



STONE MASONRY GUIDELINES FOR PAKISTAN

PRACTICAL MANUAL

Design, Construction and
Seismic Provisions for Safe
and Durable Structures



QUALITY
CONSTRUCTION



ENGINEERED
BUILDING



RESILIENT
COMMUNITY

2026 EDITION

IMPORTANT SCOPE, SAFETY, AND REGULATORY NOTICE

Purpose and hazard scope. This practical manual addresses seismic resilience and earthquake related hazards for stone masonry construction in northern Pakistan. It is not a general multi-hazard design standard. Site, slope, drainage, fire, and durability provisions are included only where they materially affect structural reliability, earthquake life safety, or safe construction.

Intended users. The document is intended for engineers, architects, local authorities, disaster management and housing agencies, technical training institutions, site supervisors, and trained masons and carpenters involved in rural stone masonry construction.

Prescriptive scope and exclusions. The prescriptive provisions apply only to simple, regular, single-story private rural dwellings on approved stable ground and within the stated dimensional and construction limits. They shall not be directly applied to schools, hospitals or other healthcare facilities, community, or public assembly buildings, two-story or multistory buildings, buildings on uncontrolled fill or unstable slopes, buildings dependent on retaining walls, or buildings with large openings, irregular plans, heavy roofs, or dimensions outside the stated limits. Such projects require project specific design and review by qualified structural engineers and, where necessary, geotechnical engineers.

Code hierarchy. This guideline is a supplementary practical manual. It does not supersede the Building Code of Pakistan-Seismic Provisions 2007 (BCP-SP-2007), Building Code of Pakistan 2021 (BCP-2021), applicable law, local bylaws, or an approved project specific design. Where a conflict occurs, the governing statutory requirement and approved engineering design shall prevail.

Interim project criteria. Any provision identified as an interim project criterion is intended for controlled pilot or project use only. It is not a national standard and shall not be copied into statutory requirements without appropriate validation and formal adoption.

Performance expectation. The primary objective is life safety and prevention of sudden collapse. Even a building that complies with these guidelines may experience cracking and repairable damage during earthquake shaking; zero damage performance is not claimed.

Vernacular systems and rubble masonry. Bhatar denotes thick stone masonry tied by horizontal timber lacing and through-wall cross-ties; Taq is a related timber laced masonry tradition; and Dhajji Dewari is a timber frame subdivided into small panels with masonry infill. Their performance depends on sound timber, reliable connections, good masonry,

workmanship, condition, and maintenance. Arbitrary imitation is not a substitute for verified construction. The provisions may be used for coursed or random rubble masonry only when the specified wall thickness, stable bedding, interlocking, bonded hearting, through thickness ties, bands, and connections can be achieved. Loose core, severely delaminated, or unstable rubble masonry falls outside the prescriptive route until corrected or specifically engineered.



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MESSAGE FROM THE VICE CHANCELLOR, UET PESHAWAR

The Khyber Pakhtunkhwa region has traditionally relied on local stone for construction; however, our seismically active environment necessitates evolving these methods to ensure public safety. At the University of Engineering and Technology (UET) Peshawar, our mission is to translate academic research into practical societal solutions. The newly developed guidelines for stone masonry fulfill this institutional commitment by integrating modern seismic safety standards with traditional practices, enabling communities to build secure homes using accessible local materials.



This critical endeavor required extensive institutional collaboration. I extend my profound gratitude to the researchers in the Department of Civil Engineering at UET Peshawar for their tireless dedication. Furthermore, this initiative was made possible through the steadfast support of our partners: the Provincial Disaster Management Authority (PDMA), Khyber Pakhtunkhwa, and the China Pakistan Belt and Road Joint Laboratory on Infrastructures. Together, this collective effort has produced a foundational resource that will guide policymakers, local builders, and development organizations toward safer community infrastructure.

Prof. Dr. Muhammad Sadiq Khattak

Vice Chancellor

University of Engineering and Technology (UET), Peshawar

MESSAGE FROM THE DIRECTOR GENERAL, PDMA KHYBER PAKHTUNKHWA

In Pakistan's mountainous regions, stone masonry remains an essential and affordable housing solution. However, tragic losses during the 2005 and 2015 earthquakes highlighted the severe risks of inadequately constructed stone buildings. The stone masonry guidelines for Pakistan offer a timely, practical framework to address this vulnerability, blending indigenous construction knowledge such as Bhatar, Taq, and Dhajji Dewari, with contemporary seismic engineering and quality control measures.



PDMA Khyber Pakhtunkhwa views resilient construction as foundational to disaster risk reduction. By detailing critical practices from proper site selection and continuous seismic bands to essential mason training, these guidelines equip local authorities, engineers, and builders to improve rural housing safety. While field application must remain consistent with the Building Code of Pakistan and site-specific technical assessments, this document provides a vital roadmap for safer development.

I extend my profound appreciation to the University of Engineering and Technology Peshawar, the China-Pakistan Belt and Road Joint Laboratory on Infrastructures, and all contributing experts. Together, we are fostering a culture of safer construction to protect lives and livelihoods across our hazard prone regions.

Mr. Arifullah Awan

Director General

Provincial Disaster Management Authority (PDMA)

Khyber Pakhtunkhwa

MESSAGE FROM THE DIRECTOR, CHINA-PAKISTAN BELT AND ROAD JOINT LABORATORY

Northern Pakistan's mountain communities have long relied on locally available stone for housing. However, the Himalayan, Karakoram, and Hindu Kush regions are highly seismic, and past earthquakes have demonstrated the vulnerability of poorly connected stone masonry. Improving safety while retaining this practical construction tradition is therefore essential.



As Director of the China-Pakistan Belt and Road Joint Laboratory on Smart Disaster Prevention of Major Infrastructures, I am pleased to see China-Pakistan cooperation reflected in this practical engineering outcome. In remote mountain areas, difficult access and the high cost of cement and steel make complete replacement of stone masonry with reinforced concrete unrealistic. A more feasible approach is to establish safer, standardized, and inspectable construction methods based on existing materials and technologies.

The Stone Masonry Guidelines for Pakistan address this need by combining indigenous systems such as Bhatar, Taq, and Dhajji Dewari with selected seismic technologies from China. They emphasize site screening, through-stones and ties, interlocked corners, horizontal bands, roof anchorage, material acceptance, and construction quality control, while following applicable Building Code of Pakistan provisions and prioritizing life safety.

Together with Prof. Dr. Khan Shahzada, I sincerely thank UET Peshawar, PDMA Khyber Pakhtunkhwa, and all Chinese and Pakistani colleagues who contributed to these Guidelines. I believe this joint effort will provide a useful reference for engineers, authorities, builders, training institutions, and communities, and will help improve the seismic safety of housing in northern Pakistan.

