

CAPITAL UNIVERSITY OF SCIENCE AND
TECHNOLOGY, ISLAMABAD



**Behavior of Mortar-Free
Interlocking-Plastic-Block Walls
at Junctions Under Harmonic
Loading**

by

Arshad Ullah

A thesis submitted in partial fulfillment for the
degree of Master of Science

in the

Faculty of Engineering
Department of Civil Engineering

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List of Publications

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1. A. Ullah and M. Ali, “Understanding The Dynamic Behavior of Junctions in Mortar-free Interlocking Block Walls Through Literature Research”, in Proc. 2nd Int. Conf. Climate Change Emerging Trends Civil Eng., Ghulam Ishaq Khan Inst. Eng. Sci. Technol. (GIKI), Topi, Pakistan, Feb. 20, 2025, Paper ID: CCETC 25-31.



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Abstract

The impact of earthquakes on infrastructure, including the collapse of buildings, roads, and bridges, can lead to devastating consequences, including significant loss of life. A comprehensive understanding of structural behavior under seismic loading is essential for developing resilient design solutions. In contrast to advanced facilities available in developed nations, such as shake tables and sophisticated data acquisition systems, many developing countries lack access to such resources. An effective alternative for simulating seismic forces in these regions is the use of low-cost, locally developed shake tables, which provide valuable insights into seismic behavior. A prevalent failure mode in masonry structures occurs at T-junctions, where the interplay between in-plane and out-of-plane dynamic forces undermines the structural integrity, especially in systems with weakened mortar. The behavior of mortar-free interlocking plastic-block walls under seismic loading, particularly at junctions, remains underexplored, despite their potential for earthquake-resistant construction due to their reduced mass and inertia. Simple, cost-effective shake table testing has demonstrated promising results in investigating such behaviors, highlighting the need for further investigation into the dynamic response of T-junctions.

This research explores the dynamic performance of a 1:4 scale model of a T-junction made from interlocking plastic blocks. The prototype T-junction, comprising 195 plastic blocks arranged in 15 layers, was secured at the base using angle sections to maintain structural stability. To monitor the structural response, five accelerometers were strategically positioned: two at the top of each wall, one at the top of the T-junction, one at the bottom of the T-junction, and one at the base plate for recording base excitation. A snap-back test was conducted by displacing the wall in the X-direction using a 400 mm wire and releasing it to evaluate the natural time period, frequency, and damping ratio using the logarithmic decrement method. A locally developed, low-cost shake table operating at frequencies of 0.5 Hz, 1.0 Hz, and 1.5 Hz simulated seismic excitation. The acceleration-time history data were processed using MATLAB and SeismoSignal software for noise reduction and baseline correction.

The average natural frequency of the interlocking T-junction was approximately 1.0 Hz, with a damping ratio reaching 14.23%. The displacement-time history analysis indicated that the out-of-plane behavior of the walls significantly influenced T-junction deformation, with its contribution remaining dominant, accounting for up to 96% of the deformation depending on the configuration. Energy absorption was assessed from base shear-displacement curves, assuming lumped mass at the top of the specimen. Wall configuration Sequence B exhibited higher energy absorption compared to Sequence A at all frequencies, with improvements of 22.9%, 54.4%, and 83.5% at 0.5 Hz, 1.0 Hz, and 1.5 Hz, respectively. A 14% deviation between experimental and empirical results is attributed to the complexity of the structure versus the simplicity of the empirical equations. This study provides valuable insights into the dynamic behavior of T-junctions in mortar-free interlocking plastic-block systems, contributing to the development of safer, more cost-effective, and resilient seismic-resistant structures.

Keywords: Harmonic behavior, Interlocking plastic blocks, T-junction, Energy absorption.

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Abbreviations

1D	One dimensional
3D	Three dimensional
CBM	Confined brick masonry
cm	Centimeter
cm/s	Centimeter per second
CMU	Conventional masonry unit
CFRC	Coconut Fiber Reinforced Concrete
Config	Configuration
Def	Deflection
Damp	Damping
Diss	Dissipation
Disp	Displacement
Emp	Empirical
Exp	Experimental
Hz	Hertz
IP	Inplane
IPB	Interlocking plastic block
IPBW	Interlocking plastic block wall
MFI	Mortar free interlocking
mm	Millimeter
MMS	Mortar less masonry system
Nm	Newton meter
OOP	Out of plane
PGA	Peak ground acceleration

PT	Post tensioned
RB	Rubber Band
SDOF	Single degree of freedom
URM	Unreinforced Masonry

Symbols

ζ	Damping ratio
Δ	Displacement in centimeter
E	Energy absorbed
E_t	Total energy absorbed
f_n	Fundamental frequency
K	Coefficient having dimensionless value
n	No. of interlocking plastic-blocks
m	No. of blocks along the length of wall in a single layer
a	Base area of interlocking plastic-block
h	key height of IPB
$Q(N)$	Base-shear
Hz	Unit of frequency
g	Acceleration
\ddot{u}_g	Average acceleration at the base of specimen
\dot{u}_g	Average velocity at the base of specimen
u_g	Average displacement at the base of specimen
\ddot{u}_t	Average acceleration at the top of specimen
\dot{u}_t	Averaged velocity at the top of specimen
u_t	Average displacement at the top of specimen

Chapter 1

Introduction

1.1 Prologue

An earthquake is a natural phenomenon characterized by the generation of intense ground motion, which can cause extensive damage, including the collapse of buildings, roads, and bridges, often resulting in significant loss of life. The vulnerability of masonry structures to seismic events is particularly pronounced, as design deficiencies frequently contribute to their failure during such occurrences, underscoring the necessity for enhanced structural design and seismic resilience in earthquake-prone regions. Such damage was evident during the 2005 Kashmir earthquake, where over 86,000 people lost their lives and more than 80,000 people were injured, resulting in an economic loss of 5.2 billion dollars [1]. Similarly, the 2008 Sichuan earthquake in China claimed 70,000 lives and caused severe destruction to over 216,000 buildings, including 6,890 schools [2]. In seismic regions, the need for cost-effective, earthquake-resistant housing solutions, especially in rural areas of developing countries, is more pressing than ever. Junction failure, often leading to the collapse of out-of-plane walls, is the predominant failure mode in unreinforced masonry structures during seismic events. The junction is considered the most vulnerable part of these structures. It is needed to improve the integrity of the structures to behave as a single unit and to ensure proper interlocking between orthogonal walls to reduce the casualties during earthquake [3].

Traditional masonry structures, characterized by unreinforced brick or stone, have demonstrated significant vulnerability during seismic events. The lack of proper reinforcement and structural deficiencies lead to devastating damages, as seen in the 2010 Haiti earthquake caused an estimated 300,000 deaths, where 80 percent to 90 percent of masonry structures were either partially or completely destroyed [4]. The 2015 Gorkha earthquake in Nepal, registering a moment magnitude of 7.8, occurred on April 25 and resulted in catastrophic consequences across the affected regions [5], [6]. The seismic event caused over 8,000 fatalities, approximately 21,000 injuries, and displaced nearly 2 million individuals [7]. Furthermore, an estimated 600,000 buildings, including residential dwellings and heritage structures of cultural significance, were either severely damaged or completely destroyed [6], [5]. Afghanistan has endured multiple catastrophic earthquakes resulting in substantial casualties and infrastructure destruction. The June 22, 2022 earthquake, with a magnitude of 6.1 to 6.2, struck Khost and Paktika provinces, claiming 1,000-1,700 lives, injuring 1,500, and damaging 70% of local residences [8], [9]. This was the region's most severe seismic event in two decades [8]. The disasters highlighted systemic vulnerabilities, such as insufficient infrastructure resilience, non-compliance with seismic building codes, and inadequate disaster preparedness mechanisms [10]. The post-earthquake response further revealed substantial challenges, including logistical difficulties, weak inter-agency coordination, and socio-cultural dynamics influencing community behavior [7]. Consequently, this event highlights the need to strengthen community participation, foster local leadership, and enhance disaster risk management frameworks to build greater resilience against future seismic hazards. [7]. There is a growing need for innovative and affordable construction methods capable of withstanding seismic forces, especially in resource-limited regions. In response, alternative systems such as mortar-free interlocking blocks have been developed, which dissipate seismic energy through relative movement at block interfaces, thereby reducing the effects of ground motion. [11], [12]. Previous research explored the use of coconut fiber-reinforced mortar-free blocks, which, despite their effectiveness, faced challenges related to their weight [13]. Interlocking plastic blocks (IPBs), by contrast, offer a lightweight

alternative with improved energy dissipation properties due to block uplift during seismic events. Advanced 3D shake tables are often employed for dynamic analysis in earthquake engineering, they are costly and resource-intensive. In contrast, low-cost uniaxial 1D shake tables provide an economical solution, enabling researchers to investigate the dynamic behavior of structures under harmonic and random excitations [11]. Despite extensive studies on various materials and configurations, there remains a knowledge gap concerning the behavior of interlocking plastic block walls (IPBWs), particularly at junctions, under harmonic loading using locally developed shake tables.

This study addresses a key research gap by investigating the dynamic behavior of mortar-free IPB wall junctions under harmonic loading using a locally developed low-cost 1D shake table. By evaluating energy dissipation, base shear, and lateral displacement, it overcomes limitations in prior work and enhances understanding of IPB system performance. Given the need for affordable, resilient housing in seismic-prone rural regions of developing countries, IPB systems offer a cost-effective means of dissipating seismic energy through block-boundary motion. As advanced six-degree-of-freedom shake tables are costly, accessible uniaxial alternatives are vital for laboratory testing. With no previous studies examining such junctions under harmonic excitation using local systems, this research contributes to economical, sustainable, and seismically resilient construction practices for vulnerable communities.

1.1.1 Previous Researches on IPB Systems

The behavior of IPB structures under different loading conditions has been widely studied, offering key insights into their structural performance, including their energy absorption capacity. Adnan [14] demonstrated that structural elements with a two-block width exhibited enhanced energy absorption and peak load capacity under compressive loads compared to those with a single-block width, which failed abruptly. Sudheer [15] study showed that IPBWs with windows performed better under lateral loads, offering greater resistance and energy absorption than

unreinforced masonry walls. Khan [16] proposed empirical equations indicating that IPB structures reinforced with rubber bands were stiffer and displayed reduced top displacement under harmonic loading. Shahzad work [17] further emphasized that vertical reinforcement with rubber bands contributed to improved energy dissipation in these walls under harmonic loading. Afzal [18] observed that unreinforced brick masonry walls failed due to weak mortar-brick bonding, whereas lighter IPBWs demonstrated superior energy dissipation. Aslam [19] concluded that IPBWs possess adequate compressive strength to support their own weight, showcasing enhanced structural performance through energy dissipation and crack control. Bashir's study [20] revealed that the use of a wooden diaphragm, which transmits loads to vertical resisting elements like frames or walls, significantly reduced top displacement and improved energy dissipation in IPBWs. Anwar's research [21] highlighted the superior seismic performance of IPBWs with block-return and diaphragm systems, which exhibited higher damping ratios, base shear, and energy dissipation, especially under OOP loading. Asad's study [22] found that the combination of block-return and rubber band reinforcement in IPBWs increased energy dissipation under harmonic loading. Although there have been studies on the out-of-plane behavior, walls with openings, and junctions, T-junctions have not been sufficiently explored. Akram [23] research focused on the dynamic behavior of corner joints in mortar-free IPBWs. This study examines the dynamic behavior of T-junctions under harmonic loading to improve understanding of their performance and to inform the design and optimization of IPB systems in regions where these junctions are common.

1.2 Research Motivation and Problem Statement

Earthquakes can cause extensive damage, including the collapse of buildings, roads, and bridges, often resulting in numerous fatalities. To mitigate such losses, it is crucial to study the precise behavior of structures during seismic events, which can inform better design practices. While developed countries have access to advanced facilities for such studies, developing countries often lack these resources,

such as shake tables. A potential solution is to investigate the behavior of structures using locally developed, low-cost shake tables (operating in one direction). Additionally, confined brick structures, though somewhat expensive, present another option. Ali suggested an economical solution, but further reduction in the mass of the blocks is needed [12]. IPB structures, potentially enhanced with fire-resistant paint and utilizing recycled plastic waste, could offer a viable alternative. However, the recycling aspect is beyond the scope of this study. Thus, the problem statement is: During earthquakes, many masonry structures collapse due to design flaws [10]. Mortar-free interlocking block structures have emerged as an innovative technique for earthquake-resistant housing. However, there is still a need to develop low-cost, environmentally friendly, and seismically safe housing solutions using locally available resources and materials. Interlocking block systems present a viable option, but the relatively high mass of conventional blocks remains a concern, as greater structural mass leads to higher inertia forces during seismic events. To address this issue, lightweight IPBs offer a potential solution. Therefore, it is essential to investigate the dynamic behavior of IPBWs, particularly at junctions, using shake table in the laboratory.

1.2.1 Research Questions

1. How do IP and OOP wall behaviors contribute to junction failure?
2. Can IPB junctions (among considered sequence) resist damage under harmonic loading?
3. How much different configurations of IPBWs affect energy dissipation?

1.3 Overall Goal of the Research Program and Specific Objectives of this MS Thesis

The overarching goal of the research program was to develop a comprehensive understanding of the 3D seismic behavior of full-scale mortar-free IPBW structures

in a controlled laboratory setting. This objective encompassed the evaluation of their structural response under harmonic and seismic loading, with the ultimate aim on improved construction practices and enhancing structural resilience.

The specific aim of the present Masters research was to investigate the dynamic performance of T-junctions in mortar-free IPB walls using a locally fabricated, low-cost, simple 1D shake table. The study analyzed load distribution, deformation, and stress at junctions under harmonic loading, offering key insights into their stability, failure modes, and suitability for cost-effective construction.

1.4 Scope of Work and Study Limitations

The research entailed experimental testing and comparative analysis to evaluate the performance of IPBW junctions under controlled harmonic loading. A prototype mortar-free T-junction was constructed using specially designed interlocking blocks mounted on a fixed base to replicate realistic structural conditions. Dynamic behavior was investigated by applying three discrete loading frequencies (0.5 Hz, 1.0 Hz, and 1.5 Hz), with responses recorded in terms of displacement-time and acceleration-time histories. A snap-back test was performed to determine the natural frequency (f_n) and damping ratio (ζ) of the system. Data acquisition was carried out using five strategically positioned accelerometers, and empirical equations were developed, in accordance with Ali's methodology, to characterize the structural response [12].

The use of a simple 1D shake table constrained the investigation to uni-axial excitation, limiting the representation of complex seismic loading. The instrumentation setup, comprising only five accelerometers, restricted the spatial resolution of the recorded data. Furthermore, acceleration-time histories obtained through MATLAB required processing using SeismoSignal software, and the testing program was confined to three loading frequencies. Additionally, the study does not examine specific plastic types or their material properties, as this lies beyond its scope. While these constraints reduced the breadth of applicability, they facilitated a focused and controlled evaluation, establishing a foundational dataset for

future research employing advanced instrumentation, multi-axial loading systems, and a broader range of dynamic scenarios. The study remains important because evaluating the prototype T-junction behavior enables the verification of its corresponding full-scale response, thereby ensuring the reliability and validity of the structural performance assessment. Providing slab would increase the lateral stiffness and load distribution, potentially reducing displacements and enhancing the overall stability. However, this is beyond the scope of the current research and may be studied in future investigations.

1.4.1 Rationale Behind the Variable Selections

In this study, a T-junction configuration of mortar-free IPBWs is selected to investigate its behavior under harmonic loading, as such junctions play a critical role in structural integrity during seismic events. A geometric scale of 1/4 is adopted for elevation dimensions in accordance with Method A of UBC-97, which relates the time period predominantly to the structural height. Wall segments of length 225 mm are provided on each side of the junction to ensure adequate representation of load transfer and realistic boundary effects. IPBs with dimensions of 62 x 62 mm, a height of 50 mm, and a 12 mm key are utilized due to their lightweight properties and energy absorption potential. Vertical reinforcement is introduced in the form of rubber bands to maintain junction stability during harmonic excitation. The testing is conducted on a low-cost, locally developed 1D shake table applying unidirectional harmonic loading, with simplified boundary conditions to allow accurate assessment of fundamental frequency, base shear, lateral displacement, and energy dissipation specific to the T-junction configuration.

