Resilient Architectural Heritage: A Study of Earthquake resistant Traditional Construction in Kashmir

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Abstract

The Himalayan mountains surround Kashmir which showcases an impressive architectural heritage that demonstrates the creative strength and enduring spirit of its inhabitants. The architectural style of Kashmir depends heavily on wood because it serves as the primary construction material. The construction material wood plays a central role in building structures which demonstrate exceptional seismic resistance. The Indian Standard codes identify Kashmir as Seismic Zone 5 because of its high earthquake risk. The construction systems of Taq and Dhaj-i-Dewari emerged as solutions to handle the extreme environmental conditions. The two architectural styles share a common feature because they use wood as their main structural component. The research investigates traditional building systems for earthquake resistance through their analysis of wood-based structural elements. The research investigates how wood maintains stability through its material properties and connection points and construction methods. The research examines how different materials and connection points and construction techniques work together to build earthquake-resistant buildings. The research investigates why people choose to abandon traditional building methods through its comparison between local construction techniques and modern architectural approaches. The research delivers essential knowledge about a hybrid method which explains how traditional architectural elements from specific regions can enhance contemporary design through local solutions

Keywords: Earthquake-Resistant Construction, Traditional Construction Methods, Hybrid Construction Approach, Seismic Resilience, Structure Stability

1 Introduction

The architectural heritage of Kashmir exists because of four essential principles which include balance and gravity and proportion and scale. The essential concepts have survived through time to establish the traditional building methods of Kashmir which direct the development of its architectural style.

The principles of balance and gravity and proportion and scale appear throughout Kashmir's built environment starting from large religious buildings down to basic

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farmer shelters and ending at ordinary boundary walls. The basic design elements of Kashmir vernacular architecture appear in all structures from small to large regardless of their purpose. The architectural language unites cultural heritage with natural surroundings and skilled construction methods to showcase the complete vernacular heritage of the region.

Fig. 1. Kashmir landscape depicting balance and harmony

The construction of traditional Kashmiri buildings depended heavily on the architectural concept of "gravity." The substantial materials used in these structures created thermal mass which helped them control indoor temperature levels. The buildings maintained both seismic stability and thermal comfort through their design.

The design of these structures as load-bearing systems required walls made of heavy materials and strong flooring and exact floor dimensions for practical and logical reasons. The structural elements functioned as a unified system to handle building loads and fight against environmental and seismic threats.

Fig. 2. Buddhist structures in Kashmir highlighting the scale and proportions

2 Research Objectives

The research assessed how traditional building methods using wood as a local material function in earthquake-prone areas to determine their suitability for modern Kashmir construction. This has been further divided into the following objectives:

1. The research aims to explore how Kashmiri vernacular architecture operates in earthquake-prone areas through its fundamental principles.
2. The research evaluates which elements lead Kashmir to shift from using traditional building methods to modern construction systems.

3 Methodology Adopted

The research combines three methods which include literature review and case study evaluation and primary data collection through surveys.

- **Literature Review**: The research used a literature review to analyze academic papers and official reports and historical documents which delivered knowledge about Kashmiri traditional buildings and their earthquake resistance and construction method development.
- **Objective 1**: The documentation and case study method enabled researchers to understand vernacular architecture through their examination of traditional Kashmiri buildings through field observations and architectural records and additional research data.
- **Objective 2**: The research team conducted surveys to determine why people in Kashmir switched from using traditional building methods to modern construction techniques. The research team conducted surveys through questionnaires and interviews with architects and engineers and builders and local community members to understand construction patterns and their underlying reasons.

4 Literature Review

The evaluation of current research about earthquake-resistant building materials and construction methods requires a complete assessment of all available literature. Multiple research studies have evaluated both conventional and innovative seismic damage reduction methods to determine their performance capabilities and practical implementation potential. The combination of traditional construction methods with modern seismic-resistant building techniques has proven successful in earthquake-prone areas. The development of new engineering solutions together with advanced materials has created high-performance building systems which improve structural safety. The review examines previous research findings about seismic resilience through both traditional and modern construction methods. The research on earthquake-resistant construction has been organized into three main areas:

1. Structural Properties of Earthquake-Resistant Materials: Research in this field investigates the fundamental characteristics of construction materials which determine their seismic performance.
2. Traditional Earthquake: Resistant Construction Techniques: Research has documented historical construction methods such as the Taq system, Dhaj-i-Dewari, reinforced adobe, and bamboo-reinforced structures, which have evolved to withstand seismic forces. The research demonstrates that flexible materials and timber-laced masonry serve as effective earthquake energy dissipation methods.
3. Current Construction Practices in Kashmir: Understanding current construction practices in Kashmir is essential to assess how modern developments align with or diverge from traditional earthquake-resistant techniques.

4.1 Structural Properties of Earthquake-Resistant Materials

A fundamental aspect of aseismic construction is selecting materials that behave in a way that counteracts the effects of earthquakes. This section focuses on understanding the desirable properties that are characteristic of materials that that contribute to aseismic construction

- **Ductility**

Ductility refers to the ability of a material to undergo extensive deformation before ultimately collapsing

[1]For ductile materials to achieve a ductile effect in the overall behavior of the component, they must be proportioned and placed so that they act in tension or bending and are subjected to yielding. Thus, a necessary requirement for good earthquake-resistant design is to have sufficient ductile material at points of tensile stress [1].