Prof. Dr. Zhao-Dong Xu

Director, China-Pakistan Belt and Road Joint Laboratory on Smart Disaster Prevention of
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中国-巴基斯坦重大基础设施智慧防灾“一带一路”联合实验室主任

寄语

巴基斯坦北部山区长期依赖当地石材建造住宅。然而，喜马拉雅、喀喇昆仑和兴都库什地区地震活动强烈，历次地震表明，连接薄弱的石砌体建筑十分脆弱。因此，在保留这一实用建造传统的同时提高安全性至关重要。



作为中国-巴基斯坦重大基础设施智慧防灾“一带一路”联合实验室主任，我很高兴看到中巴合作体现在这一务实的工程成果中。偏远山区交通不便，水泥和钢材成本较高，完全以钢筋混凝土取代石砌体并不现实。更可行的方案，是在现有材料与技术基础上建立更安全、规范、可检查的建造方式。

《巴基斯坦石砌体抗震建造规程》通过结合Bhatar、Taq和Dhajji Dewari等本土体系与中国部分抗震技术来回应这一需求。规程重点强调场地筛查、穿墙石与拉结、转角咬合、水平圈带、屋盖锚固、材料验收和施工质量控制，同时遵循《巴基斯坦建筑规范》的相关规定，并将生命安全置于首要位置。

我谨与 Khan Shahzada 教授一道，向白沙瓦工程技术大学、开伯尔-普什图省灾害管理局以及所有为本规程做出贡献的中巴同仁表示诚挚感谢。我相信，这一共同努力将为工程师、主管部门、建造人员、培训机构和社区提供有益参考，并有助于提高巴基斯坦北部住宅的抗震安全水平。

徐赵东 教授

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PREFACE

The mountainous regions of northern Pakistan have long relied on stone masonry because of local material availability, established construction practice, and the thermal mass valued in cold mountain climates. Recurrent earthquakes across the Himalayan, Karakoram, and Hindu Kush regions have also exposed the severe vulnerability of non-engineered rubble stone construction. The 2005 Kashmir earthquake and the 2015 Hindu Kush earthquake showed that catastrophic loss is strongly influenced by site instability, weak construction, and discontinuous structural load paths rather than by the mere use of stone.

A policy that simply prohibits stone construction without providing affordable alternatives is unlikely to be effective in remote valleys where industrial materials and specialist labor are limited. The engineering task is therefore to transform disconnected, brittle masonry into an integrated structural system that can sustain earthquake induced deformation without sudden collapse. Ordinary unreinforced stone walls commonly fail by multi-leaf delamination, corner separation, and out of plane overturning. Indigenous systems such as Bhatar (stone masonry tied by horizontal timber lacing and through-wall cross-ties), Taq (a related timber laced masonry tradition), and Dhajji Dewari (a timber frame subdivided into small masonry infill panels) provide important structural lessons. Their historical performance, however, depends on workmanship, member condition, connection quality, building age, and maintenance; arbitrary replication does not guarantee safety.

This guideline addresses the gap by combining locally demonstrated seismic mechanisms with verifiable contemporary engineering details. Rather than following traditional practice or defaulting to expensive reinforced concrete, the manual emphasizes regular building configuration, through-stones, or equivalent ties between wall wythes, interlocked corners and junctions, continuous horizontal bands, controlled openings, and positive roof anchorage. The primary audience comprises engineers, architects, local authorities, disaster management and housing agencies, training institutions, site supervisors, and trained rural construction practitioners.

The document is aligned with the Building Code of Pakistan-Seismic Provisions 2007 (BCP-SP-2007) and the Building Code of Pakistan 2021 (BCP-2021). It is a supplementary practical manual and does not replace mandatory code provisions, applicable law, local bylaws, or project specific structural and geotechnical design; the governing requirements prevail in case of conflict. Its prescriptive provisions are limited to simple, regular, single-

story private rural dwellings on approved stable ground. Schools, hospitals, community, and public assembly buildings, two-story or multistory buildings, and projects outside the stated site, geometry, opening, roof, or dimensional limits require qualified engineering design and review.

Durability is part of seismic safety rather than a separate post-construction concern. Freeze-thaw exposure, persistent moisture, poor drainage, timber decay, biological attack, and corrosion of connectors can progressively weaken the load path. Material selection, moisture separation, protective treatment, inspection, and maintenance shall therefore be considered from design and construction through the service life.

The performance objective is life safety and prevention of sudden collapse. Repairable cracking and other damage may occur under severe shaking, even when these provisions are followed.

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CHAPTER 1

INTRODUCTION AND TECTONIC CONTEXT

1.1 Background

Stone masonry is widely used in the Himalayan, Karakoram, and Hindu Kush regions of Pakistan, particularly in Gilgit-Baltistan, Khyber Pakhtunkhwa, and adjoining areas of Azad Jammu and Kashmir (Ali & Muhammad, 2011). In many mountain communities, its use is not primarily a matter of architectural preference. It reflects the local availability of stone, limited road access, high transportation costs for cement and steel, established construction customs, and the thermal mass required for buildings exposed to cold winters (Sharaf, 2020; De Berardinis et al., 2014).

The economic logic of stone masonry is therefore strong. Stone may be collected from local quarries, fields, slopes, rivers, or construction excavations. It generally requires less long-distance transport than industrial materials and can be placed using locally available labor and basic tools. These advantages explain why stone masonry continues to be constructed even after earthquakes have repeatedly demonstrated its vulnerability (Manandhar et al., 2026).

The central engineering problem is consequently not whether stone masonry should continue to exist, but how it can be transformed from a collection of loosely connected, brittle components into an integrated structural system capable of sustaining earthquake induced deformation without collapse. The catastrophic consequences of the 2005 Kashmir earthquake resulted primarily from weak buildings, inadequate structural integrity, poor construction, and the widespread absence of earthquake resistant features. Observations also showed that well maintained traditional timber reinforced systems generally performed better than ordinary unreinforced masonry (Bothara and Hiçyılmaz, 2008). The regional seismic context is shown in Figure 1.1.

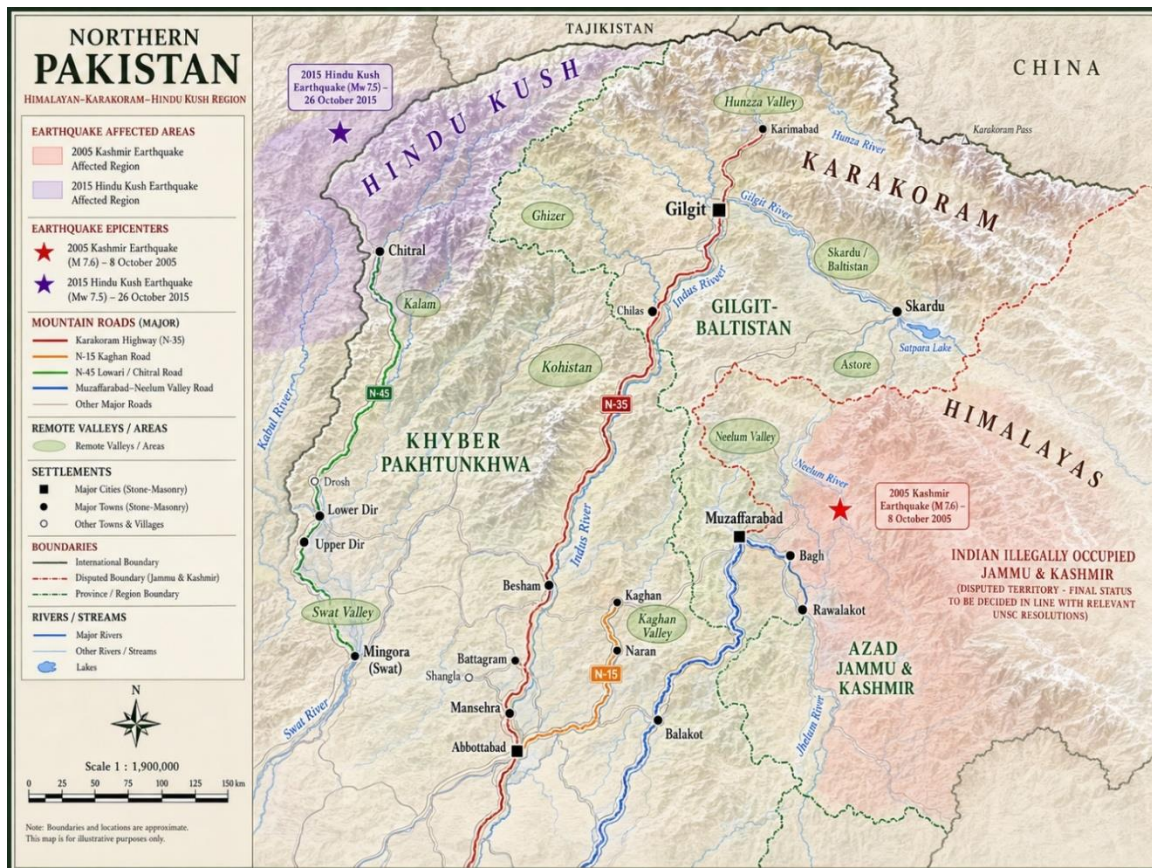


Figure 1.1. Regional seismic context of northern Pakistan.