1.5 Brief Methodology

This study employed an experimental approach to evaluate the dynamic behavior of a scaled T-junction wall assembly under controlled excitations. A reduced-scale T-junction wall model, constructed at a 1:4 geometric scale using IPBs, was

employed for experimental investigation. The prototype comprised 195 blocks arranged in 15 courses, anchored to the base using steel angle sections to ensure structural stability. Five accelerometers were strategically positioned to capture the dynamic response: two mounted at the crest of each orthogonal wall, one at the apex of the T-junction, one at the base of the T-junction, and one affixed to the base plate to record input excitation. Data acquisition was facilitated through an Arduino-based system interfaced with a laptop operating MATLAB software. A snap-back test was conducted by laterally displacing the wall in the X-direction using a 40 cm wire, subsequently releasing it to obtain the acceleration time history. This dataset was utilized to evaluate the fundamental period, natural frequency, and damping ratio via the logarithmic decrement method. Seismic excitation was simulated using a locally fabricated 1D shake table capable of operating at frequencies of 0.5 Hz, 1.0 Hz, and 1.5 Hz. Acceleration time histories, recorded in MATLAB, were processed in SeismoSignal software to perform baseline correction and noise filtering. Base shear was determined as the product of the specimens mass and the acceleration recorded at the T-junction apex, while energy absorption was derived from base shear displacement hysteresis curves, assuming the total mass to be lumped at the specimens top. Both the average energy dissipated per cycle and the cumulative absorbed energy were quantified. Empirical predictive equations were formulated considering the junction height, block geometry, and measured dynamic response. Comparison between experimental measurements and empirical predictions indicated agreement within acceptable error margins.

1.6 Research Impact on Industry

This research holds significant potential to revolutionize the construction industry by providing insights into the use of mortar-free IPBs. By addressing junction performance under seismic conditions, it bridges a critical knowledge gap, enabling the development of safer, more resilient structures. The modular design of these systems can streamline construction processes, reduce costs, and enhance project time-lines. Furthermore, the adaptability of these blocks to local materials and conditions ensures their relevance across diverse geographic regions. The research

outcomes could foster innovation in prefabrication techniques, influence building codes, and drive the adoption of sustainable practices in both commercial and residential projects.

1.6.1 Research Novelty and Uniqueness

This study uniquely examines the behavior of T-junctions in mortar-free IPBWs under harmonic loading an area with minimal prior investigation. Using a simple 1D shake table, it provides rare empirical evidence on structural response and energy dissipation, addressing a critical gap in sustainable seismic-resistant construction research.

1.6.2 Research Significance and Benefit

The findings advance understanding of modular construction systems, particularly in earthquake-prone areas. By addressing junction performance, the research supports safer and more cost-effective building practices.

1.6.3 Practical Implementation

The findings of this research offer a practical and sustainable alternative to conventional masonry and reinforced concrete systems, particularly suited for low-cost, earthquake-resistant housing in developing regions. The adoption of mortar-free IPB systems facilitates accessible, cost-effective, and time-efficient construction, supporting affordable housing initiatives and enabling rapid deployment in post-disaster scenarios through collaboration with disaster relief organizations. The modular design allows scalability and adaptability to varied geographic and climatic conditions, making it viable for both temporary shelters and permanent dwellings, while the use of lightweight, recyclable materials aligns with sustainable construction practices, reduces environmental impact, and advances long-term

strategies for resilient, inclusive, and environmentally responsible urban development.

1.6.4 National and Global Impact with Emphasis on SDGs Relevance

This research carries substantial national and global significance by advancing disaster resilience, enhancing public safety, and mitigating infrastructure losses. It catalyzes innovation within the construction sector, fosters economic growth through job creation, and enriches the national knowledge base via research-informed education and training initiatives. The introduction of modular, low-technology construction systems promotes inclusive participation, empowering local communities, including unskilled labor, and strengthening engagement in post-disaster recovery. Furthermore, the study provides evidence-based insights to inform policy formulation in disaster risk reduction, urban planning, and resilient infrastructure development, while its integration into academic curricula nurtures future professionals committed to sustainable and resilient practices. In alignment with the United Nations Sustainable Development Goals, particularly SDG 9 (Industry, Innovation, and Infrastructure) and SDG 11 (Sustainable Cities and Communities), the research addresses critical challenges in disaster-prone regions, contributing to both national development priorities and global sustainability objectives.

1.6.5 Research Challenges

The research encountered several challenges that may influence the scope and precision of the findings. Limitations included restricted access to advanced testing facilities, potential variability in material properties, and constraints in instrumentation accuracy, necessitating meticulous planning and resource optimization. The experimental setup, utilizing a 1D shake table with a limited number of accelerometers, inherently constrained the range of dynamic response data, while

the adoption of a fixed-base condition simplified boundary effects at the cost of reduced realism in structural behavior. Furthermore, accelerometer outputs required post-processing via SeismoSignal, yielding only acceleration histories without direct displacement or velocity measurements, thereby limiting the comprehensiveness of response characterization. These constraints may affect the ability to fully capture the dynamic behavior under complex loading scenarios. Future research could address these challenges through the deployment of multi-directional shake tables, an expanded sensor network, and the integration of advanced numerical simulations to validate experimental results and provide deeper insights into displacement and velocity response profiles.

1.6.6 Ethical and Management Considerations Including Risk Management

The study adheres to established ethical standards, ensuring transparency in data collection, analysis, and reporting. Risk management measures include contingency plans for equipment failure, strict safety protocols, and compliance with institutional health and safety regulations. A structured schedule supports timely execution, while ethical responsibility is upheld through fair collaborator compensation, inclusive stakeholder engagement, and sustainable resource use. By fostering community participation and ensuring accessibility of the developed technology for affordable housing, the research serves as a model of responsible, socially beneficial innovation.

1.6.7 Research Deliverables, Sale and Marketing Potential

The research is tailored for construction companies, affordable housing developers, and disaster relief organizations, highlighting practical benefits such as ease of construction, cost-effectiveness, and reduced building time. It offers a scalable solution for rapid and economical housing, especially in post-disaster and low-income contexts. The modular design and use of IPBs also provide flexibility,

enabling adaptation to various environmental conditions and community needs. Moreover, the approach supports local economies by utilizing region-specific materials and labor, promoting self-sufficiency and resilience. This research not only addresses immediate housing shortages but also sets the stage for long-term, sustainable housing solutions, improving quality of life for vulnerable populations. The research is oriented to produce cost effective and safe housing for under privileged people. Creating awareness among construction stake holders about the ease of construction, safety, cost-effectiveness and potential for reducing construction time. This research delivers high-impact publications, practical design guidelines, and industry-focused recommendations, with strong commercialization potential in modular construction for disaster-prone and low-income regions. The proposed IPB system offers scalability, adaptability to diverse environments, and benefits such as cost-efficiency, rapid construction, and ease of implementation, making it suitable for construction firms, affordable housing developers, and relief agencies. By utilizing locally sourced materials and labor, it supports economic resilience while addressing urgent housing needs and enabling sustainable, long-term solutions. Targeted dissemination will inform stakeholders of its safety, affordability, and time-saving advantages, facilitating market adoption.

1.7 Thesis Layout

This thesis is organized into six chapters as follows:

Chapter 1 introduces the study, covering the Prologue, research motivation, problem statement, overall objective, specific aims, scope of work, study limitations, methodology used, Research Impact on Industry and thesis outline.

Chapter 2 provides the literature review, discussing the prologue, earthquake damage to conventional masonry structures, a new approach for earthquake resistant construction, the impact of stiffeners on masonry structures, dynamic performance testing of prototype structures in the lab, and a summary.

Chapter 3 details the experimental program, including the prologue, techniques for constructing IPWs and unreinforced masonry walls with openings, test setup,

snap-back testing with instrumentation, harmonic load application using a shake table, analyzed parameters, empirical equation development, and a summary.

Chapter 4 presents the experimental evaluation, covering the prologue, results of the snap-back test, wall responses to harmonic loading, base shear calculations, damping ratio and energy absorption, and a summary.

Chapter 5 discusses the findings, addressing the prologue, relationships of empirical equations, practical implications, and a summary. Conclusion and Recommendations

Chapter 6 provides the conclusion and recommendations. The references follow this chapter, with annexures included at the end.

Chapter 2

Literature Review

2.1 Prologue

Earthquakes are significant natural hazards with life threatening consequences, predominantly impacting critical infrastructure such as buildings, bridges and roads. Among the structures most vulnerable to seismic activity are unreinforced masonry (URM) structures, which exhibit pronounced susceptibility to ground motion. Junction failures in URM structures are particularly critical during seismic events, as they represent structural weaknesses that can aggravate damage. The seismic vulnerability of masonry structures arises primarily from the inadequate bonding between blocks and mortar, coupled with the effects of strong ground motion. In the 2005 earthquake in Kashmir caused partial or total damage to more than 450,000 buildings [24], while the 2018 earthquake in Indonesia destroyed over several homes, primarily due to design deficiencies in masonry structures. Seismic events in South and Southeast Asia have revealed critical structural vulnerabilities, particularly in masonry and reinforced concrete buildings, due to deficiencies in material quality, design, and code enforcement. In Indonesia, the 2006 Yogyakarta earthquake destroyed over 200,000 houses, largely because of inadequate knowledge of earthquake-resistant design among local builders [25], while the generally low mechanical properties of Indonesian clay bricks further exacerbated structural fragility [26]. The vulnerability of unconfined masonry was

evident in the 2019 Pandeglang earthquake, which severely damaged the Bendung Village Head Office [27], and common weaknesses in reinforced concrete structures such as poor material quality, insufficient reinforcement, and inadequate detailing continue to undermine resilience [28]. Despite government initiatives to revise building codes and promote community-based reconstruction, insufficient enforcement has allowed structural deficiencies to persist in newly built facilities [25], [28]. Comparable shortcomings were also observed in the 2005 Kashmir earthquake, with a magnitude of 7.6, caused over 73,000 deaths, 128,000 injuries, and displaced 3.5 million people following the destruction or damage of more than 600,000 buildings [29],[30] [31]. Satellite analyses of the Uri and Punch regions in India revealed that around 25 percent of buildings were completely destroyed due to the earthquake [32], while landslides and rockfalls triggered by the seismic event further obstructed relief operations [31]. The economic losses, estimated at 5 billion US dollar [29], underscore the destructive potential of seismic-induced accelerations, which transfer through foundations and induce inertia-driven shear failures in masonry systems. Collectively, these events highlight the urgent necessity of strengthening building codes, enhancing material standards, and enforcing earthquake-resistant construction practices to reduce seismic risk in future disasters.

The development of earthquake-resistant and cost-effective housing is a critical need for earthquake-prone regions in developing countries. The lack of advanced seismic-resistant construction techniques in these areas often results in extensive structural damage and significant social and economic losses during seismic events. However, research indicates that various earthquake-resistant construction methods have been implemented to address these challenges. Examples include the incorporation of plinth and lintel beams, as well as vertical stiffeners, to enhance the seismic performance of masonry structures. Ali proposed a mortar-free interlocking block system as an innovative approach for earthquake-resistant housing, emphasizing its capacity to effectively dissipate seismic energy [13]. Despite this, the mass of coconut fiber-reinforced concrete (CFRC) blocks presents a challenge, as lighter structures typically produce lower inertial forces. Nevertheless, CFRC

has shown significant promise in seismic engineering, with Alis design of an interlocking block system incorporating CFRC exhibiting efficient energy absorption during seismic events, while maintaining the integrity of both the blocks and their connecting ropes [33]. Similarly, semi-interlocking masonry (SIM), a mortar-less system allowing in-plane sliding while preventing out-of-plane movement, was reviewed by Totoev and Harthy [34]. Wang and Chow found that CFRC cylinders absorbed more impact energy and exhibited smaller cracks compared to plain concrete, indicating improved ductility [35]. Thanushan et al. reported that coconut fiber reinforcement in earth cement blocks enhanced residual strength, ductility, and energy absorption, in addition to improving durability against alkaline and acid attacks, as well as freeze-thaw and wet-dry cycles [36]. Collectively, these studies highlight the potential of CFRC in developing earthquake-resistant and durable construction materials. Furthermore, natural fibers such as coconut and jute have shown promise in reinforcing concrete by enhancing tensile strength, flexural properties, and crack resistance [37], [38]. In particular, optimal dosages of coconut fiber reinforcement were found to improve the balance between strength and toughness [38]. Moreover, coconut coir used as fiber reinforcement and partial sand replacement in concrete hollow blocks improved durability while meeting ASTM C-129 standards for non-load-bearing CMUs [39]. Overall, coconut fiber presents itself as a sustainable, cost-effective, and eco-friendly reinforcement option, supporting green construction practices and sustainable development goals, while lightweight interlocking plastic blocks offer an additional viable alternative for reducing structural mass in earthquake-resistant construction. Research on low-cost shake tables has highlighted their significance as practical and affordable tools for analyzing the dynamic behavior of structures under seismic loading in laboratory environments.

Baran et al. [40] demonstrated that simple one-dimensional (1D) shake tables are particularly effective for simulating prototype structural responses, offering an accessible alternative to expensive large-scale testing facilities. Similarly, Darshita and Anoop emphasized their educational and research potential, particularly in developing regions, where resources are limited [41]. Advancements in this domain

include the development of medium-sized uniaxial tables capable of testing three-dimensional models, as reported by Malathy et al. [42], as well as open-source solutions such as Shakebot, which integrates robotic mechanisms and cost-efficient components, as presented by Chen et al. [43]. These innovations have expanded the capability of low-cost shake tables, enabling them to achieve considerable horizontal accelerations and velocities, thereby facilitating diverse experimental studies, including investigations on precariously balanced rocks [43]. The affordability, adaptability, and accessibility of such systems significantly enhance the scope of earthquake engineering research and education worldwide [41], [43].

2.2 Seismic Vulnerabilities of Unreinforced Masonry Walls at Junctions

Interlocking block systems are increasingly recognized in seismic construction for their advantages of improved structural stability and cost-effectiveness, utilizing blocks made from compressed earth, concrete, or stabilized soil that interlock without mortar. Anand and Ramamurthy highlighted that interlocking block masonry demonstrates superior efficiency and greater flexural capacity compared to conventional mortar-bedded masonry, with its performance influenced by block geometry and applied loading conditions [44]. Furthermore, Nayak and Dutta investigated cost-effective retrofitting strategies for unreinforced masonry (URM) structures, showing that horizontal dowel bars, polypropylene bands, and steel wire mesh significantly improve structural integrity at vulnerable junctions [3]. Such reinforcement techniques are particularly promising for affordable seismic strengthening, making them highly suitable for application in developing regions.

Unreinforced masonry (URM) structures exhibit significant seismic vulnerability, with junctions identified as critical points of failure. The absence of adequate connections at masonry junctions has been reported as a primary cause of structural damage during moderate earthquakes [45]. Reinforcement using L-shaped steel dowels or polypropylene bands has been shown to substantially improve the lateral

strength of these junctions [45]. In Pakistan, rapid visual screening of buildings in Mingora City revealed that over 90 percent of the structures fall within severe damage categories, underscoring the urgent need for retrofitting measures and greater public awareness [46]. Numerical modeling studies have further demonstrated diverse failure mechanisms in URM walls, including rocking, sliding, and diagonal cracking, depending on axial loading conditions [47]. Additionally, the assessment of out-of-plane collapse mechanisms, particularly in relation to connections with transversal walls, has been emphasized as a critical aspect of seismic vulnerability evaluation [48]. Recent seismic events, such as the Kahramanmara earthquakes of February 2023, highlighted the widespread failure of masonry wall junctions, primarily due to poor interlocking and insufficient reinforcement, leading to out-of-plane collapse and subsequent structural failure under strong ground motions [49]. These findings reinforce the necessity of incorporating junction performance into seismic design guidelines and stress the importance of developing targeted retrofitting strategies for URM structures in earthquake-prone regions.

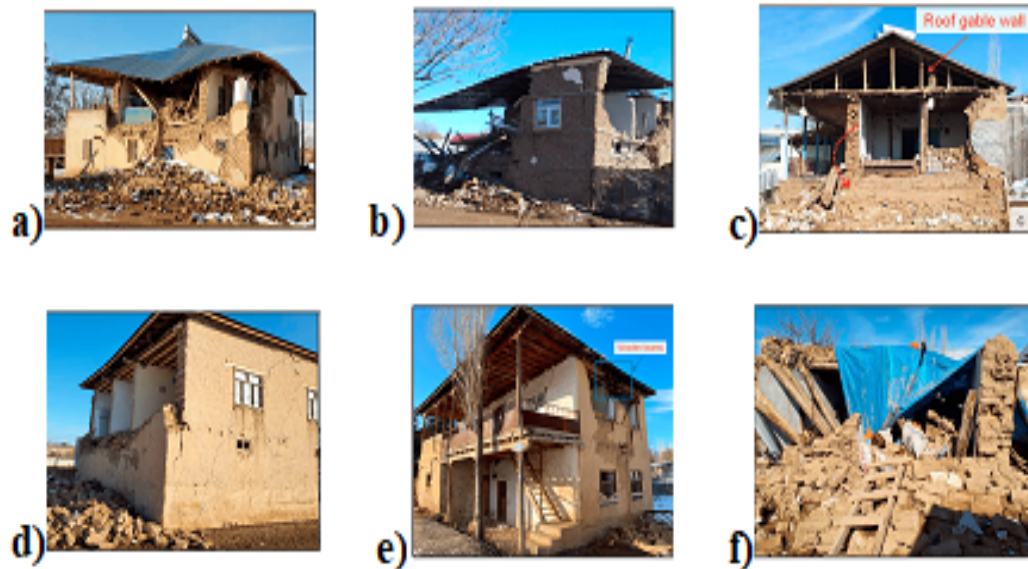


FIGURE 2.1: Structural damage in adobe buildings with different wall materials a) and b) adobe-rubble stone, c) adobe-briquette with roof failure, d) adobe-rubble stone, e) adobe-brick damage, f) adobe-rubble stone collapse. [49].