- **Deformability**

[1]Deformability can be defined as the structure's ability to displace or deform substantial amounts without collapsing. Apart from naturally relying on the materials and components' ductility, deformability requires that structures be well- proportioned, regular and well tied together so that excessive stress concentrations are avoided and forces are capable of being transmitted from one component to an- other even through large deformations [1].

[1]Ductility is a concept which can be applied to both material and structures, while deformability is applicable only to structures. Even when ductile materials are present in sufficient amounts in structural components such as beams and walls, overall structural deformability requires that geometrical and material instability be avoided [1].

- **Robustness**

[1]Robustness refers to the ability of a structure to undergo substantial damage, without partial or total collapse. A key to good robustness is redundancy, or provision of several supports for key structural members and escaping central columns or walls supporting voluminous parts of a building [1].

4.2 Traditional Earthquake - Resistant Construction Techniques

Historically, indigenous architectural practices in seismic-prone regions have demonstrated remarkable resilience against earthquakes. Traditional techniques such as the Taq system and Dhaj-i-Dewari construction in Kashmir have been studied for their flexibility, energy dissipation capabilities, and localized adaptability. These methods leverage timber-laced masonry and lightweight infill panels to reduce seismic vulnerability.

Both Taq and Dhaj-i-Dewari of Kashmir are similar to hatil and himis construction of Turkey respectively, beyond its boundaries, perhaps in part because of the widespread influence of Ottoman Empire [2]. Timber-with-brick-infill vernacular construction is said to have its first appearance in Turkey in the early eighth century [3]. A different variation on the infilled timber-frame system is common in several countries in Central America. This system, which most likely evolved from a merging of Spanish construction infill-frame practice with local Native American construction traditions, is known in Nicaragua as taquezal, or "pocket" system, and in neighboring El Salvador as bahareque [4].

[5]For this, they developed the gaiola ("cage"), which can be referred as Pombalino construction. The gaiola essentially is a well-braced form of half-timber construction. The only other known example where a similar anti-seismic system was developed is in Calabria and Sicily, where there had been frequent devastating earthquakes, including one in Calabria in 1783, 28 years after the Lisbon earthquake. This Italian system, known as "Casa Baraccata," was likely influenced by the Portuguese "Gaiola." In Italy, the Casa Baraccata became the underlying basis for an extensive series of manuals of practice, and even of patent applications for seismic resistive construction techniques up until the beginning of the 20th Century [5].

- **Timber Ring Beams**

  Description: Timber beams placed at key points in the structure
  Proper connection at wall intersections (timber joint details, steel dowels, straps)

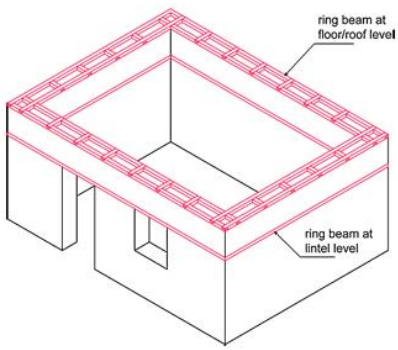


Fig. 3. Timber ring beams [6]

- **Corner Braces**

Description: Diagonal timber elements at building corners
Benefits:
- Reinforces wall-to-wall connections
- Improves post-elastic performance of walls (keeps walls working together even with cracked joints)
- Ease of application for strengthening

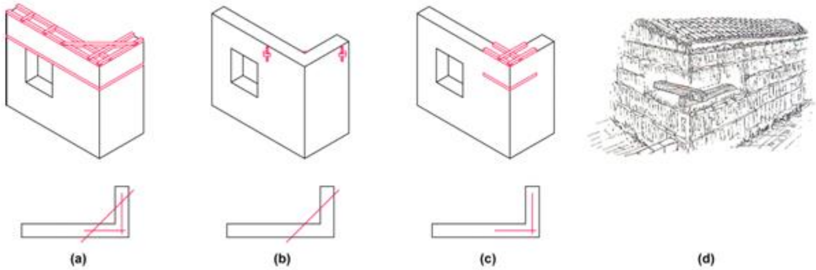


Fig. 4. Corner braces *[6]*

- **Ties**

Description: Steel tie rods or wooden tie beams to connect various structural elements
Benefits:
- Improves "box-behaviour" of the building
- Connects various walls (perpendicular, parallel, load-bearing, interior)
- Connects walls to floors and roofs
- Avoids out-of-plane collapse of parallel walls
- Redistributes load among walls

Placement: Typically, at floor and roof levels
Ease of implementation in existing structures

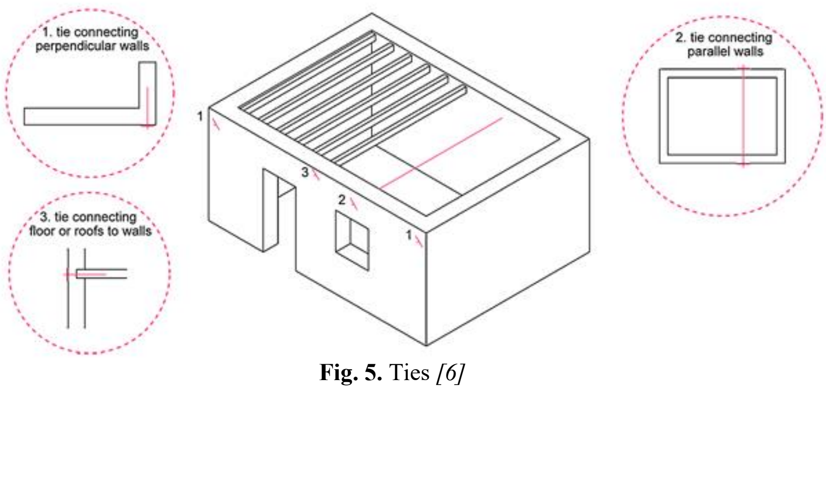


Fig. 5. Ties *[6]*

- **Timber Elements within Masonry**
  Description: Timber elements inserted into masonry walls