1.2 Seismic Setting of Northern Pakistan

The Himalayan region is among the most seismically active mountain belts affecting Pakistan. The 2005 Kashmir earthquake occurred near the western end of this system and caused intense shaking in areas where non-engineered stone masonry, brick masonry, and deficient reinforced concrete construction formed a large proportion of the building stock. Historical earthquakes affecting Kashmir and northern Pakistan demonstrate that destructive shaking is not an isolated occurrence but a recurring regional hazard (Bothara & Hıçyılmaz, 2008).

The October 26, 2015 Hindu Kush earthquake had a moment magnitude of 7.5 and affected a broad area of northern Pakistan. Although its source depth and damage distribution differed from the relatively shallow 2005 event, it again exposed the vulnerability of rural houses made from rubble stone, mud mortar, weak masonry units and poorly connected roofs. In both earthquakes, site effects, slope instability and weak cut and fill platforms intensified building losses in some mountain settlements (Ismail & Khattak, 2015; Ismail & Khattak, 2016; United States Geological Survey [USGS], 2015).

Seismic forces are inherently dynamic, generating inertial forces throughout the building's mass during ground acceleration. In properly detailed structures, these forces transfer through continuous load paths from the diaphragms, through the shear walls, and into the foundation. In non-engineered stone masonry, this load path is frequently discontinuous. Roof beams often rest unanchored, orthogonal walls lack mechanical interlocking, and multi-wythe walls lack transverse ties. As a result, seismic excitation acts upon isolated structural fragments rather than a monolithic system, a vulnerability illustrated by the contrasting load paths in Figure 1.2.

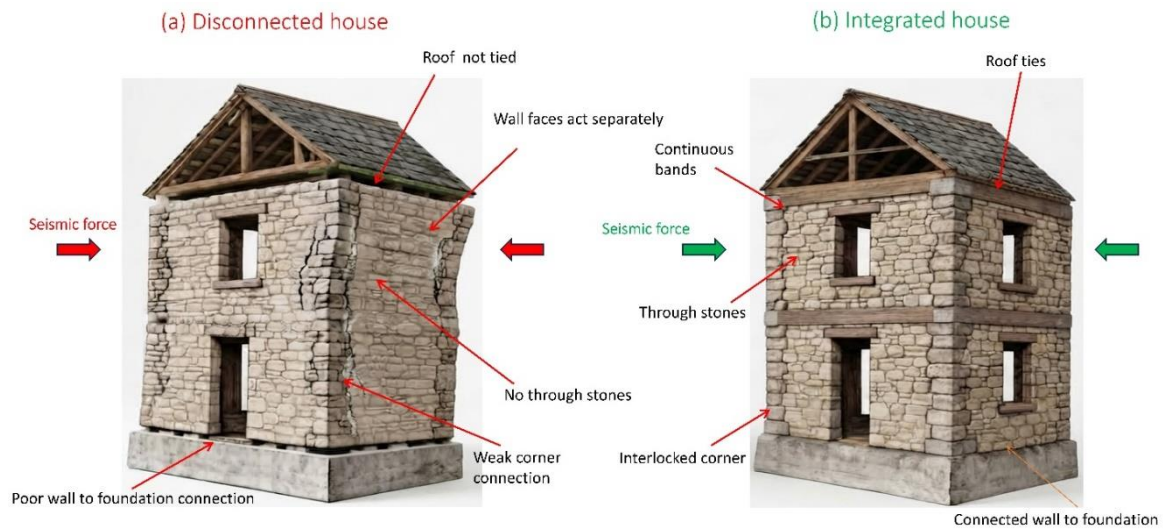


Figure 1.2. Seismic load paths in disconnected and integrated stone houses.

1.3 Human and Physical Consequences of the 2005 Earthquake

The October 8, 2005 Kashmir earthquake had a magnitude of 7.6 and caused exceptional loss of life and property in Pakistan administered Kashmir and the then North-West Frontier Province. More than 74,000 people were killed, approximately 128,000 were injured, and about 3.5 million people were affected. Approximately 2.8 million people became homeless, while around 600,000 buildings were damaged or destroyed. Thousands of educational and health facilities were also rendered unusable (Bothara & Hıçyılmaz, 2008).

Since independence, northern Pakistan has experienced repeated damaging earthquakes. The December 28, 1974 Pattan earthquake caused severe destruction in the Indus valley region and reportedly killed about 5,300 people, injured about 17,000, and left roughly 60,000 people homeless (Chandra, 1975). The 2005 Kashmir earthquake produced catastrophic loss across northern Pakistan and Pakistan administered Kashmir, while the 2015 Hindu Kush earthquake again exposed the vulnerability of rural masonry, weak roof

connections, unstable slopes, and cut and fill platforms (Bothara & Hiçyılmaz, 2008; Ismail & Khattak, 2015; Ismail & Khattak, 2016). These events show that recurring seismic hazard must be addressed together with building integrity and site safety.

These observations demonstrate that seismic disaster is intrinsically tied to structural performance. Ground shaking created the demand, but the large-scale collapse of deficient buildings converted that demand into mass casualties. Heavy stone walls and roofs produced substantial inertial forces, while brittle masonry and weak connections provided little deformation capacity. Once walls separated or overturned, the weight of falling stone, earth, timber, and concrete left occupants with limited opportunity to escape.

The 2005 earthquake also revealed a critical contrast. Ordinary random rubble and semi dressed stone masonry buildings suffered extensive collapse, whereas well maintained Dhajji Dewari, Bhatar, and related timber reinforced systems generally sustained less severe damage (Bothara & Hiçyılmaz, 2008). This contrast shows that stone itself is not the sole cause of vulnerability. Structural arrangement, continuity, workmanship, and connection quality are equally decisive. The observed contrast in building performance is illustrated in Figure 1.3.

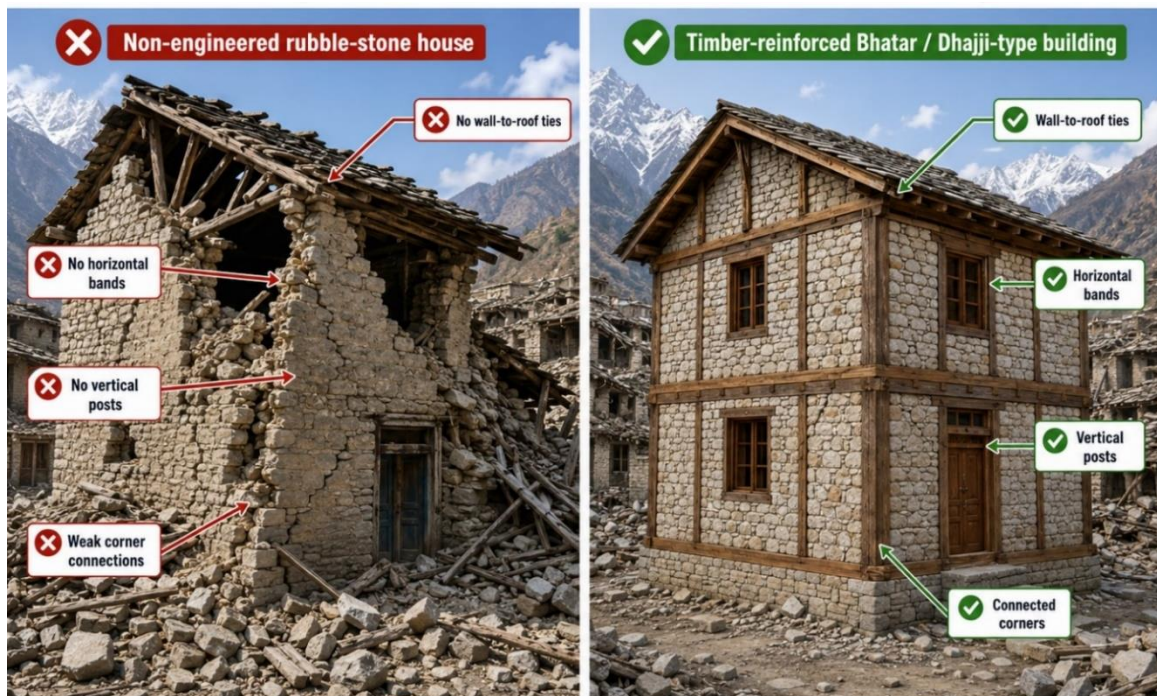


Figure 1.3. Post-earthquake performance of unreinforced and timber reinforced houses.