The development of resilient masonry systems has become a critical research focus in earthquake-prone regions, where conventional unreinforced construction often exhibits severe structural deficiencies under seismic loading. Lan et al. proposed an innovative interlocking compressed-earth block (ICEB) composite wall system

that integrates stabilized ICEBs with reinforced concrete core columns and lateral strengthening strips, aiming to enhance seismic resilience in masonry construction [50]. Experimental testing of nine scaled walls under low-frequency cyclic loading provided valuable insights into failure mechanisms, hysteretic behavior, stiffness degradation, and energy dissipation, demonstrating that the inclusion of core columns and strengthening strips substantially improves seismic performance. Moreover, past seismic events have underscored the importance of reinforcement at masonry junctions; for instance, the 2005 Kashmir earthquake revealed widespread junction failures where the absence of reinforcement led to out-of-plane wall collapses, even under moderate seismic excitations [3]. These findings highlight the necessity of incorporating reinforced junctions into masonry construction to mitigate structural vulnerabilities and ensure greater earthquake resistance.

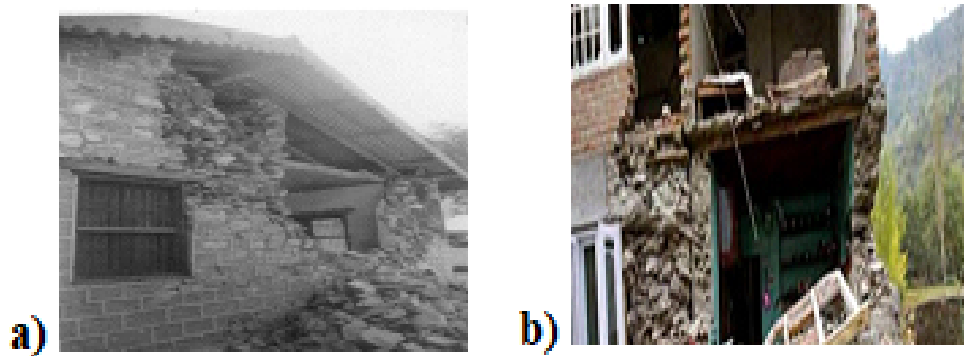


FIGURE 2.2: Junction failure during the Kashmir earthquake a) displaced masonry at t-junction, b) structural collapse at t-junction [3].

Advancements in interlocking masonry technologies have increasingly focused on enhancing structural performance without reliance on mortar, particularly for applications in seismic regions. Shi et al. investigated the compressive behavior of interlocking bricks with large shear keys, revealing that an increased number of blocks significantly enhances compressive strength, while surface roughness and material strength strongly influence stress distribution and failure mechanisms, providing critical insights for the design of mortar-less structures [51]. Complementing this, Xie et al. examined reinforced mortar-less interlocking brick walls under cyclic loading, demonstrating superior deformation capacity and strength retention after cracking, with numerical modeling further validating their effectiveness in energy dissipation and displacement control compared to conventional

masonry [52]. Experimental shake table studies also confirmed that the integration of dowel bars, bands, mesh, and interlocking blocks substantially improves structural integrity and energy dissipation, offering a cost-efficient strategy for seismic retrofitting. Collectively, these findings emphasize that interlocking block systems outperform traditional masonry in seismic contexts, making them highly suitable for earthquake-prone regions.

The seismic performance of heritage and traditional masonry structures has long been a subject of concern, particularly due to their inherent weaknesses at critical junctions and connections. Shariq et al. performed finite element analysis on the Jama Masjid, a heritage masonry structure in Aligarh, and identified critical stress concentrations at dome-wall junctions, wall-roof junctions, and minarets, with stresses exceeding permissible limits under seismic loading in both the X and Z directions, thereby underscoring the structural vulnerabilities at these locations [53]. Similarly, post-earthquake damage surveys in the Eastern Himalayas and plains regions of India attributed the failure of unreinforced masonry walls primarily to inadequate connections at masonry junctions [45]. These studies collectively highlight the necessity of strengthening junctions to mitigate seismic vulnerabilities and improve the resilience and safety of masonry structures during earthquake events.

2.3 Interlocking Block Mechanism for Wall Junctions

Wall junctions in masonry structures represent critical points of weakness under seismic loading, necessitating innovative interlocking block mechanisms to enhance strength and ductility. Baneshi et al. investigated the in-plane behavior of interlocking blocks incorporating adhesive paste, grout, and steel rebar, reporting that adhesive paste substantially increased compressive strength relative to mortar, with further improvements in both strength and ductility when combined with grout and rebar, thereby reducing brittleness and enhancing performance under

extreme loading conditions [54]. Similarly, Moshfeghi et al. analyzed out-of-plane (OOP) collapse mechanisms in masonry structures during earthquakes, demonstrating through shake table tests that strengthening methods such as carbon strips and helical bars significantly improved wall resistance and mitigated seismic damage [55]. Addressing vulnerabilities in rural construction, Guojue et al. highlighted that the absence of reinforced concrete columns and beams in Chinese rural masonry buildings contributes to seismic fragility, proposing precast concrete interlocking blocks as a cost-effective solution, with experimental and numerical evidence confirming their superior seismic performance [56]. Figure 2 illustrates fabricated columns positioned at various wall intersections, emphasizing their role in improving structural integrity.

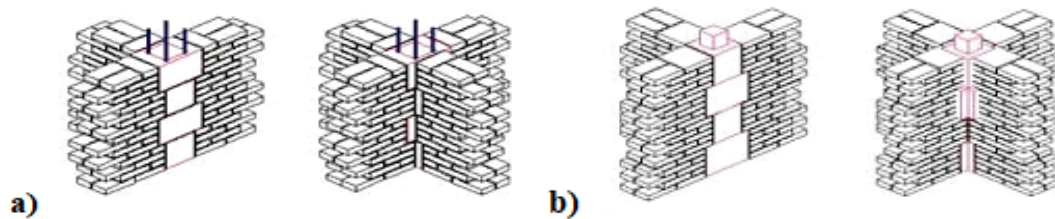


FIGURE 2.3: a) Fabricated column with vertical reinforcement at wall junction, b) fabricated column with core reinforcement at wall junction [56].

Interlocking block masonry systems have increasingly gained attention in recent years as viable alternatives to conventional masonry, owing to their potential for enhanced seismic resilience, construction efficiency, and sustainability. Xie et al. investigated mortar-less interlocking brick walls under quasi-static in-plane cyclic loading through detailed numerical modeling, revealing that while these walls exhibit high energy dissipation and deformation capacity, their performance is influenced by reinforcement placement and design parameters [57]. Further work by Xie et al. demonstrated that interlocking brick walls with large keys provide superior seismic resistance and energy dissipation compared to conventional masonry, with predictive equations for cyclic loading resistance developed through numerical simulations [52]. Tang et al. examined the residual compressive and shear strengths of coconut fiber reinforced concrete (CFRC) interlocking blocks, showing improvements of up to 3.2% in compressive strength and 5.7% in in-plane shear strength after dynamic loading, highlighting CFRCs potential in seismic applications [58].

Similarly, Sanada et al. reported that interlocking masonry units enhance the ductility and strength of unreinforced masonry (URM) walls, outperforming conventional systems [59]. The interlocking block approach also improves construction efficiency by eliminating mortar, enabling faster wall assembly with less skilled labor while allowing structural flexibility for elements such as buttresses and T-junctions [60]. Recent research on self-interlocking blocks has shown potential for cost reduction, increased construction speed, and improved seismic performance in wall junctions [61]. However, while interlocking masonry offers comparable in-plane load capacity to traditional systems, its out-of-plane resistance is reduced by approximately 20% [62]. To address performance and sustainability, porous interlocking assembly methods have been proposed to enhance thermal efficiency and reduce material consumption without compromising structural integrity [63]. Moreover, load-bearing horizontal-hole interlocking concrete blocks (LHIC) have been shown to significantly improve bricklaying efficiency and reduce mortar usage, with experimental evidence indicating that incorporating reinforced concrete tie columns, horizontal steel reinforcement, greater vertical compressive stress, and stronger mortar substantially increases seismic resilience, lateral resistance, and crack propagation control [64]. Collectively, these advancements underscore the potential of interlocking block technologies as sustainable, efficient, and structurally robust solutions for modern construction in seismic-prone regions.

2.3.1 Advancements in Seismic-resilient Interlocking Plastic Block Assemblies

Recent studies have highlighted the potential of interlocking plastic blocks in construction, particularly in earthquake-prone regions, due to their affordability, seismic resistance, and sustainability. Adnan et al. reported that two-block-wide interlocking plastic block elements exhibit higher compressive resistance compared to single-block-wide elements [14], while Kumi-Larbi Jnr et al. demonstrated that plastic-bonded sand interlocking blocks fabricated from waste polyethylene achieve greater compressive strength than conventional sandcrete blocks [65]. Similarly, self-interlocking blocks have been shown to enable mortar-free construction,

thereby reducing costs and improving efficiency [61]. Further advancements include interlocking blocks produced from waste plastics and industrial byproducts, with studies revealing that a 20:80 ratio of plastic to waste materials provides adequate compressive strength for partition walls, alongside enhanced fire resistance [66]. Collectively, these innovations underscore the promise of interlocking plastic block technology as a sustainable, low-cost, and earthquake-resistant alternative for modern construction practices.

2.4 Junction Performance in Mortar-free Interlocking Block Construction

The performance of junctions in mortar-free interlocking block construction is critical to ensuring structural stability and safety, particularly under dynamic loading such as seismic events. Baneshi et al. carried out an extensive experimental investigation on interlocking masonry blocks manufactured using 3D-printed molds, evaluating multiple block geometries including trapezoidal, Lego, cross, and checkered shapes alongside a standard control block. Their results demonstrated that block geometry significantly influences structural performance under varying loading conditions, emphasizing the importance of optimizing block shape to improve junction behavior and overall resilience of interlocking block systems during dynamic excitation [54].

Recent research has investigated the performance of mortar-free interlocking block construction in masonry structures, emphasizing their seismic response and structural efficiency. Experimental and numerical studies have shown that interlocking brick walls exhibit a rocking response under seismic loading, with damage concentrated at the bottom corners, while achieving greater seismic resistance than conventional masonry [67]. Reinforced mortarless masonry panels further demonstrate improved axial compression behavior when grouted, with block type influencing compression capacities [68]. Although interlocking masonry offers performance comparable to traditional masonry under in-plane loads, its resistance

to out-of-plane loads is reduced by approximately 20% due to the absence of mortar in horizontal joints; however, this system provides economic advantages, with construction costs reduced by up to 20% [69]. Junction performance has been identified as a critical factor, as stability relies on mechanical interlocking rather than mortar, making precision in construction and interlock design essential; misalignment or weak mechanisms can compromise structural integrity. Complementary studies on seismic performance highlight that unconfined dry-stacked masonry with self-interlocking blocks provides effective energy dissipation under low-to-moderate seismic actions [70], while confined cellular lightweight concrete block masonry walls exhibit enhanced lateral load capacity, stiffness, and ductility compared to unreinforced walls [71]. The slender rigid block model has been advanced as a framework for analyzing seismic behavior and dynamic collapse mechanisms in masonry structures [72]. Additionally, a comprehensive review of confined masonry systems reinforced their suitability for earthquake-prone areas while underscoring the need for deeper investigation into their seismic performance and failure mechanisms [73]. Collectively, these studies highlight the importance of junction integrity for resilience, while also identifying research gaps concerning the seismic behavior of interlocking block junctions under dynamic loading. Experimental findings indicate that junction enhancement requires advanced interlocking designs, precise construction methods, and reinforcements such as steel bars or fibers to improve load distribution, reduce block displacement, and enhance seismic resilience, though the effectiveness of these strategies varies across block systems and seismic conditions. Emerging research further suggests that integrating hybrid reinforcement strategies, such as combining steel confinement with fiber-reinforced polymers, can significantly enhance both in-plane and out-of-plane performance of interlocking masonry. Moreover, the development of predictive numerical models calibrated against large-scale experimental results remains an essential step toward establishing reliable seismic design guidelines for mortar-free interlocking block systems. Recent evaluations show that optimized interlocking geometries improve force transfer and enhance reliability under cyclic loading. Advances in material processing have also produced higher-density composites with improved stiffness. Together, these developments further support the adoption of

interlocking plastic blocks as a resilient and efficient construction option.

TABLE 2.1: Structural and seismic performance of block types

Ref.	Block Type	Methodology	Key Findings and Gaps
Sudheer and Ali [15]	IPB	Unidirectional lateral load tests	Higher resistance with window; limited to small-scale models, needs full-scale validation.
Adnan et al. [14]	IPB	Static Compression and Lateral Loading Tests	Two-block-wide elements performed better; lacks dynamic testing and material variability.
Gul et al. [70]	Dry-Stack Masonry (Hydraform)	Quasi-static Reverse Cyclic Loading Tests	Effective for low seismic forces; lacks material variation and high-seismic area testing.
Ali et al. [74]	CFRC Blocks	Monotonic Loading Tests	High capacity, cost-effective; no large-scale field testing.
Nayak & Dutta [3]	URM Walls	Shake Table Tests	Effective low-cost strengthening; small-scale, requires field validation.

2.5 Structural, Economic and Sustainable Perspectives of Interlocking Masonry

Interlocking block technology represents a mortar-less construction system that employs grooves and protrusions to ensure structural stability without reliance on cementitious materials [75]. This method simplifies construction processes while offering notable economic and environmental benefits, with reported savings of up to 50% in both material costs and cement consumption, alongside a 40% reduction in carbon emissions [76]. Design innovations, such as center-half bat and

tee-shaped bricks, have expanded the versatility of construction by enabling varied wall thicknesses and curved layouts [76]. Precision is ensured through tolerance limits of 0.5 mm for plain surfaces and 0.9 mm for grooved surfaces, which contribute to accurate alignment and reliable assembly [76]. Structural studies confirm the adequacy of hollow interlocking block systems for load-bearing purposes, with analytical models validating their performance under diverse loading and slenderness conditions [77]. More recent research has emphasized the seismic resilience of interlocking masonry, with scaled experiments and numerical simulations examining hysteretic response, energy dissipation, and failure mechanisms [50], [52]. The integration of digital design tools has further expanded applications, including the development of porous interlocking blocks for improved thermal efficiency [63] and homogenization-based techniques for predicting dynamic response [78]. Parallel work in sustainable development shows that interlocking systems made from compressed earth, recycled concrete rubble, and agricultural waste offer viable, resource-efficient alternatives [62]. Together, these developments position interlocking masonry as a structurally reliable, cost-effective, and environmentally sustainable construction method.

Using recycled plastics in construction helps address global waste while promoting sustainable infrastructure. Thermoplastics are highly recyclable due to their reversible nature, though durability and heat resistance remain concerns [79]. Recycled plastics are frequently used as partial replacements for natural aggregates in cementitious composites, where controlled additions of 220% preserve acceptable strength performance [80]. Beyond structural considerations, the inclusion of plastics has been shown to enhance thermal insulation, acoustic performance, and ductility, while thermoset plastics offer rigidity and chemical resistance for non-structural applications [81]. Melt-processed thermoplastics can also function as binder materials, contributing to reduced water absorption and improved flexibility in composites [81]. Related studies highlight the viability of direct recycling methods like mechanical extrusion, showing that HDPE and polypropylene wastes can achieve sufficient tensile and shear strength for structural products such as re-bars and blocks [82]. Overall, these methods demonstrate that recycled plastics

can reduce environmental impact while improving construction material efficiency [83].

2.6 Literatures Summary

Chapter 2 reviews the seismic vulnerabilities of URM structures, emphasizing junction failures as critical weaknesses during earthquakes. Past seismic events, such as the 2005 Kashmir and 2006 Yogyakarta earthquakes, highlighted issues like inadequate bonding, poor material quality, and insufficient code enforcement, leading to significant social and economic losses. To address these, various seismic-resistant strategies, including plinth and lintel beams, vertical stiffeners, and mortar-free interlocking systems, have been investigated. CFRC and natural fiber composites have shown potential in enhancing ductility, durability, and energy absorption while supporting cost-effective construction. Interlocking block systems made from concrete, earth, or plastic waste offer improved structural efficiency and seismic resilience, though out-of-plane resistance remains a challenge. Previous Experimental and numerical studies show that junction performance is crucial, with reinforcements like dowels, meshes, and optimized interlocking geometries improving stability and energy dissipation. Additionally, low-cost shake tables have broadened research and educational opportunities in earthquake engineering. The review underscores the importance of sustainable, affordable, and resilient construction solutions, with interlocking block technologies and fiber-reinforced materials as promising alternatives for earthquake-resistant housing in developing regions.