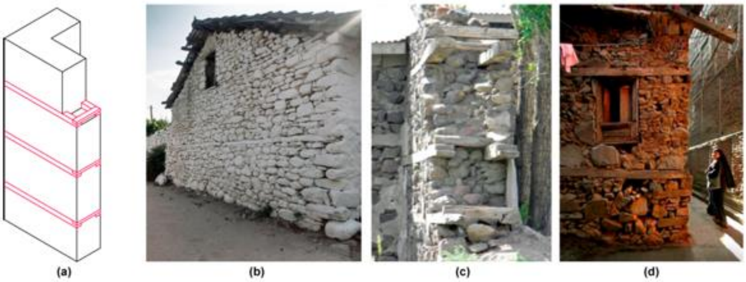


Fig. 6. Timber elements within masonry *[6]*

- **Multiple Framed Structures**
  Structural redundancy, where multiple elements share the load, is key for buildings to survive earthquakes. This traditional technique, often combining timber and masonry, has proven very effective. The houses feature a strong timber frame, but also include thick masonry walls on the ground floor. This creates redundancy. If the earthquake damages the masonry walls, they fall outward, leaving the timber frame intact. This protects occupants and allows for easier repairs. (Ortega et al., 2017)

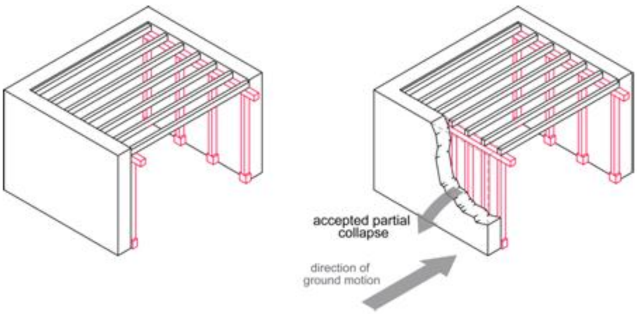


Fig. 7. Techniques allowing partial collapse *[6]*

- **Lowering the Centre of Gravity**
  Rationale: A lower center of gravity makes the building less likely to overturn.
  Techniques:
  - Scarp walls
  - Thinner upper floor walls
  - Light timber floors and roofs
  - Thickening ground floor walls (increases resisting area, reduces overturning risk

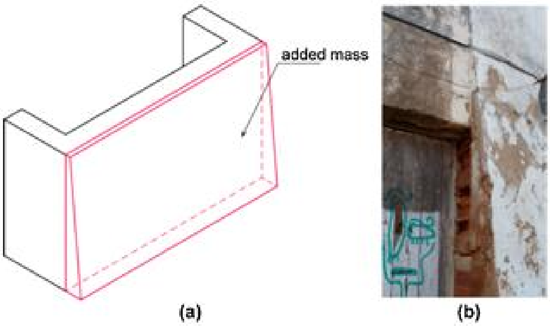


Fig. 8. Scarp walls *[6]*

Taq system of Kashmir

The timber beams in the taq system don’t form a structural frame yet still are present in the form of “timber runners” that rest along the load bearing walls, with the floor beams lapping over them. The wooden elements are meant to tie the walls together with the floors, while the weight of the masonry ensures the wall remains “prestressed”. The construction practices used for these Kashmiri buildings, which stand in contrast to today's codes and commonly-accepted practices, include the use of mortar of negligible strength, the lack of any bonding between the infill walls and the piers, the weakness of the bond between the wythes of the masonry in the walls, and the frequent (historical) use of heavy sod roofs [2].

Fig. 9. Taq system *[4]*

[2]This distribution of the forces throughout a larger area of the wall, preventing destructive cracking in one area, leads to a much greater level of energy dissipation

than would otherwise be possible. As a result, even though the mortar is extremely weak, causing the wall to yield under a much smaller load, the masonry continues to have a good chance of holding together. The timber runner beams and floor diaphragms keep the individual piers from separating, which would cause the house to break apart. In Kashmir, rigidity carries the potential for destruction. If the building is more rigid, it needs to be stronger enough to avoid fracture [2].

In contemporary times, the traditional Taq system of construction continues to be employed, albeit by a select group of innovative and forward-thinking architects in the region. While the core principles of this seismic-resistant system remain intact, certain modern adaptations and material substitutions have emerged.

Stone masonry continues to be the main architectural element in Kashmiri buildings but builders now incorporate supplementary materials into their construction. The Taq system uses timber runners as its core element which now works together with stone masonry and mud blocks to improve structural strength. The basic structural design of timber runners remains unchanged because they continue to serve as strategic supports at every sill and lintel point although some sections receive additional reinforcement for better stability. The combination of traditional building methods with contemporary solutions in these adaptations demonstrates a careful approach to maintain heritage construction methods while fulfilling present-day requirements [7].

Fig. 10. North Indian builders use taq techniques for modern construction projects throughout the region.