1.4 Socio-Economic Dependence on Stone Masonry

A policy that simply prohibits stone construction without providing an affordable substitute is unlikely to be effective in remote Pakistani valleys. Cement, reinforcement steel, manufactured masonry units, formwork, and qualified labor may be expensive or intermittently available. Difficult terrain further increases transportation costs. Local households may consequently reconstruct with the same vulnerable materials even after a damaging earthquake.

Economic safety must therefore be based on selective use of higher cost materials at locations where they provide the greatest structural benefit. A relatively small quantity of timber, cement, steel strap, wire mesh, or reinforced concrete can be strategically placed to connect walls, restrain openings, anchor roofs, and prevent wall leaf separation. The relevant question is not how much industrial material can be added, but how efficiently limited resources can be used to establish structural integrity.

This approach is consistent with the regional evidence presented by Bothara and Hiçyılmaz (2008), the seismic improvement principles described by Bothara and Brzev (2011), the experimentally observed behavior of Dhajji walls reported by Ali et al. (2012), and the broader historical evidence for timber laced masonry discussed by Gülkan and Langenbach (2021).

1.5 Objective and Scope

The objective of this document is to establish a technically rational, code aware and socio-economically feasible framework for safer stone masonry in the hilly areas of Pakistan. The primary performance objective is life safety and prevention of sudden collapse. Damage free performance is not claimed. The guideline also aims to prevent non-structural construction advice from being applied at sites where landslide, rockfall, erosion, liquefaction, fill instability or retaining wall failure governs the risk.

The document addresses:

- Indigenous timber laced masonry systems;
- Material and labor constraints;
- Vulnerabilities of non-engineered rubble stone walls;
- Earthquake failure mechanisms;

- Low cost geometric and construction improvements;
- Timber and reinforced concrete confinement;
- Wire mesh and gabion-based concepts; and
- Implementation through training, demonstration, inspection, and policy.

The prescriptive provisions do not apply to multistory, educational, healthcare, community, or public assembly buildings. Furthermore, they exclude structures located on filled or unstable slopes, as well as those dependent on retaining walls. Finally, the provisions do not cover buildings with large openings, irregular plans, heavy roofs, or dimensions outside the stated limits. Such buildings shall be designed and reviewed by qualified structural engineers and, where necessary, geotechnical engineers.

1.6 Regulatory Basis and Hierarchy

The Building Code of Pakistan - Seismic Provisions 2007 is the primary national reference for seismic zoning, design ground motion, site considerations, structural analysis, detailing, inspection and testing (Pakistan Engineering Council, 2007). Statutory Regulatory Order (S.R.O.) 971(I)/2008 made the seismic provisions applicable to engineering design of buildings and related components (Pakistan Engineering Council, 2008). The Building Code of Pakistan 2021 and applicable provincial or local bylaws govern general building requirements and approvals (Pakistan Engineering Council, 2021; United Nations Development Programme, 2015). This guideline shall be read beneath that regulatory framework and shall not be used to reduce a code requirement.

Where BCP-SP-2007 does not provide a direct prescriptive detail for low strength rubble stone masonry, this document uses comparable guidance from the Earthquake Reconstruction and Rehabilitation Authority (ERRA), Nepal National Building Code (NBC) 203, the World Housing Encyclopedia (WHE), and published comparative research. Such comparative provisions are identified in Appendix A and shall be treated as minimum construction guidance, not as a replacement for engineering design.

1.7 Seismic Hazard and Performance Objective

Before design begins, the project team shall identify the Building Code of Pakistan (BCP) seismic zone, site class and any site-specific hazard information required by the competent authority. Pakistan is divided into seismic zones 1, 2A, 2B, 3 and 4 under BCP-SP-2007.

This guideline does not assign a zone from a district name alone; the official BCP map and project location shall be used.

For prescriptive single-story dwellings, the target is Life Safety at the BCP design earthquake: significant cracking and repairable damage may occur, but global or partial collapse, roof loss, wall leaf separation and loss of a survivable space are to be prevented. Buildings assigned to higher importance categories or required to remain operational after an earthquake require explicit engineering performance objectives and shall not use this prescriptive route.

1.8 Meaning of Mandatory Language

In this guideline, “shall” identifies a mandatory condition for claiming compliance with the prescriptive package; “should” identifies a strong recommendation that may be varied only with recorded technical justification; and “may” identifies an option. Numerical values marked “interim project criterion” are requirements adopted by this document for pilot implementation and are not represented as existing provisions of BCP-SP-2007. The scope and implementation sequence are summarized in Figure 1.4.

The minimum hazard and performance actions required before using the prescriptive route are summarized in Table 1.1.

Table 1.1. Hazard and performance requirements for prescriptive application.

Hazard/performance item	Required action
BCP seismic zone	Record on the first sheet of the project file and approved drawings
Site class/ground condition	Confirm by competent investigation; do not assume rock simply because the site is mountainous
Slope and platform hazards	Screen under Chapter 4; refer high risk sites for geotechnical assessment
Prescriptive performance target	Life safety/no sudden collapse at code design earthquake; damage is expected
Important or irregular buildings	Project specific structural design and enhanced inspection

The hierarchy used to resolve conflicts and identify the role of each source is set out in Table 1.2.

Table 1.2. Hierarchy of regulatory, technical, and research sources.

Priority	Source	How it is used
1	Applicable Pakistani law, BCP-SP-2007, BCP-2021 and local bylaws	Governing requirements; prevail over this guideline
2	Approved site specific structural and geotechnical design	Controls the individual project and any engineered exception

Priority	Source	How it is used
3	Earthquake Reconstruction and Rehabilitation Authority (ERRA) reconstruction and resilient construction guidance	Pakistan specific implementation, site, and workmanship guidance
4	Nepal National Building Code (NBC) 203, World Housing Encyclopedia (WHE) publications, and published comparative research	Comparative prescriptive details where Pakistan documents are silent
5	Published experimental and reconnaissance research	Mechanistic evidence and limitations
6	Interim criteria developed in this guideline	Must be validated by pilot work and clearly labeled as project criteria

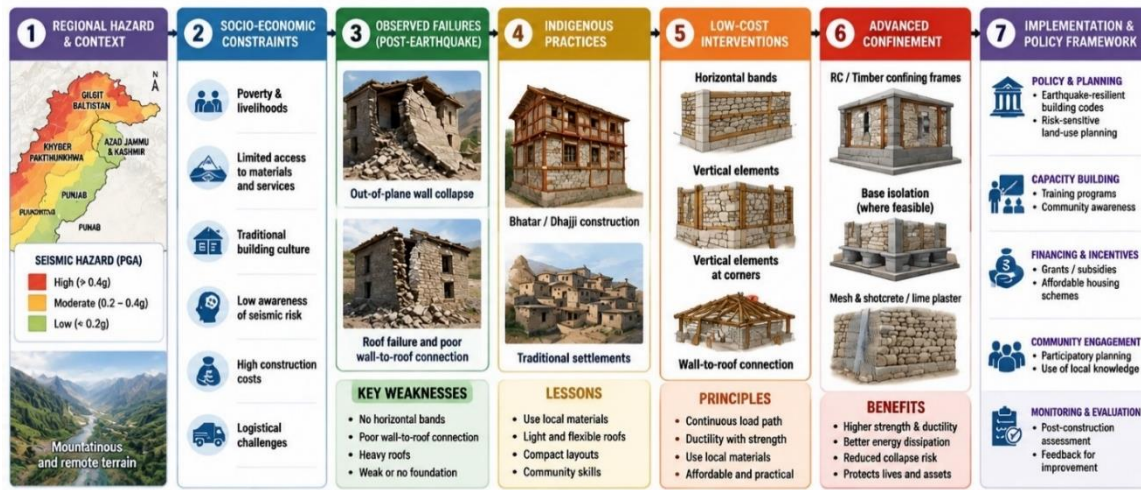


Figure 1.4. Scope and implementation framework.