Chapter 3

Experimental Program

3.1 Prologue

Experimental investigation is a fundamental aspect of structural engineering research. Accurate prediction of structural behavior under seismic loading is essential for the design and safety of structures in earthquake-prone areas. To achieve this, comprehensive dynamic testing of prototype structures in laboratory settings is widely employed. This chapter presents the construction methodology for interlocking T-junctions using plastic block walls, outlining the experimental setup, instrumentation used for snap-back testing, the application of dynamic loads via a shake table, the assessment of key response parameters, and the development of empirical equations to predict structural performance under seismic conditions.

3.2 Research Extension

The enhancement of structural resilience to earthquakes is a key focus in modern engineering, emphasizing innovative materials and construction techniques. Khan and Ali [11] explored interlocking plastic-block systems for earthquake-resistant housing, noting their lightweight nature reduces inertia forces and improves seismic performance. Lighter materials, like plastic blocks, lessen seismic-induced stresses

on structures, enhancing stability. The interlocking design strengthens integration, dissipates energy under cyclic loading, and supports cost-effective construction. Using recycled plastics reduces environmental impact and handling demands. The proposed blocks measure 150 mm x 150 mm x 140 mm, while prototype models for testing are 62 mm x 62 mm x 50 mm. This research builds on Khan [16] work, examining the dynamic response of mortar-free IPB walls, advancing earthquake-resistant housing through improved resilience, efficiency, and sustainability. The study does not investigate specific plastic types or their material properties, as such analysis falls beyond the defined scope of this research.

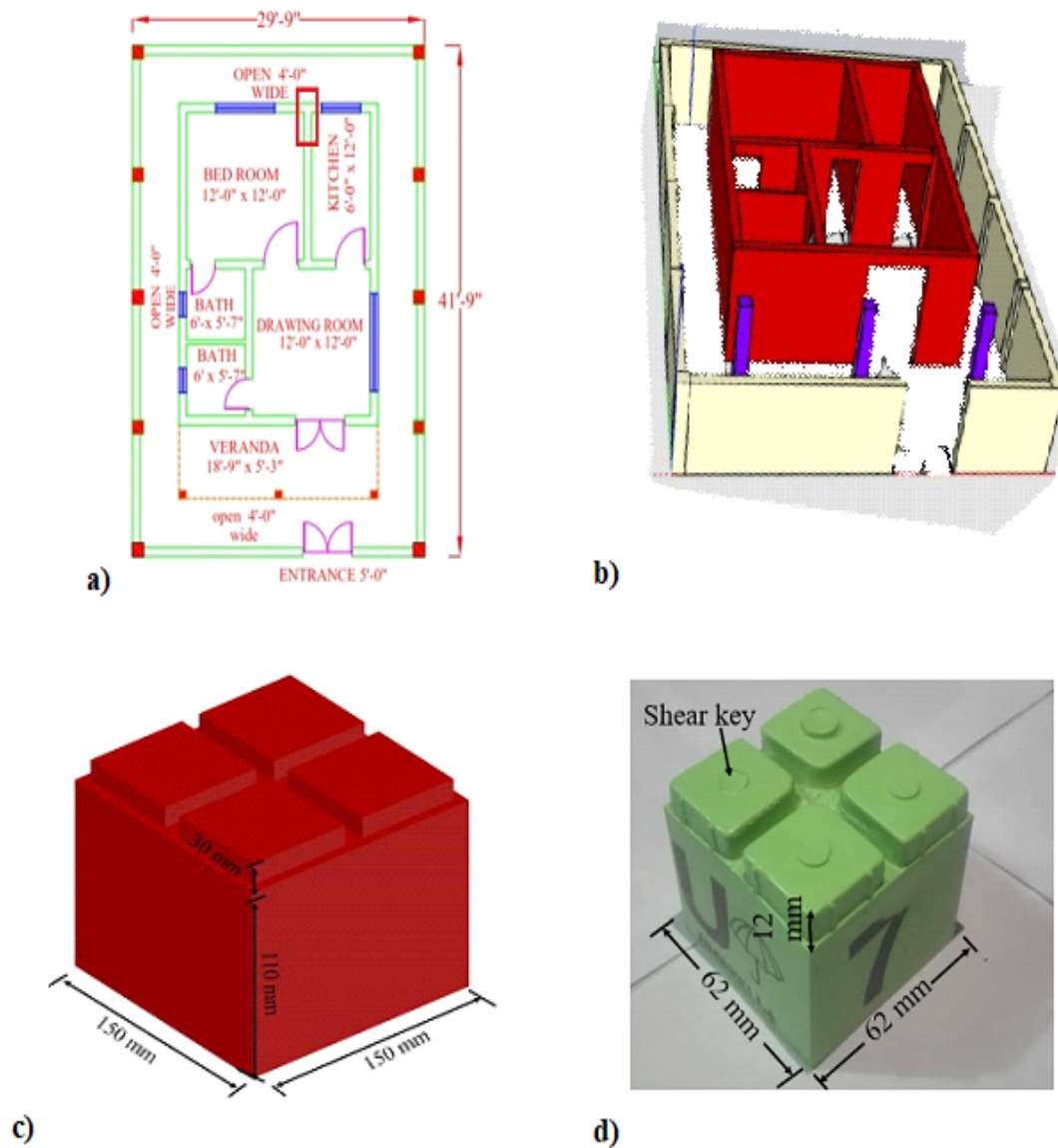


FIGURE 3.1: The figure illustrates a) floor plan of a IPB house layout with room dimensions, b) 3D model of the structure, c) real red modular block d), prototype green modular block with shear key [11].

Experimental validation through prototype testing serves as a fundamental step in bridging the gap between theoretical analysis and practical implementation in structural engineering. Prototype testing provides specifications for practical applications, as opposed to theoretical models, facilitating the evaluation of real or proposed systems. The scaling and construction techniques employed here align with established research practices documented in the literature [84], [85], [86], helping elucidate the behavior of full-scale structures. Researches show different scale used for the study of prototype of structure. Colombo et al. [87] carried experimental, numerical and analytical investigations of masonry using 1:4 scale. Ahmad et al. [88] used 1:3 scaled down structure for study confined masonry and semi-confined masonry. Sudheer and Ali [15] used 1/10 scale for studying the behavior wall with window. For current investigation 1/4 scale is used. Currently the specimen reduced to 1/4 scale depending upon the shake table limitation. The primary objective of this study is to investigate the Behavior of Mortar-Free IPBW's at Junctions Under Harmonic Loading. Structural time period, a key parameter for such analyses, depends significantly on the height of the structure (UBC-97); thus, elevation dimensions in this study are scaled to maintain proportionality with the full-scale model. While minor differences exist in the dimensions of the scaled wall prototypes at T-junction, the elevation dimensions are approximately consistent across both models, as depicted in Figure 3.2. This research specifically focuses on analyzing mortar-free IPB walls at junctions, leveraging the insights gained from prototype studies. Such studies aim to refine design and construction practices, improving structural performance under dynamic loading conditions.

The findings contribute to advancing the application of IPB technology in earthquake resistant housing solutions. The present study investigates the structural behavior of mortar-free IPB walls at T-junctions subjected to harmonic loading, with particular emphasis on the time period of the structure, a fundamental parameter governed by the height of the wall as specified in UBC-97. To address this, a scale-down modeling approach was adopted for the elevation dimensions, whereby the wall, originally 900 mm in length from the T-junction centerline and 3000 mm in height, was represented at a reduced scale of 225 mm length and

750 mm height, with bottom fixity provided to simulate realistic boundary conditions. The units used in the scaled model exhibited slight dimensional variations compared to the full-scale prototype, yet effectively captured the essential geometric and structural characteristics of the T-junction. The original plan and elevation with T-junction are presented in Figure 3.2(a), while the corresponding scaled-down boundary conditions and wall configurations (Sequences A and B) are illustrated in Figures 3.2(b) and 3.2(c). For stability, the T-junction was anchored to a steel base plate using angle sections. The analysis was conducted in the x-direction, with the assumption based on symmetry that the structural response in the y-direction would remain comparable, thereby enabling a focused and controlled evaluation of the junctions dynamic behavior under harmonic excitation.

3.3 Construction of Scaled-Down T-Junction Prototype IPB Walls

This study investigates a scaled prototype of a T-junction wall system to assess the effects of vertical pre-tensioning on structural performance. Although reduced to one-fourth the height of an actual wall, the model accurately replicates real-world behavior, especially under bending forces commonly encountered in construction. Vertical pre-tensioning is simulated using rubber bands threaded through the center of the blocks to enhance stability and minimize deformation. The model consists of 195 plastic blocks, scaled down by a factor of 4 and arranged into 15 layers, resulting in a total height of 750 mm. Simplified boundary conditions are applied, following the methodology of Ali et al. [13]. Two construction sequences are employed: in Sequence A, Wall I bends outward from the T-junction, while in Sequence B, Wall II experiences symmetrical out-of-plane movement originating from the junction. To strengthen the wall, four rubber bands are used as vertical stiffeners one at the junction and three at the wall ends ensuring consistent tension along the wall height. Figure 3.3 shows the scaled prototype T-junction wall constructed with IPB, showing vertical pre-tensioning through rubber bands and

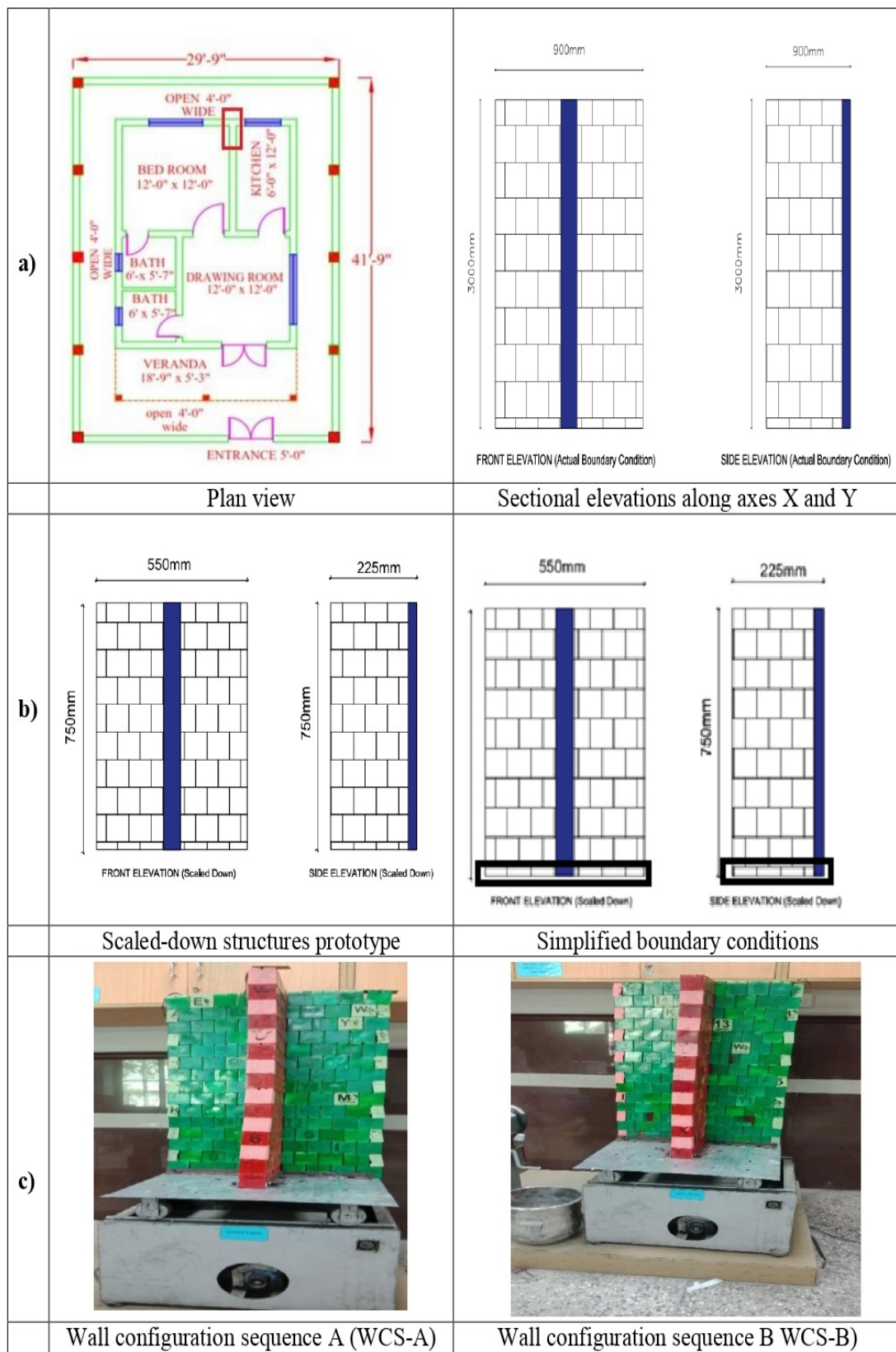


FIGURE 3.2: Representation of the T-junction; (a) plan and elevation of the house illustrating the original T-junction configuration, (b) scaled and idealized boundary conditions, and (c) T-junction incorporating wall configuration sequences A and B.

<p>a)</p>	<p>Schematic diagram of the T-junction.</p>		<p>WCS-A</p>
	<p>Real view of the T-junction.</p>		
<p>b)</p>	<p>Schematic diagram of the T-junction...</p>		<p>WCS-B</p>
	<p>Real view of the T-junction.</p>		

FIGURE 3.3: (a) WCS-A Schematic diagram and Real view of the T-junction
 (b) WCS-B Schematic diagram and Real view of the T-junction

color block arrangement. The structure is mounted on a shake table using nuts, bolts, and angle connectors to simulate realistic seismic conditions.

The prototype structure is securely mounted on a shake table to ensure uniform dynamic excitation during testing. No extra mass is applied to the top of the T-junction, and the total mass of the jointed section is measured at 4.68 kg. To enhance the stability of the T-junction and reduce the risk of collapse under motion, four rubber-band stiffeners are strategically installed one at the junction and the remaining three distributed across the two connecting walls, with each wall containing at least one vertical reinforcement. This reinforcement setup is intended to replicate real-world structural conditions and responses. Two distinct

wall configurations are tested to evaluate the system's behavior under varying load orientations and dynamic conditions.

The T-joint in the IPB wall system is laterally secured to a shake table using nuts, bolts, and angled connectors, enabling realistic replication of field conditions and ensuring controlled dynamic testing. The experimental analysis is limited to one direction specifically, the X-direction as the Y-direction is considered structurally equivalent due to the symmetry of the configuration. This study aims to generate meaningful insights into the seismic resilience and structural performance of IPB systems, ultimately supporting the advancement of more robust and safer construction techniques utilizing such modular materials.

3.4 Test Setup

3.4.1 Snap Back Test and Instrumentation

The snap-back test, illustrated in Figure 3.4, was utilized to evaluate the dynamic response of the IPB T-junction wall under free vibration. A 400 mm wire was attached to the top of the T-junction to induce controlled displacements, and an accelerometer was mounted at the same location to record the acceleration-time history of the structural response. Testing was conducted with two wall configurations, Sequence A and Sequence B, using lateral displacements of 2.5 cm and 5.0 cm in the X-direction, while the Y-direction was excluded from analysis due to assumed symmetry. Upon displacement, the wall was released to oscillate freely, simulating dynamic excitation. Figures 3.4(a) and 3.4(b) offer a schematic overview of the experimental setup and methodology used to assess the seismic performance and vibration control potential of the IPB T-junction walls.

The recorded acceleration data were processed using the logarithmic decrement method to derive key dynamic parameters, such as the damping ratio (ζ) and the fundamental frequency (f_n). These parameters were calculated based on the number of oscillation cycles and their respective maximum accelerations, providing insight into the system's energy dissipation and natural vibration tendencies.

