at both ends due to foundation connection failure.

Under both monotonic and cyclic loadings, bamboo splitting is primarily concentrated at the pole-to-top timber plate connections with mortar infill. This damage is attributed to the dowel action of the j-bolts connecting the bamboo poles to the top timber plates. However, in Panel CBFT-M-1, splitting is also present in poles without mortar infill (i.e. poles 2 and 4), caused by the nail withdrawal at bamboo-top timber plate connection.

Cladding detachment from the bamboo frame resulted from the withdrawal of nails connecting the rib-lath matrix to the frame (see Figure 10c). Buckling of flat bar bracing is only observed around the top right corner (Q2) of panel CBFT-C-2 (see Figure 10e). The cement plaster cracking consistently developed during the main loading phases. These cracks are mostly localized around the top left quarter (Q1) of the panels (see Figure 10f), but did not result in a significant reduction in the structural performance of the panels.

Overall, no panel exhibited premature failure and was able to reach its maximum resistance capacity for both monotonic and cyclic tests. The damage modes identified for the CBFT panels are consistent with the reported behaviors of bamboo and timber configurations [36,37,38].

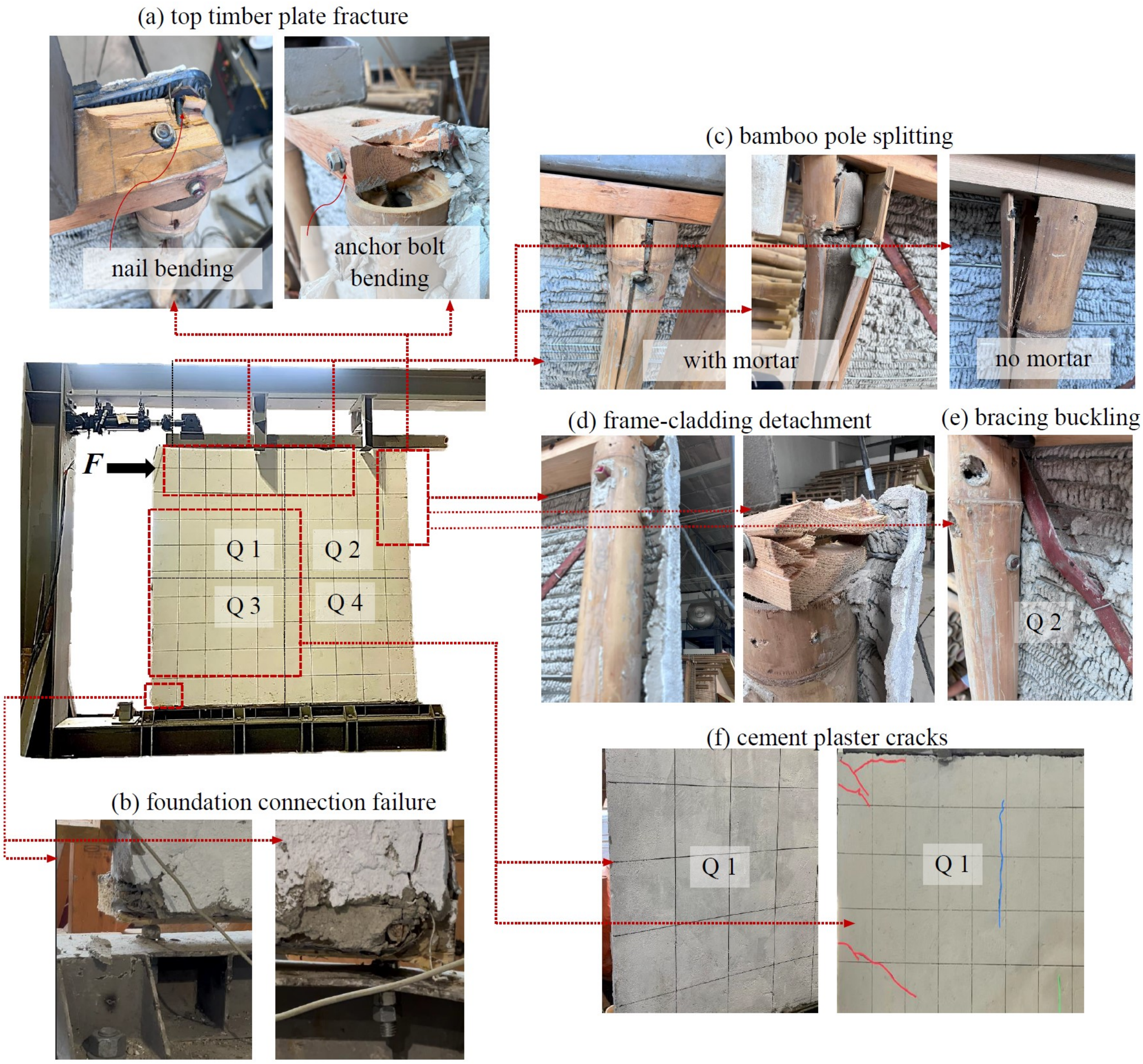


Figure 10. Damage modes

4. Conclusions

The study is designed to enhance the comprehension of the structural behavior of panels made using Cement-Bamboo Frame Technology incorporating *Bambusa blumeana* as its primary framing component, and provide valuable insights into the application of engineered bahareque in low-cost housing construction. The proposed framework is intended for the comprehensive experimental testing of test panels considered as LCBF structures in accordance with ISO 22156:2021. Eight 2.4 m x 2.4 m test panels of uniform configurations are subjected to monotonic and cyclic loadings to determine the maximum displacement capacities and examine the damage modes of the samples. The tests are conducted to allow for Method II boundary conditions of ISO 21581:2010(E).

Goodness-of-fit tests confirmed the suitability of the adopted testing protocols. Across both monotonic and cyclic tests, the most common damage mechanisms included cracking of the top timber plates, foundation connection failures leading to uplift, splitting of bamboo poles at the connections, buckling of flat-bar bracing, and surface cracking of the cement plaster. Nail connection failures were identified as a recurring factor contributing to timber plate cracking, bamboo splitting, and partial detachment of the cladding from the bamboo–timber frame. Surface cracks developed across the panels but do not significantly affect the structural performance of the panels. Overall, the CBFT panels maintained their structural integrity as a composite system. Comparisons with existing data on Composite Bamboo Shear Wall (CBSW) subsystems showed that CBFT panels exhibit comparable mechanical performance falling within the expected range for light bamboo- or timber-based shear walls. The calculated characteristic value, determined in accordance with ISO 12122-6, can be used for the establishment of a design value applicable to different subsystems of bamboo-based structures. Although there are limitations due to the sample size presented in the study, findings strongly affirm the potential of CBFT for sustainable, disaster-resilient low-cost housing applications.

The overall findings demonstrate that CBFT panels possess adequate strength and damage tolerance to support their application in low-cost housing construction. The consistency of their performance with established bamboo and timber shear wall configurations further reinforces their suitability for broader adoption and contribution to addressing the research gap in the standardization of bamboo-based structural components; however, a more in-depth investigation is required. For future research, it is recommended to explore the influence of alternative loading protocols relative to ISO 21581:2010(E) on the performance of different CBFT panel subsystems. Moreover, testing under Method I boundary conditions with hold-down connectors is recommended to enable direct comparison with Method II boundary conditions.

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Conflicts of Interest

All authors declare that they have no conflicts of interest.

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