The building process includes all stages where Kashmiri vernacular construction aseismic characteristics receive precise implementation. Poplar trunks of considerable diameter and length serve as horizontal beams that connect the peripheral walls and ensures the ‘box-like configuration’ of the structure, thereby enhancing its overall stability.

Timber runners, strategically placed at sill and lintel levels, substantially improves the ductility, deformability, and robustness of the construction. The entire structure is usually anchored by a sturdy stone foundation, which provides a solid base while distributing loads uniformly. The way these materials work together evidently highlights the regions deep understanding of material and seismic resilience.

Fig. 11. Timber runners at sill level in taq construction (left); Wooden beams to transfer load and enhance box nature of structure (Right)

Fig. 12. Modern day usage of taq techniques in North India

Dhaj-i- Dewari System

The half-timber, brick-nogged type, known as the Dhaj-i-Dewari, exists side-by-side with the Taq in Kashmir. Half-timbered construction continues to provide an efficient and economical use of materials. The use of wood, while kept to a minimum, nonetheless enables the thin masonry walls to resist out-of-plane collapse, while also restraining the in-plane movement of the masonry [8].

The Dhaj-i-Dewari system uses timber frames for confining masonry in small segments. There are vertical elements in the frames of timber along with cross bracing members, which has the role to divide the masonry infill into various small panels. A significant characteristic of this construction type is the use of lean mud mortar. It is a very common practice in the region to use the Dhaj-i-Dewari system in upper story walls, especially for the gable portion.

Structural action of Dhaj-i-Dewari construction

Researchers have extensively studied the performance of Dhajji houses in Kashmir and Turkey after earthquakes by examining the insides of their structures. Their findings have revealed that the brick infill walls within the timber frames play a critical role during an earthquake. These walls "work" by shifting slightly at the joints between the bricks and wood, which helps absorb a significant amount of the earthquake's energy. The structure becomes more resilient because of both the timber frame flexing and the building movement.

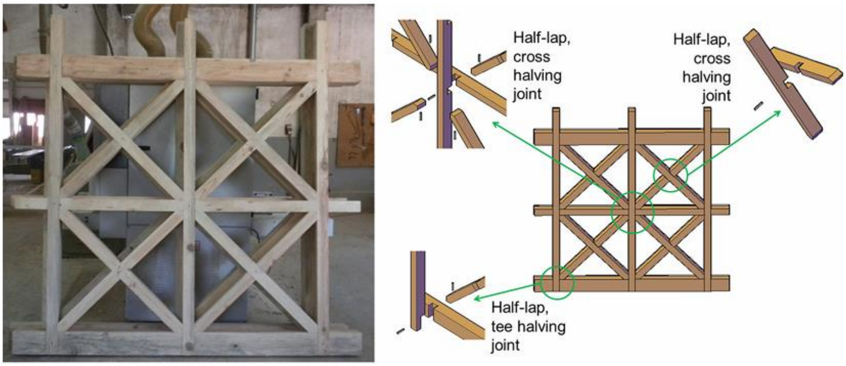


Fig. 13. Structural framing of Dhaj-i-Dewari systems *[9]*

In addition, the closely spaced wooden studs within the walls play another key role in preventing large cracks from spreading ("X" cracks) and stopping the brick panels from falling out entirely. Large panel failures were typically found in barns, not houses, and were often linked to rotten timbers, oversized panels, or a combination of both.

Another factor contributing to the good performance of Dhajji walls was the historical use of weak mortar. The weak mortar encouraged the bricks to slide along their joints instead of cracking when the wall panels deformed. This sliding also helped dissipate energy and reduce stress between the rigid brick panels and the flexible timber frame [9].

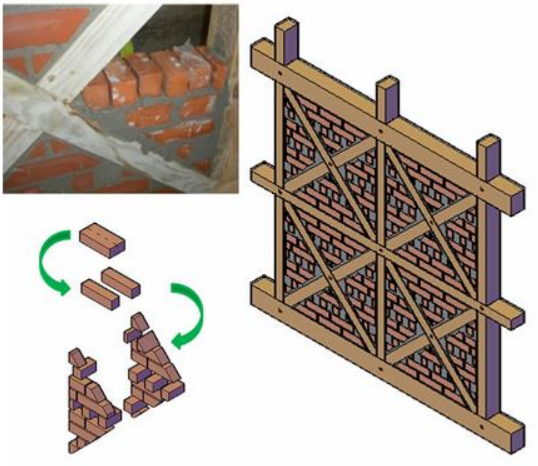


Fig. 14. Details of Dhaj-i-Dewari system *[9]*

The basic principle behind Dhajji walls' earthquake resilience is the absence of strong, rigid elements that attract the full force of the tremors. This allows the building to "survive" the earthquake by not directly resisting it. The movement during an earthquake can continue for a significant time before becoming severe enough to cause major damage.

In essence, the engineering behind Dhajji walls is simple. By subdividing the walls into smaller panels with studs and horizontal members, and using weak mortar, the design prevents large cracks that could lead to wall collapse. Additionally, the redundancy provided by the numerous interior and exterior walls in a typical house reduces the chance of catastrophic frame failure [9].