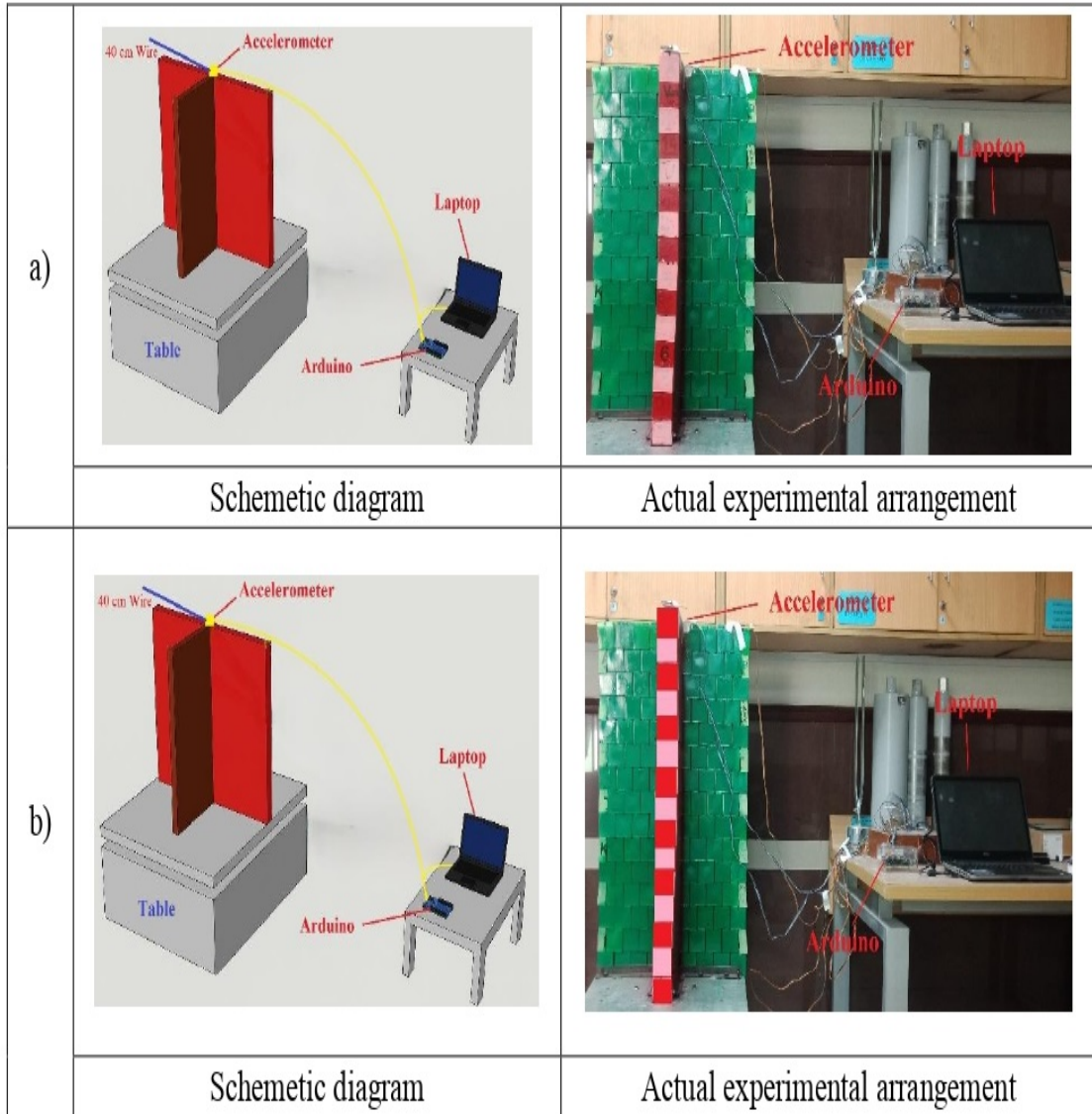


FIGURE 3.4: Instrumentation and setup for the snapback test, illustrating the schematic diagram and actual experimental arrangement for (a) Wall configuration sequence A and (b) Wall configuration sequence B.

The damping ratio was determined using Equation (3.1), which incorporates the maximum amplitude values from each cycle. The fundamental frequency is crucial for evaluating the risk of resonance with seismic excitations, as a match between the structure’s natural frequency and the predominant frequency of an earthquake can amplify structural vibrations, increasing the potential for failure.

$$\zeta = \frac{1}{2\pi N} \ln \left(\frac{x_0}{x_1} \right) \times 100 \quad (3.1)$$

Where x_0 and x_1 represent the acceleration amplitudes of the first and last cycles, respectively, and N represents the total number of cycles considered. The fundamental frequency, which characterizes the natural vibration frequency of the structure, plays a critical role in seismic performance assessment. When the fundamental frequency of a structure aligns with or is near the predominant seismic frequencies, resonance may occur, significantly amplifying vibrations and enhancing the risk of structural failure. Therefore, in earthquake-resistant design, it is crucial to ensure that the fundamental frequency is sufficiently separated from the dominant seismic frequencies to minimize resonance risks and enhance overall structural safety.

3.4.2 Shake Table Test Setup and Instrumentation

To evaluate the seismic performance of IPB T-junctions, a well-instrumented shake table setup was developed as shown in Figure 3.5, the instrumentation comprises (a) a schematic diagram and (b) the corresponding experimental test arrangement. The T-junction specimen was securely mounted on the shake table using angle sections and nut-and-bolt connections to ensure stability and prevent slippage under dynamic excitation. A total of five accelerometers were employed to capture the structural response at critical locations. One accelerometer was installed at the base of the shake table to record ground excitation, Two accelerometers were installed at the top of each IP and OOP wall to monitor their individual contributions to the junction behavior and to identify potential failure mechanisms, one accelerometer was mounted at the top of the T-junction and one at the bottom of the T-joint to record relative motion and deformation between critical regions, thereby providing a reference for evaluating the system response.

The structural response of the T-junction was primarily assessed through acceleration time histories recorded by the accelerometers. These raw data were processed using SeismoSignal software to obtain velocity-time and displacement-time histories, enabling a detailed evaluation of the junctions dynamic characteristics. Such processed records provide valuable insights into displacement demand, energy dissipation, and stiffness degradation of the IPB T-junction under repeated loading.

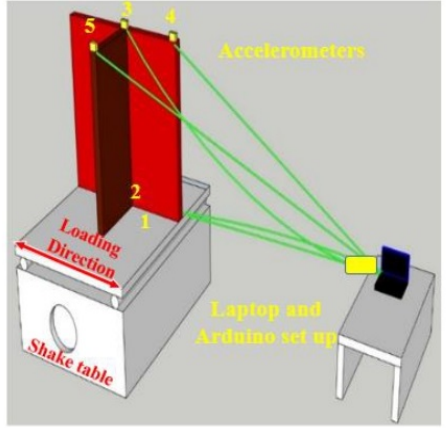
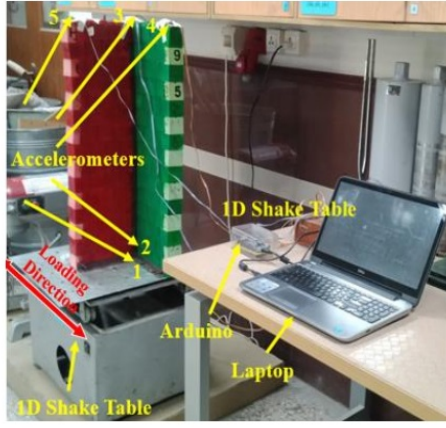
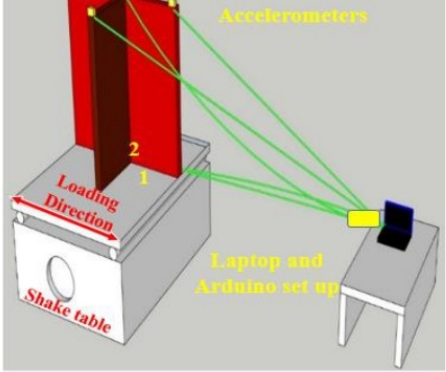
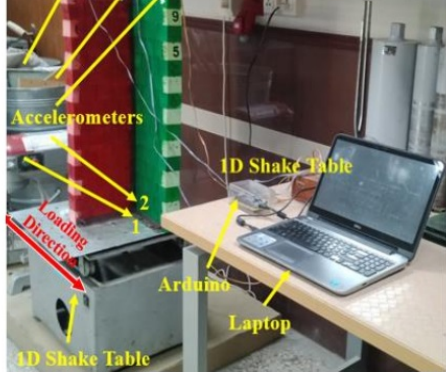
<p>a)</p>		
	<p>Schematic diagram</p>	<p>Actual experimental arrangement</p>
<p>b)</p>		
	<p>Schematic diagram</p>	<p>Actual experimental arrangement</p>

FIGURE 3.5: Instrumentation and setup for shake table testing, showing the schematic diagram and actual experimental arrangement for (a) Wall configuration Sequence A and (b) Wall configuration sequence B.

The experimental setup not only captured the global seismic response of the structure but also revealed the influence of localized interlocking mechanisms at critical interfaces, which are essential in enhancing structural stability.

3.5 Dynamic Loading

3.5.1 Snap Back

The snap-back test was conducted to evaluate the free vibration characteristics of mortar-free IPB T-junction walls. In this procedure, the wall was laterally

displaced by 2.5 cm and 5.0 cm at the top using a connected wire, which was abruptly released to induce free vibration. An accelerometer installed at top of T-junction of the IPB wall, recorded the acceleration-time history response for both wall configurations, Sequence A and Sequence B, tested in the X-direction. The recorded data were analyzed using the logarithmic decrement method to determine the damping ratio and fundamental frequency, thereby providing critical insights into the dynamic behavior of the wall junctions, with the applied displacement magnitudes summarized in Table 3.1.

TABLE 3.1: Magnitude of Snap-Back Loading for Tested Specimens

Serial No.	Specimen ID	Loading Direction	Applied Displacement Amplitude (cm)
1	WCS-A	x-axis	2.5, 5.0
2	WCS-B	x-axis	2.5, 5.0

3.5.2 Harmonic

To study the dynamic response of mortar-free IPB walls at T-junctions, harmonic excitation tests were carried out under controlled laboratory conditions. The loading parameters used in the program are shown in Table 3.1. Harmonic excitations were applied in the X-direction with a fixed displacement amplitude of 2.5 cm at frequencies of 0.5 Hz, 1.0 Hz, and 1.5 Hz. During each test, acceleration, velocity, and displacement time histories were recorded at both the top of the wall and the shake table base to measure overall and local responses. The wall specimens, prepared according to Table 3.2, were built using half plastic blocks at alternate layers to avoid continuous vertical joints, following a stretcher bond similar to traditional brick masonry. Two wall combinations were tested under three junction setups: in Sequence A, Wall 1 was subjected to in-plane loading while Wall 2 faced out-of-plane excitation, whereas in Sequence B the orientation was reversed. In all cases, the T-junction was firmly fixed to the shake table with steel angle sections to ensure stability and avoid slippage. The choice of harmonic parameters was based on earlier experiments and published studies. A snap-back test

performed before harmonic loading identified 1.0 Hz as the fundamental frequency of the system. To extend the frequency range, 0.3 Hz was added, while 0.5 Hz and 1.5 Hz were used for comparison. Similar methods have been adopted by Khan [11], Afzal [18], and Sudheer and Ali [15] in their studies on harmonic response of columns, solid masonry walls, and walls with openings. A constant displacement amplitude of 2.5 cm was applied in both Sequences A and B to maintain uniform boundary conditions, allowing direct comparison of junction behavior under different initial positions. This harmonic loading approach thus provides a reliable basis for assessing the seismic resilience of IPB wall junctions, emphasizing the role of frequency variation and initial configuration in dynamic interaction, energy dissipation, and overall structural performance. Furthermore, this methodology ensures a comprehensive understanding of how harmonic excitation influences the structural integrity of IPB walls, particularly at T-junctions, under varying dynamic conditions.

TABLE 3.2: Parameters of Harmonic Loading Applied to Wall Configurations

Sr. No.	WCS	Loading Direction	Amplitude (cm)	Frequency (Hz)
1	A	X	2.5	0.5, 1.0, 1.5
2	B	X	2.5	0.5, 1.0, 1.5

3.6 Analyzed Parameters

3.6.1 Analyzed Parameters from Snap-back Test

For the mortar-free IPB wall at the T-junction, acceleration - time histories were recorded to evaluate the dynamic response of the structure under applied harmonic loading; however, extraneous noise was inevitably captured during data acquisition, which necessitated a systematic filtering process to ensure accuracy. MATLAB was initially employed to perform preliminary filtering and reduce excessive

noise, after which SeismoSignal software was applied using its bandwidth filtering capabilities to further eliminate unwanted frequency components while preserving the essential signal characteristics. From the refined dataset, the fundamental frequency (f_n) and damping ratio (ζ) were determined following established procedures [89], [13] as these parameters are critical for assessing resonance conditions and understanding the energy dissipation behavior of the system. The accurate identification of these dynamic properties not only enhances the reliability of the experimental data but also provides a robust basis for modeling and predicting the seismic performance of IPB T-junctions, thereby contributing to improved evaluation and design of resilient structural systems.

3.6.2 Analyzed Parameters from Shake Table Test

Harmonic loading with frequencies of 0.5 Hz, 1.0 Hz, and 1.5 Hz was applied to the interlocking plastic-block wall at the junction to evaluate its dynamic performance. The wall's response was recorded in terms of acceleration-time history, which provided critical insights into its vibrational behavior. Using the recorded acceleration-time history, velocity-time history and displacement-time history were calculated through Seismosignal software, enabling a more comprehensive analysis of the wall harmonic behavior. Furthermore, the acceleration-time history data was utilized to derive base shear (Q) displacement curves for both the interlocking plastic-block wall. Base shear (Q) was calculated as $Q=Mx\ddot{u}_t$ where M represents the mass of the wall and \ddot{u}_t is the acceleration recorded at the top of the wall. These curves were instrumental in understanding the relationship between applied shear forces and the resulting displacements, which are critical for assessing the energy dissipation and overall stability of the walls under dynamic loading.

3.6.3 Development of Empirical Equations

To evaluate the dynamic response of mortar-free IPB walls, particularly at T-junctions, empirical equations were formulated by integrating experimental data with theoretical models to characterize essential dynamic parameters such as damping ratio, fundamental frequency, and displacement response under varying

harmonic and seismic loading conditions. These equations accounted for structural variables including IPB geometry, block size, wall height, and input loading parameters, following the methodology outlined by Khan [16]. Their accuracy and reliability were assessed by comparing experimental and empirical results, with a correction factor of $K = 0.98$ applied to reduce discrepancies and improve consistency between predicted and observed responses. Remaining variations were attributed to material non-linearity, boundary conditions, and measurement uncertainties, which informed further refinements of the models. Ultimately, the proposed empirical equations provide a robust analytical framework for predicting the dynamic behavior of interlocking plastic block wall, thereby supporting seismic design optimization and enhancing structural resilience in engineering practice.

3.7 Summary

Chapter 3 outlined the experimental program devised to assess the seismic performance of mortar-free IPB walls at T-junctions through scaled prototype testing. Building upon prior research on lightweight earthquake-resistant housing, scaled-down wall models were constructed with vertical pre-tensioning to replicate realistic conditions and tested under two construction sequences to capture in-plane and out-of-plane responses. Snap-back tests were employed to determine fundamental frequency and damping ratio, while shake table tests under harmonic loading provided acceleration, velocity, displacement, and base shear-displacement relationships for evaluating dynamic behavior. Data processing using MATLAB and SeismoSignal ensured accurate identification of structural properties, and empirical equations were developed by integrating experimental findings with theoretical models, incorporating parameters such as geometry, wall height, and boundary conditions, with a correction factor applied to improve accuracy. IPB T-junctions maintain structural integrity and dissipate seismic energy effectively, thereby validating their potential as a sustainable, modular, and earthquake-resistant construction solution.

Chapter 4

Experimental Evaluation

4.1 Prologue

The previous chapter provided a comprehensive description of the experimental procedures, including specimen preparation, instrumentation, and test execution, which laid the foundation for subsequent data interpretation. Building upon that foundation, this chapter is dedicated to the analysis and evaluation of the experimental data recorded during the dynamic testing of mortar-free interlocking plastic-block walls at T-junctions. Particular emphasis is placed on determining the damping ratio (ζ) and fundamental frequency (f_n), as these parameters are critical indicators of the structural response under dynamic loading. These values were extracted from the acceleration-time history data obtained during testing. To ensure the reliability and accuracy of the processed data, advanced signal processing techniques were applied. Initially, MATLAB filtering methods were employed to minimize excessive background noise and remove high-frequency disturbances that could distort the recorded signals. Following this preliminary step, the SeismoSignal software was utilized for further refinement, where its bandwidth filtering capabilities were applied to eliminate undesired frequency components and enhance the clarity of the useful signal. In addition to noise reduction, SeismoSignal was also employed to derive velocity-time and displacement-time histories from the acceleration-time history, thereby providing a multi-dimensional perspective

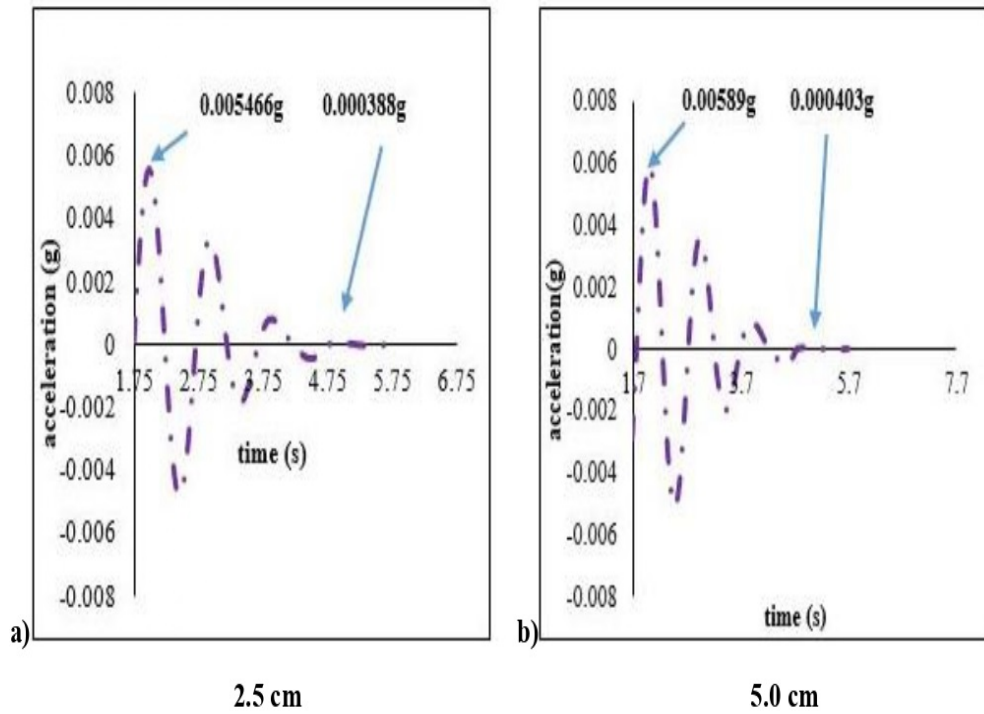
of the walls dynamic performance. This comprehensive data processing framework allowed for a more robust assessment of the seismic behavior of the interlocking plastic-block wall system, ensuring that the subsequent interpretations and conclusions are based on reliable and scientifically validated results.