CHAPTER 2

INDIGENOUS SEISMIC PARADIGMS

2.1 Indigenous Engineering as Structural Knowledge

Traditional construction in earthquake prone mountain regions developed through repeated interaction with local materials, climate, workmanship, and past seismic experience. Such systems were not derived from modern analytical codes, but some incorporate structural principles now recognized as beneficial: reduced unsupported masonry dimensions, distributed timber reinforcement, flexible connections, multiple load paths, confinement, and frictional energy dissipation.

Two systems are particularly relevant to Pakistan: Bhatar is a thick stone masonry system in which continuous horizontal timber runners on both wall faces are tied through the wall thickness by cross-ties. Taq refers to a related regional timber laced masonry tradition. In this manual, Bhatar is used consistently as the primary term for the paired face lacing system, while Taq is retained where the source material or local tradition is specifically discussed.

2.2 Bhatar and Taq Construction

2.2.1 Structural Arrangement

Bhatar construction, closely related to Taq construction, uses horizontal timber runners embedded within stone masonry. Timber members are placed along the wall faces and linked through the wall thickness by transverse pieces. Together, the longitudinal and transverse members form a ladder like arrangement at selected levels (Carabbio et al., 2018).

The system improves behavior in several ways. First, the through-wall cross-ties restrain the inner and outer wall faces, reducing the tendency for the two wythes to separate. Second, continuous horizontal face runners tie wall segments together and bridge local discontinuities in the stonework. Third, timber bands connect cross walls when properly joined at corners. Fourth, the timber provides limited tensile and flexural resistance where unreinforced stone masonry is weak. Field stages of timber laced stone construction are shown in Figure 2.1.

(a)



(b)



Figure 2.1. Timber laced stone masonry during construction (Location: Diamir; Photos Credit: Engr. Noshad Khan).

2.2.2 Box Action

The principal objective of timber lacing is not merely to strengthen individual walls. It is to cause the walls, roof, and foundation to behave as a connected box. In an unconnected structure, each wall may respond separately under ground motion. A long wall subjected to force perpendicular to its plane may detach from the return walls and overturn. When continuous bands pass through or around corners and are tied to cross walls, the perpendicular walls restrain one another.

This three-dimensional interaction is known as box action. The roof and horizontal bands distribute seismic forces between walls, while interlocked corners prevent premature separation. The global building response then depends on the combined resistance of multiple walls rather than the weakest isolated panel. The resulting box action is illustrated in Figure 2.2.

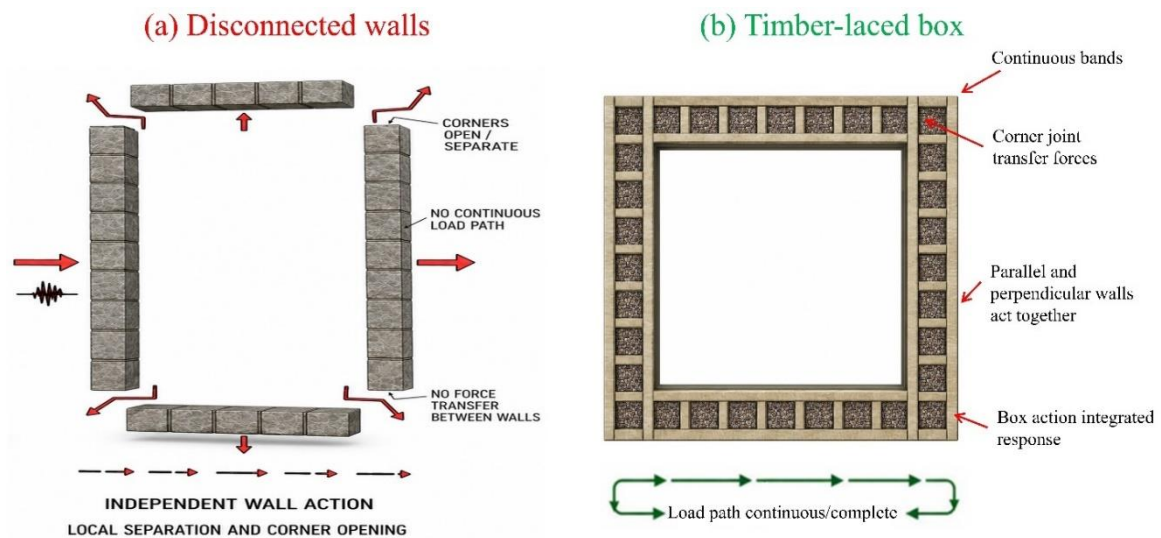


Figure 2.2. Box action in disconnected and timber laced plans.

2.2.3 Deformation and Energy Dissipation

Stone masonry is stiff and strong in compression but weak in tension. Timber is comparatively light, flexible, and capable of deforming without the immediate brittle fracture associated with unreinforced masonry. The timber masonry composite therefore provides a more gradual response.

During repeated lateral movement, small slips may occur at timber joints, between timber and masonry, and between individual stones. Friction at these interfaces converts part of the earthquake input energy into heat and local deformation. Controlled sliding and joint movement can limit the accumulation of damaging tensile stress within the masonry. The objective is not to prevent all movement, but to prevent movement from developing into uncontrolled wall separation and collapse.

This beneficial behavior depends on sound timber, adequate cross-ties, continuous bands, and reliable corner connections. Timber lacing that terminates before a corner, lacks transverse ties, or has decayed cannot provide the intended three-dimensional confinement. A common unsafe field practice is to install horizontal timber only on the visible wall face. Face-only lacing without through-wall cross-ties does not confine the full wall thickness and can permit the two masonry faces to delaminate during shaking.

2.2.4 Observed Performance

The well maintained Bhatar and related traditional systems generally performed better in the 2005 Kashmir earthquake than many conventional buildings (Bothara and Hıçyılmaz,

2008). This observation supports the structural logic of horizontal timber lacing but does not imply that every old timber laced house is safe. Performance depends on maintenance, timber condition, spacing of bands, wall dimensions, quality of joints, roof mass, and foundation stability. A completed field example is shown in Figure 2.3.



Figure 2.3. Completed timber laced stone house (Location: Kohistan; Photo Credit: Engr. Ayub Khan).

2.3 Dhajji Dewari Construction

2.3.1 Origin and Terminology

Dhajji Dewari as a traditional timber braced frame with random rubble masonry infill, practiced mainly in Kashmir and in mountainous parts of Pakistan and India (Ali et al., 2012; Hiçyılmaz et al., 2011). In local Kashmiri usage, *Dhajji* denotes an interconnected or patchwork quilt arrangement, while *Dewari* refers to a wall. The terminology reflects the visual pattern created by timber posts, horizontal members, and diagonal braces subdividing the wall into small infilled panels.