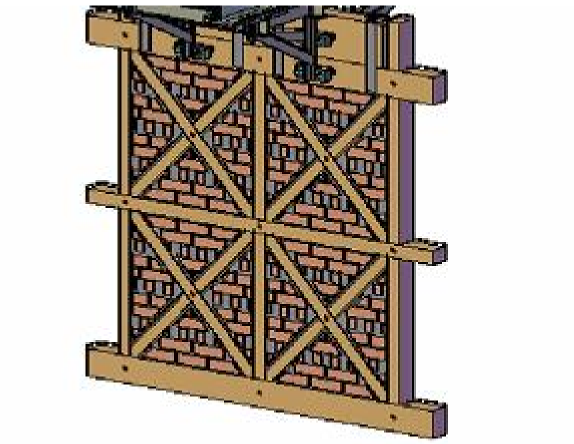


Fig. 15. Structural framing *[9]*

While these structures may not be exceptionally strong laterally, they do have a certain lateral capacity. They respond to earthquakes by swaying, rather than trying to resist them head-on with rigid components. This response is not elastic (springing back), but plastic (with some permanent deformation). When these structures lean during an earthquake, the cracking that occurs is minor and spread throughout the wall due to the interaction of the timber frame with the confined masonry. In simpler terms, even though the brick and mortar are brittle, the entire system behaves in a more flexible way than its components [10].

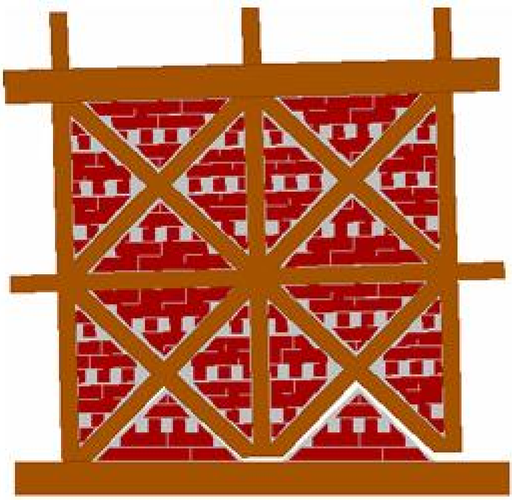


Fig. 16. Overturning of Dhaj-i-Dewari wall *[9]*

This design, with its small panels, weak mortar, and distributed movement, prevents the formation of large diagonal cracks that typically lead to collapse in unreinforced masonry walls under earthquake loads. The Dhajji wall structure maintains its structure through stud and cross-piece frameworks which operate during both horizontal and vertical seismic events. The non-destructive panel movement through construction joints generates substantial friction which decreases building shaking and protects other structural components [9].

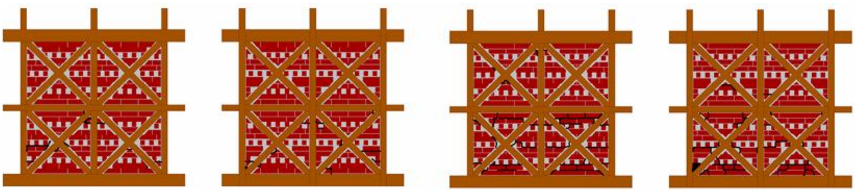


Fig. 17. Dhaj-i-Dewari wall showing its cracking patterns *[9]*

The Dhajji wall system demonstrates successful earthquake-resistant building construction methods according to all research findings.

[9]The system provides a basic yet powerful solution to safeguard people and their belongings when earthquakes strike. The system enables architects and engineers to build earthquake-resistant buildings which protect their occupants during seismic events [9].

Fig. 18. Dhaj-i-Dewari system *[4]*

5 Analysis

5.1 Structural Testing on the Systems of Kashmir

The seismic performance of traditional architectural and structural systems in Kashmir exceeds modern construction methods which lack retrofitting techniques. The following section examines three building systems which include unreinforced masonry (URM) and reinforced masonry (RM) and timber frame infill walls (TIW). The evaluation of these systems focuses on four essential criteria:

- Lateral Strength
- Ductility
- Energy Dissipation
- Stiffness

Lateral Strength

A building's ability to fight against horizontal forces determines its lateral strength. The measurement of lateral strength occurs through displacement tests that apply lateral loads to structures.

- **Wood**:
  The diagonal members of timber frame infill walls (TIW) showed increased displacement because they switched between tensile and compressive states. The diagonal members showed greater movement when they were under tension because their connections to the main frame structure tended to separate. The failure of one structural element caused the diagonals to experience greater displacement because

the connection points between them and the main frame structure experienced increased movement [9]. The 50kN load caused TIW walls to experience a 30mm displacement.

- **Masonry**:
  The maximum load capacity of reinforced masonry (RM) reached 55kN but unreinforced masonry (URM) managed to sustain 45kN. The displacement of URM reached 3.7mm when loads were applied but RM showed a displacement of 23.7mm [11].

Ductility
A material demonstrates ductility through its ability to deform elastically when it reaches peak load strength without losing substantial strength.

- **Wood**:
  The addition of infill to timber frame walls enhances ductility because the main resistance mechanism shifts from shear to shear and flexural behavior under strong pre-compression forces. The ductility of TIW walls reached 5.2 [9].
- **Masonry**:
  Testing revealed that URM exhibited a ductility value of 1.298, while RM demonstrated a significantly higher ductility of 4.968 [11].

Stiffness
A structure's ability to resist deformation when loads are applied determines its stiffness rating. The elastic modulus of a material determines its ability to recover its original form after deformation.