4.2 Modal Damping Ratio and Base Natural Frequency

The fundamental frequency (f_n) of a structure refers to its natural vibration frequency, which is critical in determining how it responds to dynamic loads such as seismic excitations. If the fundamental frequency (f_n) is too close to the dominant frequency of seismic ground motion, resonance can occur, leading to amplified vibrations that significantly increase the risk of structural failure. Therefore, a seismic-resistant design should ensure that the fundamental frequency (f_n) is sufficiently distanced from the typical frequencies of seismic activity to prevent resonance. Figure 4.1 presents the results from snap-back tests conducted on a T-junction structure. In these tests, the top of the T-junction was laterally displaced from its equilibrium position by 2.5 cm and 5.0 cm, representing two different displacement scenarios. Using the logarithmic decrement method, the fundamental frequency (f_n) and damping ratio (ζ) of the T-junction structure were calculated. The results reveal the dynamic behavior of the T-junction across different imposed displacement levels, demonstrating through acceleration-time histories how the structural response changes when the system is subjected to two distinct displacement inputs. This detailed examination enhances understanding of the junction mechanical behavior, particularly its capacity for energy dissipation, which is critical for assessing performance under harmonic or seismic-type loading. The observed shifts in frequency content and damping ratios further highlight the non-linear response of the interlocking assembly when exposed to larger amplitudes of motion. Collectively, these findings emphasize the importance of evaluating frequency-dependent characteristics to achieve more reliable seismic assessments.

Such insights contribute directly to refining design strategies aimed at improving the junction stability, energy absorption efficiency, and overall structural resilience.

WCS-A



WCS-B

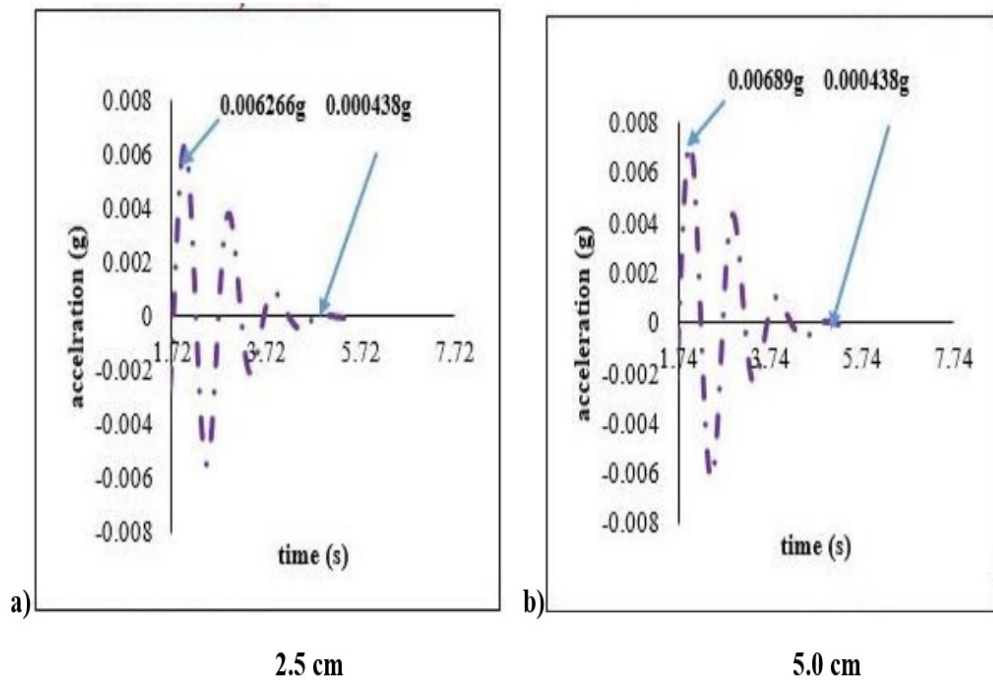


FIGURE 4.1: Accelerationtime response (\ddot{u}_t) curve for the snap-back: (a) 2.5 cm WCS-A, (b) 5.0 cm WCS-B, (c) 2.5 cm WCS-A, and (d) 5.0 cm WCS-B.

The following section presents the experimental results obtained from the snapback tests on the mortar-free interlocking plastic-block walls, which are fundamental to this study's investigation of dynamic structural behavior. These tests specifically focus on the determination of the modal damping ratio (ζ) and the base natural frequency (f_n) of the walls under varying displacement amplitudes. The data derived from these tests are essential for understanding the dynamic response of the wall system to harmonic loading conditions. Table 4.1 summarizes the key findings, providing a detailed analysis of the relationship between displacement amplitude, natural frequency, and critical damping ratio across the different test on wall configuration sequences (WCS).

TABLE 4.1: Snapback test results for wall configurations

Wall Structure	Amplitude (cm)	Natural Freq. (Hz)	Damping Ratio (%)
WCS-A	2.5	0.996	14.03
	5.0	0.991	14.23
WCS-B	2.5	0.994	14.11
	5.0	0.993	14.61

Table 4.1 presents the experimental results from snapback testing on different wall configurations, highlighting the relationship between displacement amplitude, natural frequency, and critical damping ratio. The results show two distinct sequences, A and B, tested at two displacement amplitudes (2.5 cm and 5.0 cm). The natural frequency, measured in Hertz, slightly decreases with an increase in displacement amplitude, indicating a potential shift in the system's vibrational behavior as the displacement increases. Specifically, Sequence A shows a reduction in natural frequency from 0.996 Hz at 2.5 cm to 0.991 Hz at 5.0 cm, while Sequence B experiences a similar decrease from 0.994 Hz to 0.993 Hz. On the other hand, the critical damping ratio, which indicates the extent to which oscillations are suppressed, exhibits a slight increase with higher displacement amplitudes. For Sequence A, the damping ratio increases from 14.03% at 2.5 cm to 14.23% at 5.0 cm, and Sequence B shows a more significant increase from 14.11% to 14.61%. These findings suggest that while displacement amplitude has a minimal effect on the natural frequency, it influences the damping characteristics of the wall

configurations. The slight increase in damping at larger displacements may indicate a greater resistance to oscillation, which could be significant for evaluating the dynamic behavior of wall structures under varying conditions, particularly in applications requiring vibration control and structural stability analysis.

4.3 Response of Prototype Walls Against Harmonic Loading

4.3.1 Response in Terms of Acceleration time and Displacement time Histories

The harmonic loading response of the interlocking plastic-block wall at the T-junction was investigated using acceleration-time and displacement-time histories recorded between 45 s and 55 s, as depicted in Figures 4.2 and 4.3. The shake table, providing harmonic excitation, served as the base input, while the top response of the wall was monitored to assess its dynamic behavior. To facilitate a comprehensive evaluation of the walls performance, acceleration data were processed using SeismoSignal software to generate the displacement-time histories. The excitation process was divided into three phases: initial vibration build-up, steady-state response, and free vibration, with only the steady-state portion shown for clarity. The results revealed that as the excitation frequency increased from 0.5 Hz to 1.5 Hz, both acceleration and displacement responses at the top of the wall exhibited a corresponding increase, illustrating the frequency-dependent nature of the structure. During harmonic loading, the wall demonstrated stable performance with no significant loss of structural integrity throughout the applied frequency range. The locally developed shake table was calibrated $\pm 25\text{cm}$, which maintained consistent amplitude, ensured reliable data for evaluating averaged acceleration, velocity, and displacement for both the base input and the wall's response. While the wall experienced higher response magnitudes at increased excitation frequencies, it displayed notable resistance and adaptability to the applied loads. These findings underscore the structural effectiveness of the interlocking plastic-block system

at T-junctions under progressive harmonic shaking, highlighting its potential as a resilient construction alternative in seismic-prone areas.

Figure 4.2 illustrates the acceleration-time history of a T-junction subjected to harmonic loading at three distinct frequencies: 0.5 Hz, 1.0 Hz, and 1.5 Hz. This figure is designed to effectively capture the dynamic behavior of the interlocking plastic-block wall, with a particular focus on the acceleration experienced at various critical points within the structure. These key locations include the base of the junction, the top of the junction, the in-plane wall, and the out-of-plane wall. Each panel in the figure represents the time-dependent acceleration at these specific points, with Panel a corresponding to the 0.5 Hz frequency, Panel b representing 1.0 Hz, and Panel c representing 1.5 Hz.

At the lowest frequency of 0.5 Hz (Panel a), the acceleration response exhibits relatively mild fluctuations, with the acceleration at the top of the junction remaining relatively low. This reflects the limited dynamic response of the structure at lower frequencies, where the vibrations induced by the excitation are not significantly amplified and remain within a moderate range. As the frequency increases to 1.0 Hz, shown in Panel b, the acceleration response becomes more pronounced, with more significant fluctuations. These fluctuations are particularly evident at the top of the junction and in the in-plane wall, indicating that the structure becomes increasingly sensitive to the excitation at this intermediate frequency. When the excitation frequency is raised to 1.5 Hz (Panel c), the acceleration response reaches its peak, with substantial fluctuations observed both at the top of the junction and in the in-plane wall, while the base of the junction remains relatively stable and unaffected by these variations.

This progression clearly highlights the frequency-dependent nature of the structures dynamic response. As the excitation frequency increases, the acceleration at the top of the junction and in the in-plane wall amplifies, demonstrating a more pronounced reaction of the structure to higher-frequency excitations. The figure thus provides a comprehensive illustration of how the magnitude of acceleration increases as the excitation frequency rises, offering valuable insights into the dynamic behavior of the wall when subjected to varying harmonic loads and

highlighting the complex interplay between frequency, structural response, and dynamic behavior. This emphasizes the need to consider excitation frequency for accurate evaluation of structural dynamic performance.

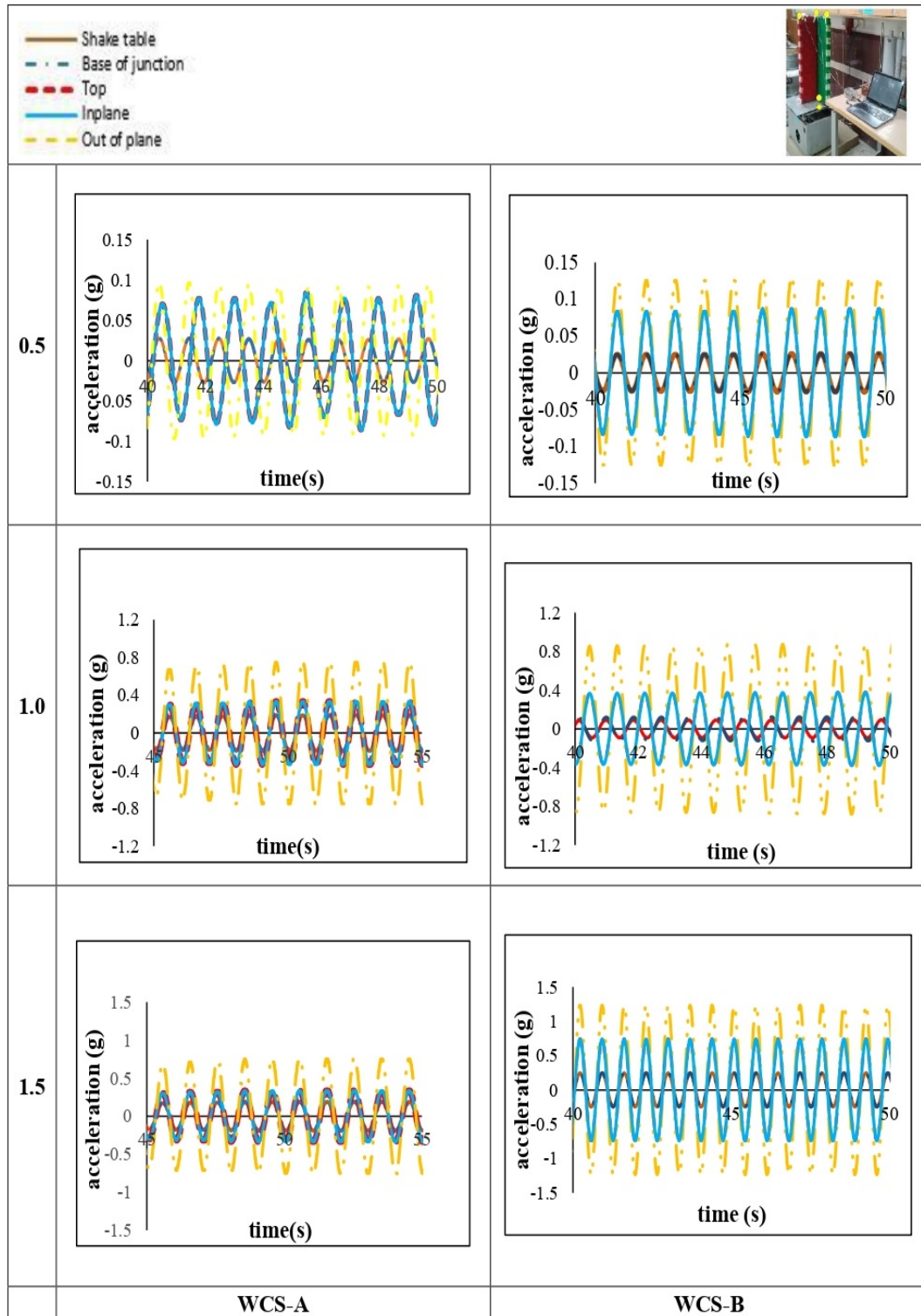


FIGURE 4.2: Acceleration-time history curve of T-junction.

Figure 4.3 provides a detailed depiction of the displacement-time history for the T-junction structure subjected to harmonic loading at different excitation frequencies of 0.5 Hz, 1.0 Hz, and 1.5 Hz. The displacement experienced at key locations on the structure, such as the base of the junction, the top of the junction, the top of the specimen, as well as at the in-plane and out-of-plane walls, is meticulously monitored and documented over the course of time. This displacement-time history is presented in a comprehensive manner across three separate panels. As illustrated in Figure 4.2, Panel a corresponds to the data for 0.5 Hz, Panel b presents the results for 1.0 Hz, and Panel c displays the data for the highest frequency of 1.5 Hz. At the 0.5 Hz frequency (Panel a), the displacement response is relatively small, with only modest displacements observed at the top of both the specimen and the junction. In this instance, the in-plane and out-of-plane walls exhibit very minimal displacements, which suggest that the structure has limited flexibility and undergoes only minor deformation when subjected to low-frequency excitation. This behavior signifies that, under these lower-frequency conditions, the structure remains relatively stiff and resistant to movement. As the excitation frequency increases to 1.0 Hz (Panel b), the magnitude of the displacements becomes significantly more pronounced. This is especially evident in the out-of-plane wall, where a substantial increase in displacement is observed, suggesting that the structure is experiencing greater overall deformation. Similarly, the displacement in the in-plane wall also becomes more noticeable, reflecting a significant increase in the overall flexibility of the wall and its greater responsiveness to the higher-frequency excitation. At the highest excitation frequency of 1.5 Hz (Panel c), the displacement reaches even greater magnitudes, with the most significant displacement observed at the top of the specimen and the out-of-plane wall. This observation further demonstrates the wall's enhanced flexibility and its greater susceptibility to larger movements under higher-frequency excitation. The results clearly highlight the frequency-dependent nature of the system, showing that the magnitude of displacement progressively increases as the excitation frequency rises, thereby inducing greater structural motion. This behavior demonstrates the wall inherent adaptive flexibility, revealing how its deformation response evolves in accordance with changes in harmonic loading. The findings

also indicate the system heightened sensitivity to variations in input frequency, underscoring the importance of evaluating its performance across a broad range of dynamic loading conditions for accurate structural assessment.