Analogous timber frame masonry traditions exist in several regions. The similar Turkish system is known as *hımış*, in which relatively light timber frames confine thin masonry infill (Gülkan and Langenbach, 2021). Such analogies are valuable because they show that distributed timber framing and masonry infill represent a recurring seismic construction

paradigm, although regional systems differ in geometry, materials, joinery, and construction sequence.

2.3.2 Construction System

A typical Dhajji wall comprises:

- A timber bottom plate;
- Vertical end posts and intermediate posts;
- Horizontal framing members;
- Diagonal braces;
- Small masonry infill panels; and
- A timber top plate connected to the roof or upper framing.

The vertical and horizontal elements establish the load bearing frame (Schacher & Ali, 2009). Diagonal braces increase in-plane stability and subdivide the infill. Irregular stones or bricks are placed within the panels, generally as relatively thin infill rather than as a massive load bearing wall. The principal Dhajji construction stages are summarized in Figure 2.4.

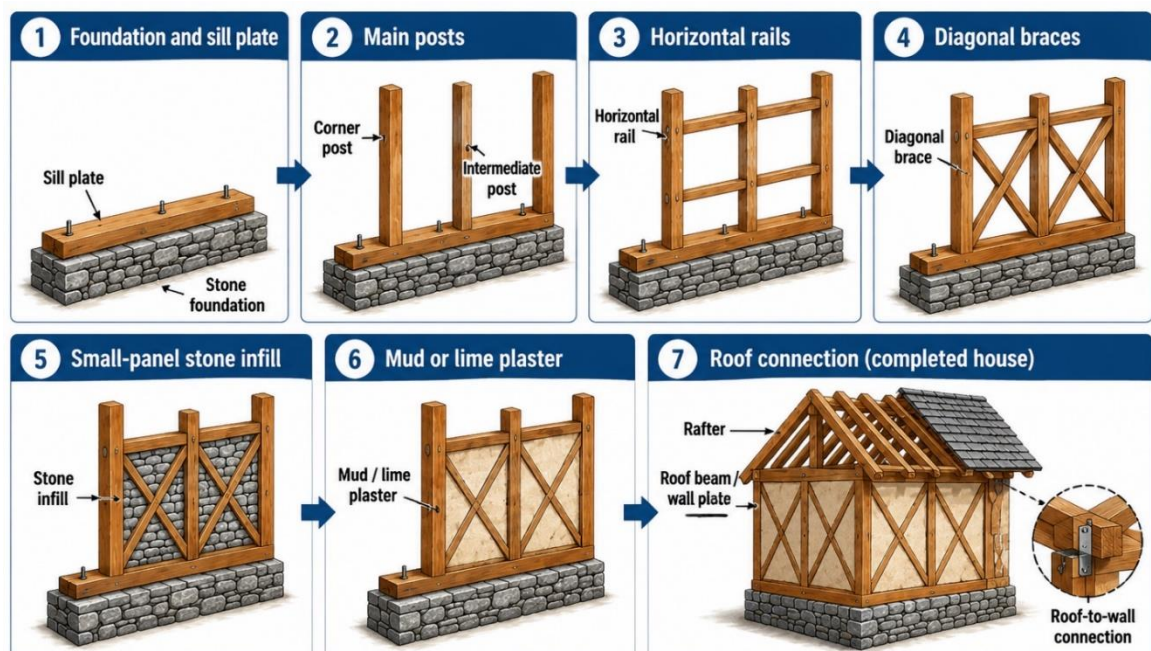


Figure 2.4. Dhajji Dewari construction sequence.

2.3.3 Lateral Resistance

The in-plane response of Dhajji Dewari is governed principally by the timber frame, bracing, and connections. Ali et al. (2012) tested full scale Dhajji walls under cyclic loading and found that the system possessed substantial resilience against lateral forces. The connections, particularly those between the main vertical posts and the bottom plate, strongly influenced the overall response.

The masonry infill had only a marginal contribution to lateral load capacity in the tested walls, but it significantly increased energy dissipation. This distinction is important. The infill should not be assumed to function as a conventional strong masonry shear wall. Its principal seismic contribution is associated with interaction, friction, distributed contact, and confinement within the timber sub panels. The interacting lateral resistance mechanisms are illustrated in Figure 2.5.

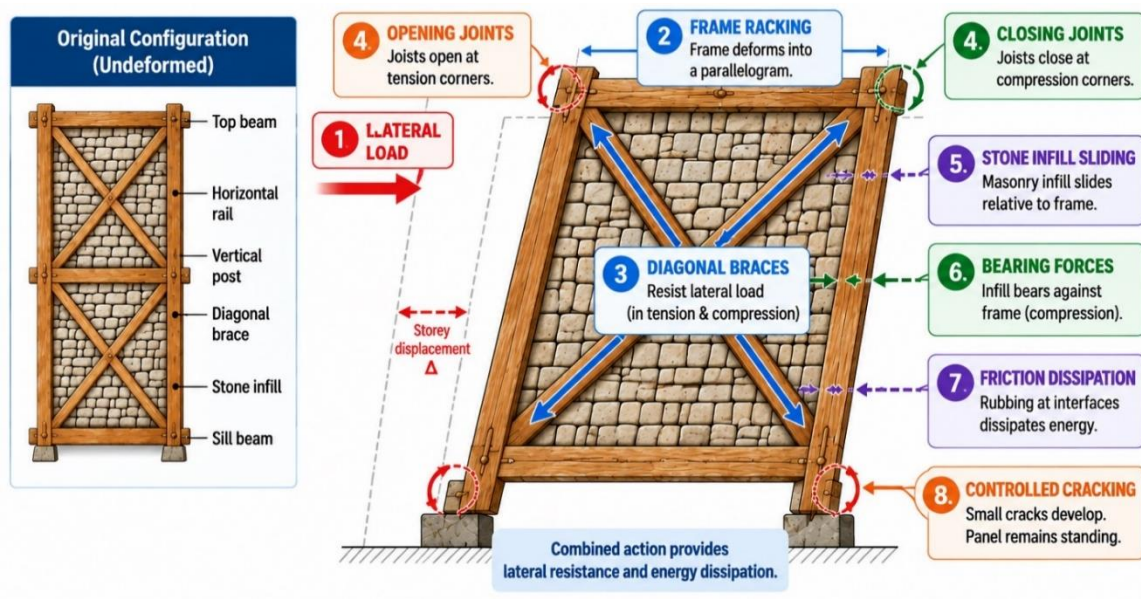


Figure 2.5. Lateral resistance mechanisms in a Dhajji panel.

2.3.4 Progressive and Non-Brittle Response

A major advantage of Dhajji Dewari is its ability to sustain deformation through a sequence of local mechanisms rather than a single catastrophic fracture. Timber joints may rotate or open, braces may slip, and infill may crack or locally dislodge while the primary frame remains standing. Ali et al. (2012) observed connection opening, rocking, and progressive separation at high deformation levels, illustrating that the response of the system is controlled by a series of interacting components.

This behavior contrasts with an unreinforced stone wall that may retain an apparently undamaged appearance until tensile resistance is exceeded, after which a large portion overturns or disintegrates. Dhajji damage can therefore be more visible and repairable, while still preserving a life safety frame.

2.3.5 Importance of Connections

The experimental evidence indicates that Dhajji performance cannot be attributed to timber alone. The vertical post to bottom plate connection, brace attachment, corner connection, continuity of the plates, and anchorage to the foundation and roof are critical. Poorly fitted joints relying on a small number of nails may pull apart before the intended deformation mechanisms develop.

Traditional carpentry joints can provide bearing, interlock, and controlled movement. Where traditional workmanship is no longer available, engineered straps, bolts, screws, plates, or equivalent mechanical connectors may be required. Their detailing must avoid splitting the timber, corrosion, inadequate edge distance, and discontinuity at corners. Representative post to sill connection alternatives are compared in Figure 2.6.