- **Wood**:
  The stiffness of TIW walls reached 3.75 kN/mm but the measurement results depended on the connection types of structural connections used in the construction [9].
- **Masonry**:
  URM exhibited a stiffness value of 13.48 kN/mm, while RM showed a stiffness of 8.63 kN/mm under similar conditions [11].

Energy Dissipated
A structure's energy dissipation capacity determines its ability to distribute seismic forces while protecting specific areas from concentrated damage.

- **Wood**:
  TIW walls demonstrated significant energy dissipation, with a value of approximately 8000 kN/mm [9].
- **Masonry**:
  URM dissipated 66 kN/mm of energy, while RM dissipated 616 kN/mm under comparable loading conditions [11].

5.2 Comparison Chart

Table 1. Comparison Chart

S. NO.	TIW	URM	RM
LATERAL STRENGTH	30mm	3.7mm	23.7mm
DUCTILITY	5.2	1.298	4.968
STIFFNESS	3.75kN/mm	13.48kN/mm	8.63kN/mm
ENERGY DISSIPATED	8000kN/mm	66kN/mm	616kN/mm

Findings

- The displacement range of TIW structures exceeds what URM and RM structures can achieve.
- TIW shows ductility comparable to RM, significantly outperforming URM.
- TIW has the lowest stiffness values, suggesting its ability to maintain elastic deformation.
- The seismic load handling capacity of TIW exceeds that of masonry structures because it demonstrates superior energy dissipation capabilities.

5.3 Analysis of Earthquake-Resistant Construction Techniques

The evaluation of earthquake-resistant construction methods depends on the parameters which Section 4.1 describes.

Table 2. Analysis of earthquake resistant construction

	Corner Braces	Ties	Scarp Walls	Taq System	Dhaj-i-Dewari System
Ductility	Yes	Yes	No	Yes	Yes
Deformability	No	Yes	No	Yes	Yes
Robustness	No	No	No	No	Yes

The use of wood as a structural component helps buildings achieve better ductility because it enables them to handle dynamic forces more effectively. The stability and seismic performance of scarp walls suffer because they depend mainly on mass and gravity for prevention of overturning. The required flexibility for scarp walls becomes possible through wood reinforcement which solves their structural weaknesses.

The Dhaj-i-Dewari system demonstrates outstanding performance for earthquake-risk zones. The timber frames with lightweight masonry infill enable structures to distribute seismic forces uniformly throughout their construction. The buildings follow a design principle which allows them to withstand earthquakes by shaking but remaining standing. The Dhaj-i-Dewari system achieves exceptional performance in seismic areas because it provides controlled flexibility and effective energy dissipation.

5.4 Survey results specific to the study region

The research team began by interviewing 30 families who lived in Kashmir to understand their firsthand accounts of the area. The researchers distributed 50 questionnaires to people who spent time in Kashmir even though they lived elsewhere. The researchers selected these individuals because they believed these people would understand traditional Kashmiri houses even though they lived outside the region. This includes structures such as *Dhaj-i-Dewari* (traditional mud-brick houses) and *Taq* (a type of timber house), both of which are prominent architectural features in the region. By involving this broader group, the study sought to capture a wider range of perspectives on how these iconic house styles are perceived and used in the cultural context of Kashmir.