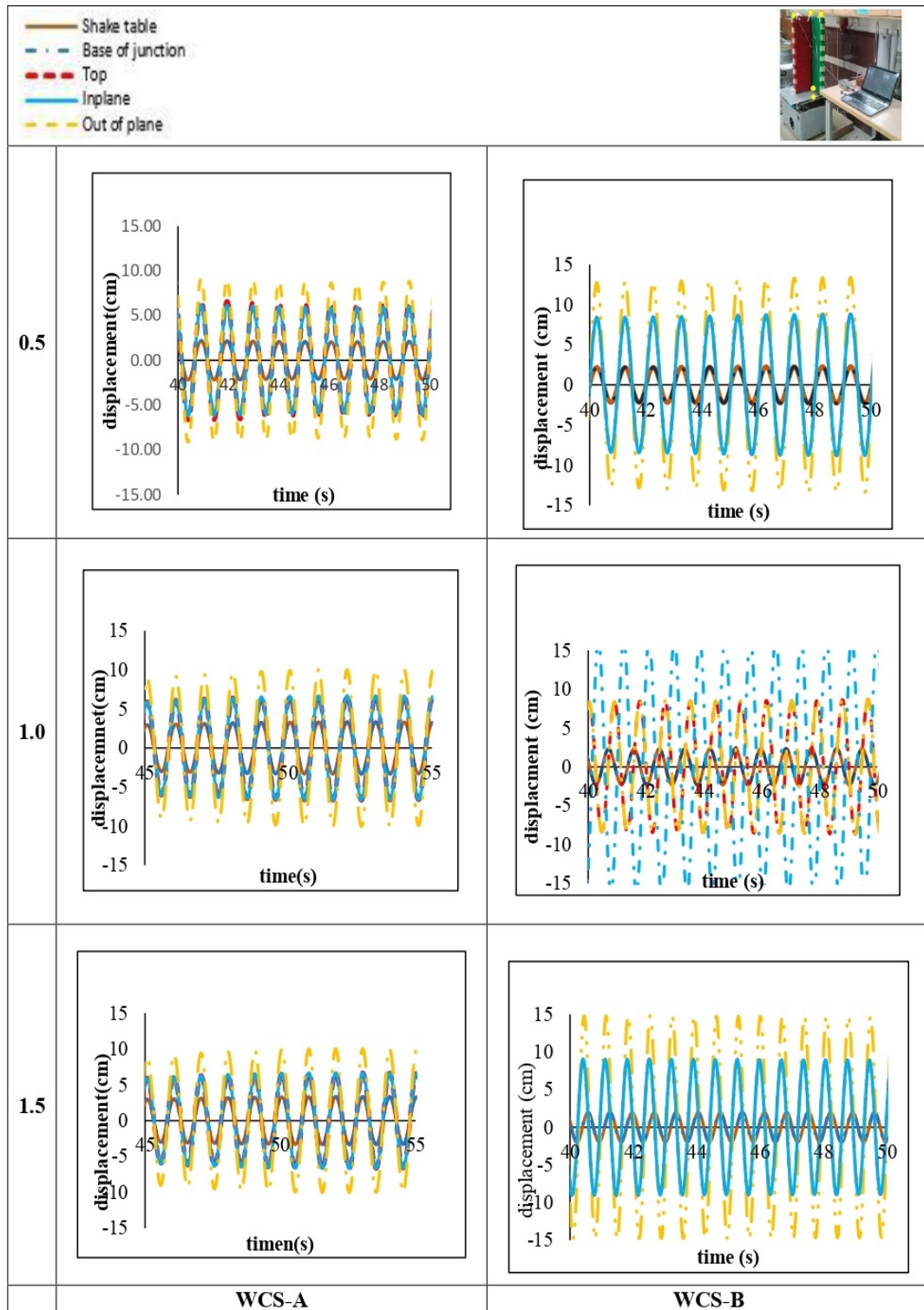


FIGURE 4.3: Displacement-time history curve of T-junction.

Figures 4.2 and 4.3 provide a comprehensive understanding of the interlocking plastic-block walls dynamic response under harmonic excitation. The increase in both acceleration and displacement with higher excitation frequencies emphasizes the walls ability to accommodate higher dynamic forces while maintaining its structural integrity. These figures collectively underscore the resilient and adaptable nature of the T-junction, particularly in seismic-prone environments, where it can effectively resist progressive dynamic loads.

TABLE 4.2: Wall influence on T-junction performance

Wall Structure	Freq. (Hz)	IP Disp. (cm)	OOP Def. (cm)	Percentage Impact
WCS-A	0.5	7.5	9.3	24
	1.0	8.35	9.87	18.20
	1.5	8.18	11.8	44.25
WCS-B	0.5	8.18	12.8	56.47
	1.0	8.34	16.4	96.64
	1.5	8.7	13.7	57.47

Table 4.2 provides a detailed comparison of the influence of wall arrangements on the performance of T-junctions subjected to harmonic excitation at varying frequencies. The table presents data for two distinct wall configurations sequences, WCS-A and WCS-B, and evaluates their impact in terms of in-plane displacement, out-of-plane deflection, and the percentage impact on the performance at excitation frequencies of 0.5 Hz, 1.0 Hz, and 1.5 Hz. For WCS-A, at 0.5 Hz, the in-plane displacement is 7.5 cm, while the out-of-plane deflection is 9.3 cm, with a percentage impact of 24%. As the frequency increases to 1.0 Hz, the in-plane displacement slightly increases to 8.35 cm, and the out-of-plane deflection rises to 9.87 cm, with a percentage impact of 18.20%. This indicates that at this frequency, the system shows a marginal increase in displacement, but the overall percentage impact on performance decreases. At 1.5 Hz, the in-plane displacement reaches 8.18 cm, while the out-of-plane deflection increases significantly to 11.8 cm, resulting in a notable percentage impact of 44.25%. This suggests that the structures

response becomes more pronounced at higher frequencies, particularly in terms of out-of-plane deflection, which shows a substantial increase at the highest frequency tested. In WCS-B, the in-plane displacement at 0.5 Hz is 8.18 cm, with a larger out-of-plane deflection of 12.8 cm, yielding a high percentage impact of 56.47%. At 1.0 Hz, the in-plane displacement increases slightly to 8.34 cm, and the out-of-plane deflection further increases to 16.4 cm, resulting in a dramatic rise in the percentage impact to 96.64%. This indicates a substantial increase in the systems deformation at this frequency, particularly in the out-of-plane direction. At 1.5 Hz, the in-plane displacement increases to 8.7 cm, and the out-of-plane deflection decreases slightly to 13.7 cm, leading to a percentage impact of 57.47%. This decrease in percentage impact compared to 1.0 Hz indicates that the structures behavior becomes less sensitive at higher frequencies, although still exhibiting considerable deformation. In summary, Table 4.2 highlights the significant influence of wall arrangement on T-junction performance under harmonic excitation. WCS-B generally exhibits larger deflections and higher percentage impacts compared to WCS-A, particularly at the 1.0 Hz frequency. This suggests that wall configuration plays a critical role in the dynamic response of T-junctions, influencing the overall displacement and deflection behavior at varying frequencies. The results emphasize the frequency-dependent nature of structural deformation, with higher frequencies leading to more significant out-of-plane deflections and varying levels of impact on performance.

4.4 Energy Dissipation and Base Shear Displacement Relationships

The dissipation of energy is crucial in assessing the performance of structures exposed to harmonic loads, such as seismic and vibrational forces. The interlocking plastic-block wall with a T-junction is designed to efficiently dissipate energy to ensure structural stability during harmonic loading. In this context, the mass (M) of the wall is considered to be concentrated at the top, and the acceleration response history (represented as (i.e., \ddot{u}_t)) is used to calculate the base shear (Q)

through the equation $M \cdot \ddot{u}_t$. This equation quantifies the force at the base of the wall due to dynamic excitation. The Q- curves, illustrated in Figures 4.4 are essential in understanding the relationship between the displacement of the wall and the shear forces at its base. These curves provide insights into key structural characteristics such as stiffness, energy dissipation, and damping properties, all of which are critical in evaluating the wall's ability to withstand dynamic forces. Ali et al. [13] outline a method to derive these curves, offering a solid foundation for analyzing the wall's performance in absorbing and dissipating energy during dynamic loading, which is crucial for avoiding permanent damage and ensuring the wall's resilience in the face of repeated loading. The energy dissipation mechanism, represented by the hysteresis loops in the Q- curves, illustrates the cyclic behavior of the structure under dynamic loading. These loops demonstrate how the wall absorbs, stores, and releases energy during the loading and unloading phases, significantly enhancing its resistance to forces and reducing the chances of structural failure. This dynamic behavior is crucial for maintaining the integrity of the wall. The Q- curves, shown in Figure 4.4 and Table 4.3, further highlight the wall's response to varying excitation frequencies (0.5 Hz, 1.0 Hz, and 1.5 Hz) across two different scenarios, Scenario 1 and Scenario 2. In Scenario 1, the curves demonstrate that at lower frequencies, such as 0.5 Hz, larger displacements occur for a given base shear, while at higher frequencies like 1.5 Hz, smaller displacements correspond to similar shear values. The non-linear character of the wall behavior is clearly illustrated by the yellow curves depicting the system response, which reveal the intricate relationship between base shear and displacement as the excitation frequency changes. This interaction vividly demonstrates how the wall experiences continuous transitions in stiffness and deformation states, highlighting the complex and nonlinear characteristics of its dynamic response under varying harmonic excitations. Detailed examination of these response patterns provides a deeper and more nuanced understanding of the wall capacity to resist lateral forces while maintaining structural stability and integrity across a spectrum of loading intensities. Collectively, these insights emphasize the critical importance of accounting for both frequency-dependent behavior and displacement response in the design, assessment, and optimization of resilient structures subjected to

dynamic, cyclic, or seismic loading conditions.

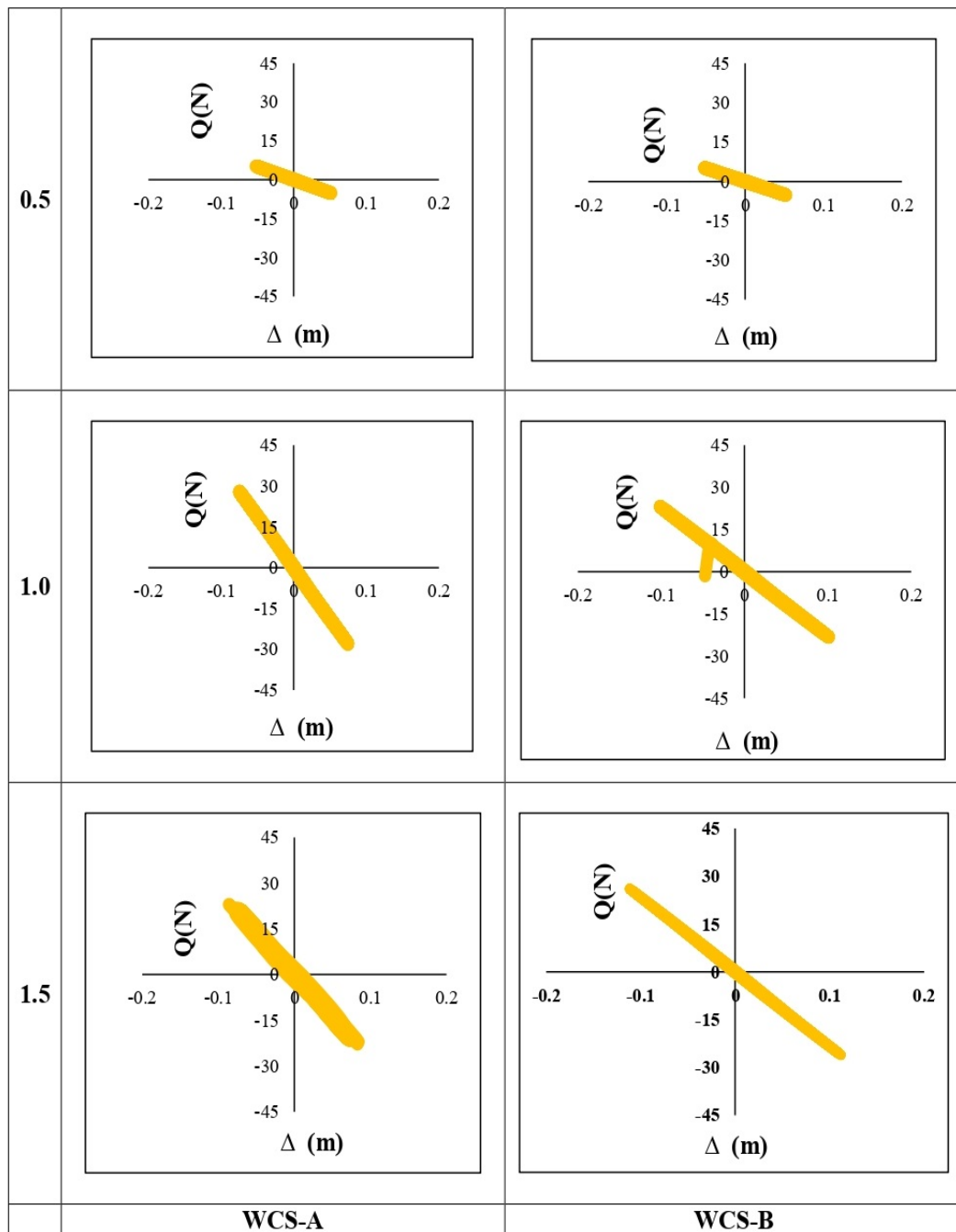


FIGURE 4.4: Q- Δ curve of the T-junction.

The figure 4.4 Base Shear-Displacement Curves of Interlocking Plastic-Block Wall with T-Junction for Different Frequencies illustrates the relationship between base shear (Q) and displacement (Δ) for a T-junction wall subjected to frequencies of 0.5 Hz, 1.0 Hz, and 1.5 Hz across two scenarios. The curves show how the wall's

dynamic response changes with frequency, with both base shear and displacement values plotted. At 0.5 Hz, the system exhibits a moderate response, while at higher frequencies (1.0 Hz and 1.5 Hz), the base shear and displacement increase significantly, indicating a stronger structural response. These curves provide insights into the wall's behavior under varying dynamic loading conditions, crucial for optimizing its design and performance.

TABLE 4.3: Energy absorption under harmonic loading conditions

Wall Structure	Freq. (Hz)	Mean Energy Diss. (Nm)	Cycles	Cumulative Energy (Nm)	Eq. Damp. Ratio (%)
WCS-A	0.5	0.54	85	46.04	16.67
	1.0	1.90	90	170.64	20.63
	1.5	2.23	121	269.88	19.73
WCS-B	0.5	0.67	85	56.67	19.58
	1.0	2.90	91	263.51	19.61
	1.5	4.13	120	495.32	19.43

Table 4.3 illustrates the energy dissipation characteristics of the T-junction wall configuration, highlighting variations in energy dissipation across different excitation frequencies and wall configurations. The table presents key metrics, including the mean energy dissipated per cycle (in Newton-meters), the number of cycles, cumulative energy dissipation, and the equivalent damping ratio for two scenarios: Seq. A and Seq. B, subjected to excitation frequencies of 0.5 Hz, 1.0 Hz, and 1.5 Hz. In Sequence A, the mean energy dissipated per cycle increases with frequency, starting at 0.54 Nm at 0.5 Hz, rising to 1.90 Nm at 1.0 Hz, and reaching 2.23 Nm at 1.5 Hz. Additionally, the number of cycles and cumulative energy dissipation both increase with frequency. The equivalent damping ratio, indicating energy dissipation efficiency, peaks at 1.0 Hz (20.63%) and slightly decreases at 1.5 Hz (19.73%). Sequence B follows a similar trend, with the mean energy dissipation rising from 0.67 Nm at 0.5 Hz to 2.90 Nm at 1.0 Hz, and 4.13 Nm at 1.5 Hz. Although the number of cycles remains comparable to Sequence A, the cumulative energy dissipation in Sequence B is higher across all frequencies, with values of 56.67 Nm at 0.5 Hz, 263.51 Nm at 1.0 Hz, and 495.32 Nm at 1.5 Hz. The equivalent damping ratio for Sequence B remains relatively stable, fluctuating between

19.43% and 19.61% across the tested frequencies. Overall, the data indicates that both wall configurations exhibit higher energy dissipation at higher excitation frequencies, with Sequence B consistently demonstrating greater cumulative energy dissipation and a slightly higher energy dissipation efficiency. These findings offer important insights into the structural behavior and energy dissipation properties of the T-junction wall under dynamic loading conditions.

4.5 Summary

Chapter 4 presents an in-depth experimental evaluation of the dynamic behavior of mortar-free interlocking plastic-block walls at T-junctions subjected to harmonic excitation. Utilizing advanced signal processing tools like MATLAB and SeismoSignal, the study focuses on extracting key parameters, including the modal damping ratio (ζ) and fundamental frequency (f_n), revealing stable damping ratios between 14.03% and 14.61%. The results indicate that the wall maintains structural integrity under varying excitation frequencies (0.5 Hz to 1.5 Hz), with notable increases in acceleration and displacement in response to higher frequencies. Additionally, energy dissipation characteristics, analyzed through Q curves, show enhanced energy absorption at higher frequencies, reinforcing the walls adaptability and resilience. These findings highlight the interlocking plastic-block walls potential as a sustainable, seismic-resistant solution, particularly in earthquake-prone regions, demonstrating its capacity to absorb dynamic forces while maintaining structural stability.