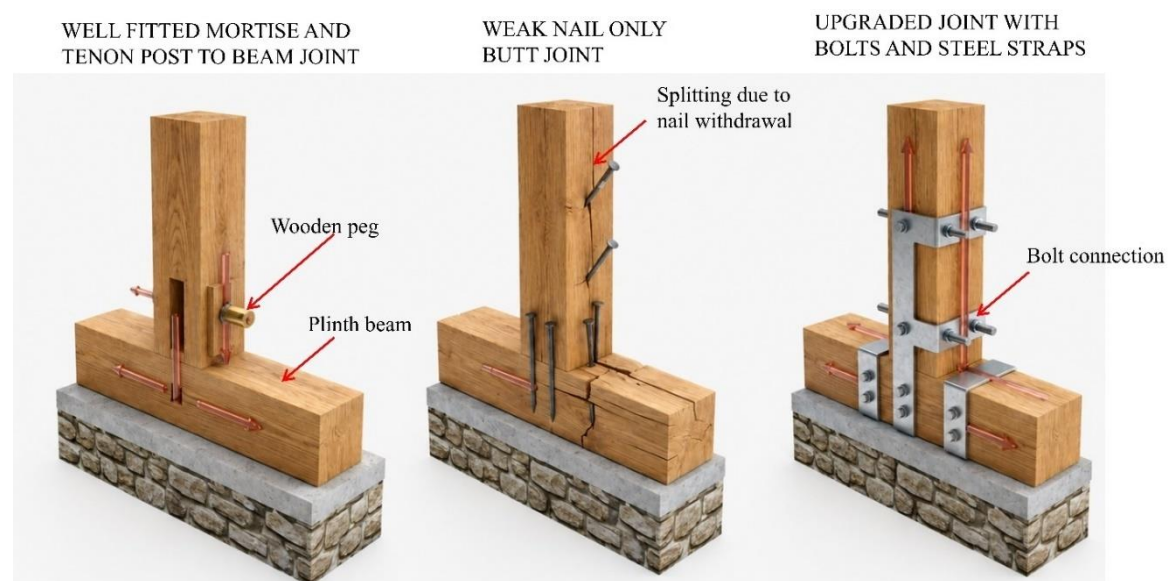


Figure 2.6. Post to sill connection alternatives.

2.4 Comparison of Bhatar/Taq and Dhajji Dewari

Bhatar/Taq and Dhajji Dewari share the use of timber to improve masonry behavior, but their structural functions differ:

- In Bhatar/Taq, masonry remains the principal wall mass, and horizontal timber lacing restrains, ties, and confines it.
- In Dhajji Dewari, the timber frame is the principal load bearing skeleton, while masonry serves as confined infill.

CORE DHAJJI DEWARI RISK: The timber frame is the primary load bearing skeleton. If primary timber members decay or critical joints lose their integrity, the masonry infill has little independent seismic resistance and shall not be relied upon to stabilize the building.

- Bhatar relies strongly on through wall cross-ties and continuity of horizontal bands.
- Dhajji relies strongly on post, brace, plate, and joint performance.
- Bhatar walls are generally thicker and heavier.
- Dhajji walls are divided into smaller and lighter panels, thereby limiting unsupported masonry dimensions.

Both systems demonstrate the same broader principle: seismic resilience is improved when brittle masonry is subdivided, tied, confined, and connected to a deformation tolerant framework. The principal differences between Bhatar/Taq and Dhajji Dewari are summarized in Figure 2.7.

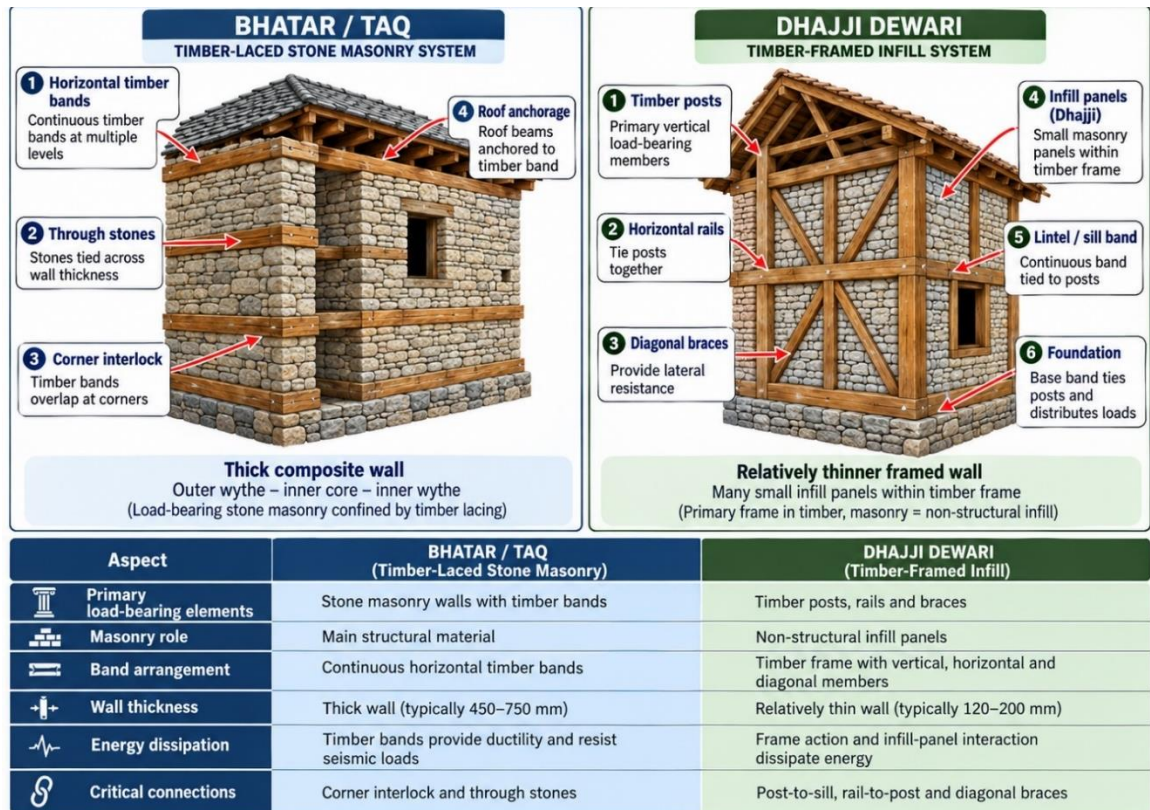


Figure 2.7. Structural comparison of Bhatar/Taq and Dhajji Dewari.

2.5 Limitations of Indigenous Systems

Vernacular construction techniques should not be idealized or adopted without empirical verification. Inherent vulnerabilities frequently include:

- Decayed, unseasoned, or undersized timber;
- Loss of skilled joinery;
- Discontinuous bands;
- Missing cross-ties;
- Inadequate foundation anchorage;
- Termite or moisture damage;
- Excessively large openings;
- Heavy roofs;
- Weak retaining walls or unstable platforms; and
- Later alterations that remove braces or interrupt framing.

The objective of contemporary adaptation is therefore to preserve effective indigenous mechanisms while introducing clearer dimensions, inspection requirements, connection standards, durability measures, and engineering oversight.

Timber stone hybrid buildings should receive a documented visual inspection at intervals not exceeding 2-3 years and after a significant earthquake, roof leak, flooding/wetting event, or evidence of termite or fungal attack. Decay, insect activity, connector corrosion, joint opening, and loss of timber section require prompt repair or engineering assessment.