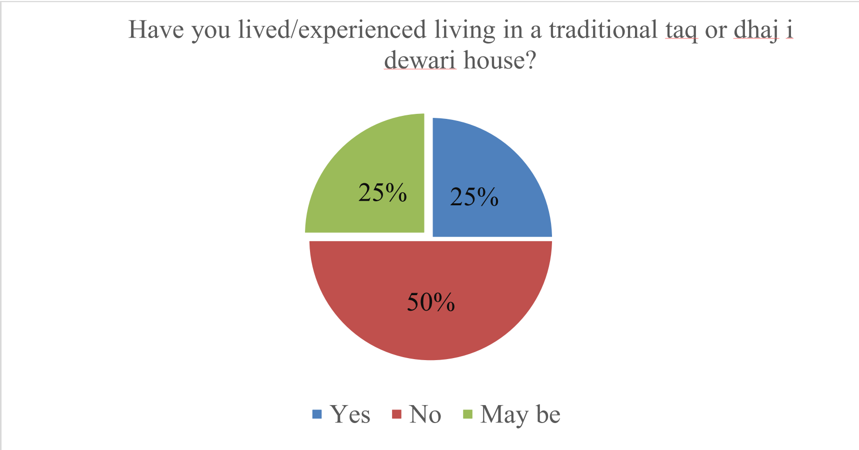


Fig. 19. Survey 1

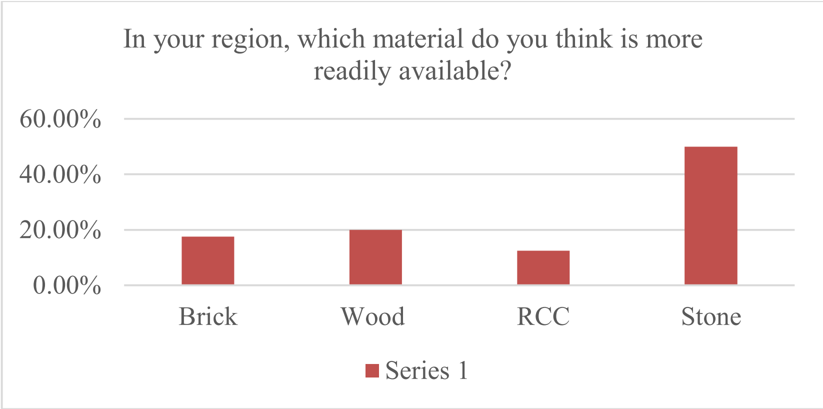


Fig. 20. Survey 2

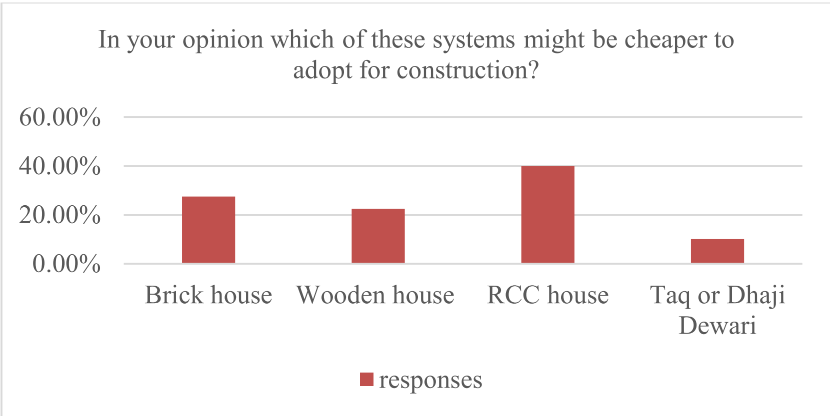
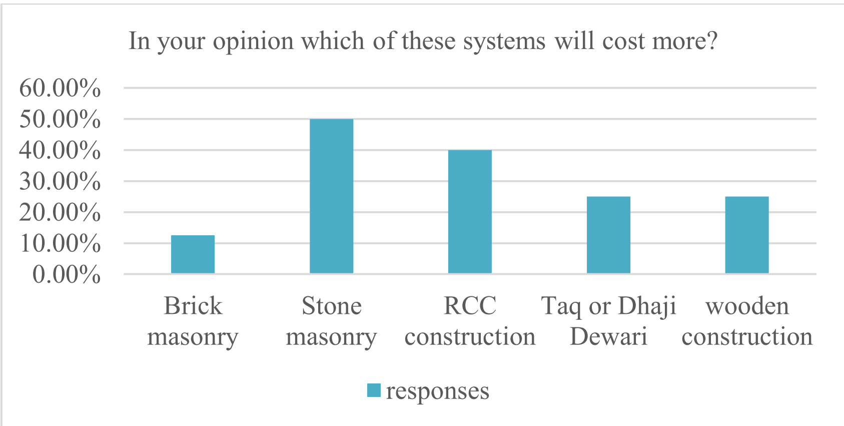


Fig. 21. Survey 3



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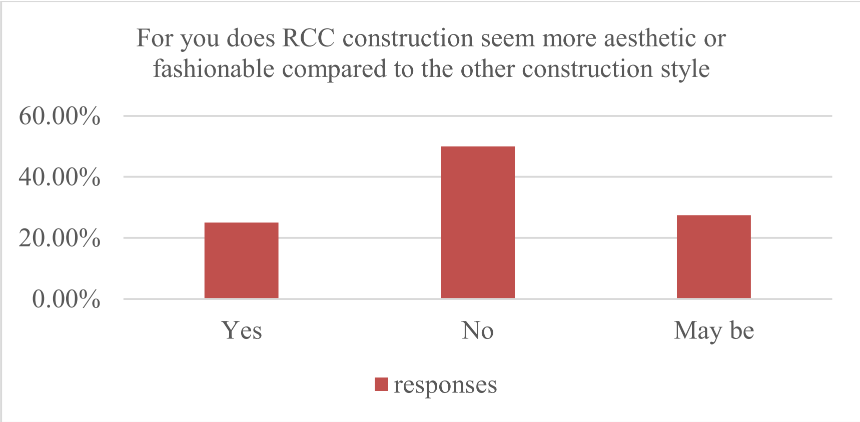