Chapter 5

Discussions

5.1 Prologue

In the preceding chapter, the outcomes of the acceleration-time, velocity-time, and displacement-time histories, along with the base shear-displacement curves, were comprehensively examined. The analysis revealed notable energy dissipation in the IPB wall at the T-junction. The present chapter seeks to establish a correlation between the experimental results and the corresponding empirical predictions to evaluate the behavioral response of IPB walls incorporating T-junctions. Additionally, the percentage deviation between the empirical estimations and experimental measurements is quantified and presented.

5.2 Development of Empirical Equation from Structural, Geometric and Loading Parameters

Khan and Ali [54] developed empirical equations that incorporate the geometry of interlocking blocks, column height, column response, and input loading parameters. Building upon their work, Sudheer [90] introduced a new variable to enhance

the prediction accuracy of IPB walls with openings, leading to the development of additional empirical equations. To further refine these predictions, Sudder's [90] empirical equations were also applied to model the response of IPB walls with T-junctions. These updated equations integrate the newly introduced variable to account for the unique structural characteristics of T-junction configurations, thereby improving the accuracy of dynamic performance predictions. The inclusion of this variable enhances the overall framework for evaluating the seismic behavior of IPB wall systems.

$$\ddot{u}_t = \frac{a}{h^2 n} \times m \times k^{(1+\frac{2n}{100})} \times \ddot{u}_g \quad (5.1)$$

$$\dot{u}_t = \frac{a}{h^2 n} \times m \times k^{(1+\frac{2n}{100})} \times \dot{u}_g \quad (5.2)$$

$$u_t = \frac{a}{h^2 n} \times m \times k^{(1+\frac{2n}{100})} \times u_g \quad (5.3)$$

In the study of dynamic responses of IPB walls, the dimensionless coefficient K , denoted as 0.98, is employed, with n representing the number of IPBs and m signifying the number of blocks arranged along the length of the T-junction wall in one layer. The base area of the IPB is denoted as a , while \ddot{u}_g , \dot{u}_g , and u_g represent the average acceleration, velocity, and displacement at the specimens base, respectively. Similarly, \ddot{u}_t , \dot{u}_t , and u_t correspond to the respective motion parameters at the top of the specimen. The dimensions of the blocks are 62 mm 62 mm, and the key height is 12 mm, with a total of 195 blocks arranged along the wall. The value of K is considered to be 0.98, producing a minimal discrepancy of -14.29% to 7.74% in the observed results. The dynamic response is evaluated by recording motion parameters at both the base and the top of the T-junction wall.

Table 5.1 illustrates the comparison between the experimental and empirical values for the response of the T-junction of the IPB wall. Previous studies have utilized a range of K -values to investigate the behavior of different structural configurations. Khan [16] employed a K -value of 1.05 in his research, while Afzal [18] used 0.45,

TABLE 5.1: Comparative analysis of experimental and empirical responses for T-Junction of interlocking plastic-block wall

Config.	Excitation Freq. (Hz)	Response Parameter	Exp. Values	Emp. Values	Percentage Difference (%)
WCS-A	0.5	Acceleration (g)	0.083	0.0865	4.05
		Velocity (cm/s)	27	26	-3.85
		Displacement (cm)	7.5	8.01	6.37
	1.0	Acceleration (g)	0.31	0.336	7.74
		Velocity (cm/s)	49	52.5	6.67
		Displacement (cm)	8.35	8.5	1.76
	1.5	Acceleration (g)	0.75	0.755	0.66
		Velocity (cm/s)	78.5	78.7	0.25
		Displacement (cm)	8.18	8.356	2.11
WCS-B	0.5	Acceleration (g)	0.086	0.088	2.27
		Velocity (cm/s)	26.27	26.8	1.98
		Displacement (cm)	8.18	8.6	4.88
	1.0	Acceleration (g)	0.31	0.33	6.06
		Velocity (cm/s)	60	52.5	-14.29
		Displacement (cm)	8.3	8.5	2.35
	1.5	Acceleration (g)	0.75	0.76	1.32
		Velocity (cm/s)	83.5	80.2	-4.11
		Displacement (cm)	8.3	8.7	4.60

and Sudheer and Ali [15] selected a value of 0.5, particularly for configurations such as columns and OOP solid walls. Akram [23] utilized a K -value of 1.14 for examining corner joints. These varying values reflect the diversity of applications and structural contexts in which K is used, indicating the influence of different geometric and loading conditions. In contrast, the current study focuses on the T-junction wall, where a K -value of 0.98 was chosen. This value provided the most accurate results, with the response falling within a deviation range of -14.29% to 7.74%. This selection highlights the importance of adjusting K -values to suit the

specific structural characteristics under investigation, ensuring precise and reliable outcomes.

The dynamic response analysis of IPB walls shows that the average ground acceleration, velocity, and displacement (\ddot{u}_g , \dot{u}_g , and u_g) at a frequency of 0.5 Hz WCS-A are 0.083 g, 27 cm/s, and 7.5 cm, respectively. As the excitation frequency increases, these values progressively rise, reaching 0.75 g, 78.5 cm/s, and 8.18 cm at 1.5 Hz. Similar trends were observed in WCS-B, where the values at 0.5 Hz were 0.086 g, 26.27 cm/s, and 8.18 cm, and at 1.5 Hz, they increased to 0.75 g, 83.5 cm/s, and 8.3 cm. The structural parameters include a block base area of 62 mm \times 62 mm, a key height of 12 mm, 195 total blocks, and an effective wall length of 675 mm. The coefficient K , remains 0.98. Notably, differences of 4.05% for acceleration at 0.5 Hz WCS-A, 6.67% for velocity at 1.0 Hz WCS-A, and 6.06% for acceleration at 1.0 Hz WCS-B were observed, with a maximum deviation of 14.29% for velocity at 1.0 Hz in WCS-B. These results substantiate the accuracy of empirical equations in predicting the seismic behavior of IPB walls under harmonic loading, thereby supporting their use in structural and seismic design.

The comparative analysis in Table 5.1 evaluates the dynamic responses of T-junctions in IPB walls subjected to varying excitation frequencies (0.5 Hz, 1.0 Hz, and 1.5 Hz) under both experimental and empirical conditions. The response parameters acceleration, velocity, and displacement are assessed to understand the wall's seismic behavior, specifically in terms of dynamic amplification and structural response under harmonic loading. At an excitation frequency of 0.5 Hz, the experimental acceleration was measured at 0.083 g, while the empirical prediction was 0.0865 g, yielding a percentage difference of 4.05%. Similarly, velocity and displacement were recorded at 27 cm/s and 7.5 cm, respectively, showing discrepancies of -3.85% and 6.37% between experimental and predicted values. As the excitation frequency increased to 1.0 Hz and 1.5 Hz, the differences in the response parameters remained within acceptable limits, with percentage deviations ranging from -14.29% to 7.74%. Notably, the acceleration at 1.0 Hz was 0.31 g experimentally and 0.336 g empirically, exhibiting a small difference of 7.74%. Furthermore, the velocity and displacement values showed less than 15% variance at 1.0 Hz

and 1.5 Hz, indicating good agreement between experimental and empirical data. These minimal deviations are consistent with the structural engineering principle of acceptable error margins in dynamic analysis and seismic response evaluation, reinforcing the reliability of the empirical model for assessing the performance of interlocking plastic-block wall systems under dynamic loads. The results validate the proposed empirical equations, confirming their applicability for earthquake engineering practices, especially in modeling the dynamic characteristics, stiffness, and energy dissipation behavior of such structures during seismic events. The empirical equations used in this study are based on prototype-scale experimental data, capturing the fundamental response trends of mortar-free IPB T-junctions. To extend their applicability to full-scale structures, appropriate scaling laws and dimensional analysis principles (such as those based on similitude theory) can be applied. The equations can serve as a baseline predictive model, where geometric, material, and loading parameters are adjusted using scale factors corresponding to full-size units.

5.3 Study Outcomes in Relation to Practical Applications

The application of harmonic loading using a locally developed shake table effectively simulates base ground motion, allowing for the study of structural behavior under dynamic conditions. The observed response of the IPB wall with junctions aligns closely with findings from previous research, demonstrating consistent results in terms of structural stability and energy absorption. These findings highlight the potential of this system for earthquake-resistant construction, particularly in reducing seismic impact. Further exploration is needed to assess the interaction of the wall with other structural elements. Additionally, as Table 5.2 illustrates, the current study shows a strong correlation with prior research, particularly in terms of energy dissipation in mortar-free structures, reinforcing the effectiveness of interlocking plastic-block walls for seismic resilience.

TABLE 5.2: Comparative evaluation of previous research findings with current study

Previous Research Findings	Current Study Findings
A complex shake table assessed mortar-free interlocking structures' dynamic behavior [84].	A simple 1D shake table was used to evaluate the T-junction in an IPB wall.
More inertial force was generated in CFRC blocks due to its weight [12].	While less inertial force is generated in IPB due to its light weight.
Energy dissipation was observed in mortar-free interlocking structures under dynamic loading [13].	The T-junction in the mortar-free IPB wall also demonstrated energy dissipation under dynamic loading.
Pre-tensioning with coconut fiber ropes reduced energy dissipation compared to configurations without ropes [12].	Rubber bands at the T-junction enhanced energy dissipation during harmonic loading.
Minor damage was observed during column collapse in interlocking blocks [12].	No visible damage occurred due to the shake table's operational limits.
Interlocking masonry walls reduced earthquake-induced forces [67].	The IPB walls at T-junctions also reduced seismic forces through energy absorption and dissipation.
Coconut fiber reinforcement improved concrete blocks' ductility, enhancing seismic resilience [36].	Rubber-band reinforcement at T-junctions improved IPB walls' flexibility and seismic resilience under dynamic loading.

Table 5.2 Continued from previous page

Previous Research Findings	Current Study Findings
Semi-interlocking masonry systems showed strong energy absorption and damping under seismic excitations [36].	The IPB system exhibited strong energy dissipation and damping, with T-junctions performing better at higher frequencies (1.5 Hz).
Dry-stack masonry with modular interlocking blocks improved lateral load resistance [91].	The IPB walls at T-junctions showed similar lateral load resistance and increased base shear resistance at higher excitation frequencies.
Natural fiber-reinforced concrete absorbed more seismic energy and showed fewer cracks [35].	The IPB system absorbed energy similarly, with minimal cracks at higher excitation frequencies.
Reinforced interlocking blocks improved stability and energy dissipation in seismic tests [92].	IPB walls with T-junctions exhibited excellent energy dissipation and stability across various frequencies.

Table 5.2 compares the findings from previous research with the observations in the current study on IPB walls at T-junctions. It highlights that while earlier studies used complex shake tables [84], this study employed a simpler one-dimensional shake table. Previous research on coconut fiber-reinforced concrete blocks [12] noted higher inertial forces due to their weight, while the IPB system in this study exhibited lower inertial forces due to its lightweight nature. Both studies observed significant energy dissipation under dynamic loading, but the current study used rubber bands at the T-junction for enhanced energy dissipation. Furthermore, the current study confirmed the findings from prior research on improved seismic performance of modular interlocking blocks [67], energy absorption in natural fiber-reinforced concrete [35], and the positive impact of reinforced interlocking

systems [92]. Overall, the IPB system at T-junctions demonstrated reduced seismic forces, improved lateral load resistance, and energy dissipation, aligning with and extending previous findings.

5.4 Challenges in Seismic Resilience of Masonry and Remedial Measures

Reducing a structure's mass is a fundamental strategy in seismic design, as it leads to a decrease in inertial forces during seismic events. According to the UBC 1997, base shear, a key factor in seismic force calculation, is directly proportional to the weight of the building, as expressed by the equation:

$$V = \frac{C_v \times I}{RT} \times W \quad (5.4)$$

This relationship highlights the importance of mass reduction in mitigating seismic forces and minimizing potential damage. By significantly decreasing a structure's mass, seismic demand is reduced, leading to better overall performance during earthquakes. The use of mortar-free interlocking plastic blocks offers an innovative solution, providing a lightweight yet resilient alternative that enhances energy dissipation, particularly at critical junctions like T-junctions. These blocks employ a dry assembly system that accelerates construction, reduces dependency on skilled labor, and allows for easy disassembly and re-usability, making them a cost-effective and environmentally friendly option.

In addition to their structural benefits, mortar-free interlocking plastic blocks allow for increased flexibility in design, making them suitable for various building types, including those with irregular geometries that are more vulnerable to seismic forces. Their ability to distribute seismic forces efficiently and improve overall stability further enhances the resilience of buildings. Moreover, the modular design of these blocks promotes faster construction, making them an ideal choice for large-scale, earthquake-resistant projects in seismic-prone regions. Recent research, including studies referenced in [92], has demonstrated the effectiveness of

these systems in strengthening the seismic performance of buildings, offering a promising alternative to traditional construction methods. Such advancements in seismic engineering contribute to the development of safer and more sustainable infrastructure, addressing both the practical and economic challenges of building in earthquake-sensitive areas.

5.5 Summary

Chapter 5 of the thesis discusses the dynamic behavior of IPB walls with T-junctions under harmonic loading, establishing correlations between experimental data and empirical predictions to evaluate their seismic performance. The chapter presents refined empirical equations incorporating structural, geometric, and loading parameters, demonstrating that a K -value of 0.98 provides minimal deviation between experimental and empirical results, validating the accuracy of the developed model. A detailed comparison of experimental and empirical responses at different excitation frequencies (0.5 Hz, 1.0 Hz, and 1.5 Hz) reveals that the empirical equations reliably predict the dynamic behavior of IPB walls, with minimal percentage differences in acceleration, velocity, and displacement. The study highlights the potential of IPB systems in earthquake-resistant construction, emphasizing their energy dissipation capabilities and structural stability under seismic forces. Additionally, it compares the findings with prior research, confirming the effectiveness of IPB systems in reducing seismic impact and improving structural resilience. The chapter concludes by addressing challenges in seismic resilience, proposing remedial measures such as reducing mass and using lightweight mortar-free interlocking blocks for large-scale construction in seismic zones.

Chapter 6

Conclusion and Future Work

6.1 Conclusions

This study investigates the harmonic behavior of a 1:4 scaled interlocking plastic-block T-joint, aiming to understand its structural response under different loading conditions. The test model was composed of 195 plastic blocks, arranged in 15 layers, and secured at the base using angle sections. To monitor the structural response, five accelerometers were strategically placed: two at the top of each wall end, one at the T-junction top, one at the T-junction bottom of the wall and one at the base plate of the shake-table. Additionally, a snap-back test was conducted to determine key dynamic parameters, such as the natural frequency, time period, and damping ratio, using the logarithmic decrement method. The experiment was carried out on a locally manufactured one-dimensional shake table, operating at frequencies of 0.5 Hz, 1 Hz, and 1.5 Hz, to simulate real-world seismic events. The raw data collected from MATLAB was subsequently refined using SeismoSignal for noise filtering and baseline correction, ensuring the accuracy and reliability of the results. Based on the findings of this research, the following conclusions can be drawn:

- The mean fundamental frequency is around 1 Hz, and the damping ratio at the T-junction is sustained at up to 14.12%.

- The prototype T-junction's response was documented through acceleration-time and displacement-time histories.
- The OOP wall exerts a greater influence on the behavior of the T-junction, with displacements attaining up to 96.6% of those observed under IP harmonic loading.
- WCS-B absorbs 22.9%, 54.4%, and 83.5% more energy than WCS-A at frequencies of 0.5 Hz, 1 Hz, and 1.5 Hz, respectively.
- The T-joint in mortar-free interlocking plastic block walls contributes to energy dissipation, emphasizing its potential for earthquake-resistant construction.
- The acceleration at 1.0 Hz showed a small difference of 7.74%, while velocity and displacement variances were under 15%, indicating strong agreement between experimental and empirical data. These minimal deviations align with acceptable error margins in dynamic analysis, validating the empirical model's reliability for assessing IPB wall systems under dynamic loads. The results confirm the applicability of proposed equations for earthquake engineering, particularly in modeling dynamic characteristics and energy dissipation during seismic events.
- The lightweight T-joint in mortar-free interlocking plastic block walls enhances energy dissipation under harmonic loading and improves structural safety. This sustainable housing innovation provides an affordable and resilient solution for earthquake prone communities, ensuring a decent standard of living.

6.2 Future Recommendations

The following may be considered to further explore the behavior of interlocking plastic block structures:

- Enhancing T-junction configurations for a balanced seismic response in interlocking block structures.
- Empirical modeling approaches for predicting T-junction behavior in modular wall systems.
- Investigate the effect of incorporating a slab on stiffness, load distribution, and overall structural stability through extended experimental or numerical analysis.
- Evaluating a broader range of plastic types to support more comprehensive sustainability assessments.

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