Fig. 23. Survey 5

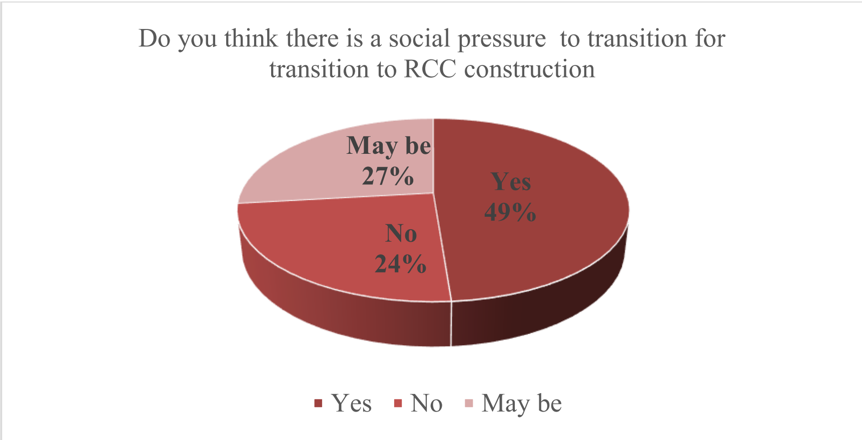

Fig. 24. Survey 6

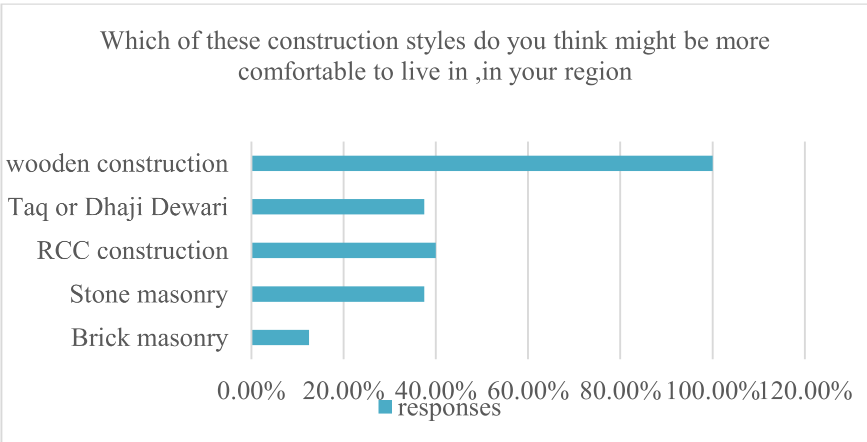

Fig. 25. Survey 7

6 Discussion & Conclusion

An abundance of indigenous knowledge has contributed to the seismic resilience of vernacular building in Kashmir, as evidenced by the research of earthquake-resistant conventional construction methods. Because of their distinct structural compositions, the Taq and Dhaj-i-Dewari systems, which were created by millennia of empirical experience, have exceptional flexibility to seismic pressures. These historic designs' incorporation of cross-bracing and timber runners improves flexibility, ductility, and energy dissipation

The Taq and Dhaj-i-Dewari systems, two historic earthquake-resistant building methods in Kashmir, have been analysed and found to have major seismic performance advantages. When compared to contemporary brick construction techniques, these traditional technologies exhibit higher lateral strength, ductility, energy dissipation, and stiffness. In these crucial areas, the Taq system's timber-infilled walls outperform unreinforced masonry, showing greater potential displacements and ductility levels comparable to reinforced masonry. The TIW walls demonstrate the lowest stiffness values because they can absorb elastic deformations while effectively dissipating energy according to their energy dissipation capabilities.

The Dhaj-i-Dewari system uses wooden frames to make buildings more elastic and robust. The light masonry packed into timber frames ensures that a structure shakes but not collapse as it distributes the forces evenly

The survey results denote a shift towards contemporary architecture styles despite the everlasting significance of traditional architecture. This shift has been due to a number of factors, including changing aesthetic tastes, skill shortages, the cost and availability of building materials, and economic restrictions.

Traditional construction has been abandoned due to factors like the rising cost of wood, the shortage of skilled masons and workers, societal pressures, the desire for modern aesthetics, and the need to build buildings within a short seasonal window.

The study has proven the benefits of traditional construction in Kashmir due to greater energy dissipation and structural durability under seismic load. While modern RCC-based architecture has revealed serious structural flaws when not constructed with adequate seismic reinforcement. The decline of traditional systems in Kashmir has also been impacted by growing ecological concerns over timber usage. Regulations restricting timber usage also owe to a shift to contemporary materials.

The forementioned reasons necessitate the need for a hybrid approach that substitute traditional materials and technology with innovations that can endure in contemporary times. For instance, bamboo can be used as an alternate to the role played by timber in traditional construction systems. Similarly, a feasible way to incorporate traditional methods without causing environmental deterioration may be offered through engineered timber solutions and sustainable forestry practices.

7 Way Forward

This study clearly identifies the strength of traditional materials and construction systems in aseismic construction. However, survey data also identifies problems with the systems that owe to people transitioning towards contemporary architecture systems and materials.

In section 4.1, desirable properties of aseismic materials are identified and elaborated. Upon analyzing traditional construction systems in Kashmir, we identify wood and mud masonry to be the materials satisfying the properties mentioned in section 4.1. Similarly other material sets working in unison could be identified that replace the forementioned materials to perform better in seismic conditions. These substitutions based on restrictions, availability and economical viability will initiate a hybrid system which accentuates the favorable aspects of both traditional and contemporary construction.

- **Adobe with Cane** [12]
  Similar to the Dhaj-i-Dewari systems, however, the timber is substituted with cane reinforcements inside adobe masonry. The cane here provides ductility to the structure to allow elastic deformations. It also makes the structure robust enough to avoid complete failure.

- **Brick with PCM and steel bars** [12]
  Brick masonry with steel reinforcements makes the structure robust and ductile as the steel here replaces the timber in traditional construction. After the masonry wall is completed, it is plastered over with polymer cement mortar. This enhances the elastic behavior of the masonry wall

- **Polymer cross bracing for brick masonry** [12]
  A cross bracing over traditional brick masonry can be used to achieve the role of timber in traditional Dhaj-i-Dewari construction. This cross bracing can be done with any materials satisfying the properties mentioned in Section 4.1.

  Fiber reinforced polymer or old car tire strips can easily be used to incorporate recycling as well as environmental aspects.

There is a need of multi-disciplinary collaboration between stakeholders inclusive of policymakers, architects, and engineers in order to develop guidelines that incentivize the hybrid approach of construction system. Public awareness campaigns, skill development programs, and research initiatives can further support the adoption of these resilient construction methods. By bridging tradition with innovation, Kashmir can build a safer, more sustainable future.

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List of Abbreviations

URM	– Unreinforced Masonry
TIW	– Timber Infill Walls
RM	– Reinforced Masonry
PCM	– Polymer Cement Mortar

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