CHAPTER 3

MATERIAL AND SOCIO-ECONOMIC CONSTRAINTS

3.1 Locally Available Stone

Undressed and semi dressed stones are the principal masonry units in many rural regions. Stone generally possesses high compressive resistance compared with weak mud mortar, but the performance of a wall is not determined by stone strength alone. Shape, size distribution, bedding orientation, surface roughness, interlock, joint thickness, and wall assembly govern the behavior of the masonry composite.

Rounded river stones are difficult to stabilize because they provide limited bearing surfaces and tend to roll or slide when disturbed. Angular and roughly rectangular stones provide better mechanical interlock. Flat stones can be advantageous when placed on their natural beds, but thin stones laid as facing pieces may create separate wall skins without adequate connection to the core.

The use of large, stable stones at corners, wall junctions, openings, and band levels are more important than achieving an attractive outer face. A visually regular façade may conceal a loose interior core and poor through thickness bond. Preferred and unsuitable stone characteristics are compared in Figure 3.1.



Figure 3.1. Stone selection and bedding orientation.

3.2 Mortar

3.2.1 Mud Mortar

Mud mortar is inexpensive and widely understood, but it normally provides low tensile and bond resistance and is vulnerable to water. Under cyclic loading, joints may crack, crush, erode, or permit stone movement. In an unconfined wall, this movement can initiate wall leaf separation and loss of stability.

Weak mortar does not automatically make a confined timber frame system unsafe. In Dhajji Dewari, controlled sliding and friction within small infill panels can contribute to energy dissipation (Ali et al., 2012). However, this mechanism depends on a functioning timber frame. The same weak mortar in a large, unreinforced, multi-leaf load bearing wall provides no comparable protection against delamination or overturning.

3.2.2 Cement Mortar

Cement mortar can increase bond, water resistance, and compressive capacity when correctly proportioned, mixed, placed, and cured. However, weak cement rich looking masonry may still perform poorly if mortar joints are excessively thick, incompletely filled, poorly cured, or applied only at the visible wall faces.

The belief that any cement mortar automatically creates earthquake resistant masonry is therefore incorrect (Schildkamp et al., 2020). Mortar must be combined with through-stones, interlocked corners, continuous bands, suitable wall dimensions, and roof anchorage.

3.2.3 Stabilized Mud Mortar

INTERIM TRIAL-MIX WARNING: Cement contents of 5%, 7%, and 9% by dry soil mass are starting trial proportions only. They are not mandatory design mixes and shall not be adopted for construction until field trials and all applicable acceptance checks in Appendix B have been completed and documented.

Stabilized earth mortar may be used as an economical intermediate material only after local soil trials. Binder content shall be stated as a percentage of the oven dry or air-dry mass of screened soil, not as an undefined percentage by volume. For cement stabilization, an initial trial series may use 5%, 7% and 9% cement by dry soil mass; this is a trial program derived from comparative soil stabilization practice, not a universal prescription. Lime stabilization shall be selected only after confirming that the soil contains reactive fines and that the chosen lime is suitable. The lowest binder content that meets the acceptance criteria in Appendix B shall be adopted.

Representative soil and water from the construction site shall be used to prepare trial batches. Each batch shall be recorded by mass, screened particle size, water content, mixing time and curing condition. A mix shall be accepted only after it satisfies the field shrinkage, wet erosion, cohesion, and construction panel checks in Appendix B. Stabilization improves durability and joint integrity; it does not replace through-stones, corner interlock, bands, roof anchorage or dimensional control. The expected behavior of the principal mortar types is compared in Figure 3.2.

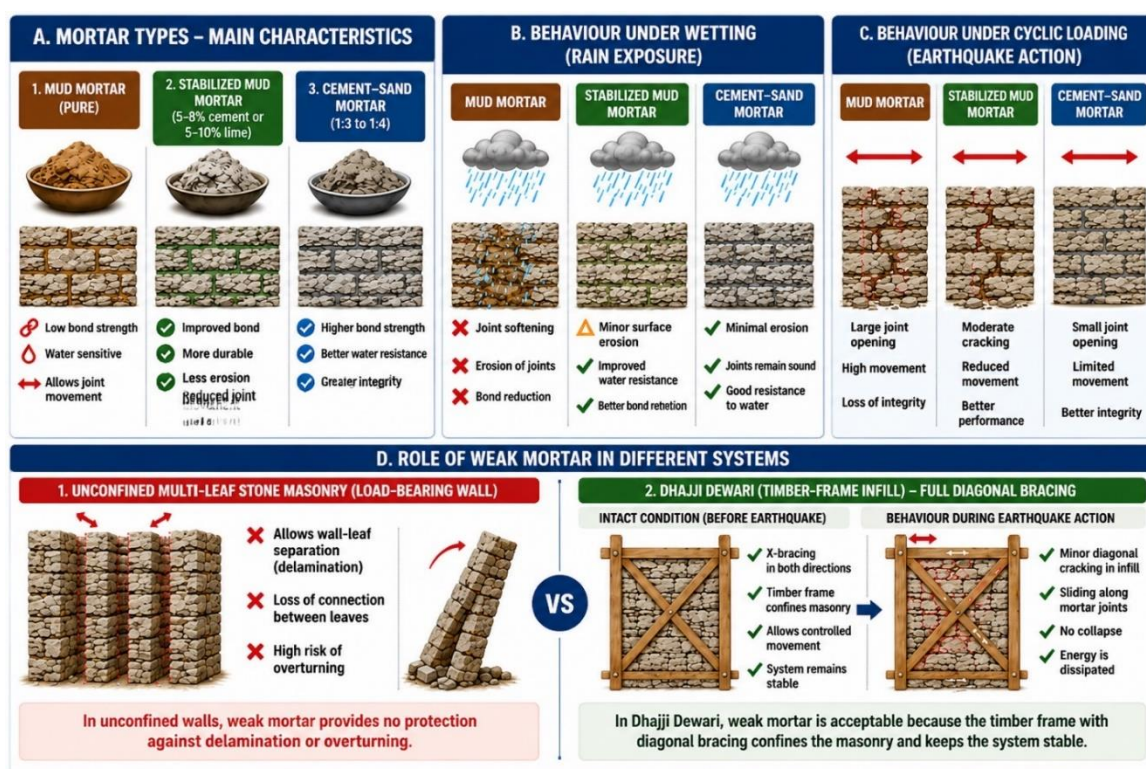


Figure 3.2. Behavior of common mortar types.

3.2.4 Field Acceptance and Batch Control

Material acceptance shall occur before full-scale wall construction. A field team shall not approve mortar because it “looks rich” or because cement is visible on the surface. The acceptance record shall identify the source of soil, sand, water, and binder; the batching basis; trial panel date; curing period; test results; and the approving supervisor.

The minimum field acceptance criteria and required disposition for failed checks are summarized in Table 3.1.

Table 3.1. Field acceptance criteria for masonry materials and workmanship.

Material/check	Minimum field acceptance criterion	Disposition if failed
Stone soundness	No through cracks, friable layers, deep weathering, or pieces that break under normal dressing blows	Reject or use only as non-structural hearting after approval
Stone seating	Unit remains stable on a broad natural bed without rocking before mortar is added	Redress or replace
Mud/stabilized mortar shrinkage	No continuous through crack in the trial bar/panel; total linear shrinkage not greater than the interim limit in Appendix B	Adjust soil grading, sand or stabilizer and repeat trial
Wet erosion resistance	Joint face remains coherent after the Appendix B wetting and brushing/spray procedure	Reject for exposed load bearing work

Material/check	Minimum field acceptance criterion	Disposition if failed
Cement sand mortar batching	Measured loose volumes, clean sand, and water; nominal 1:6 cement: sand where this guideline specifies lean mortar	Discard uncontrolled batch
Construction panel	Stones remain bonded and joints remain filled after curing and controlled handling	Revise mix/workmanship and rebuild panel

3.3 Timber

Timber used for seismic bands, cross-ties, posts, sills, lintels, roof-wall connections, and frames, is a structural material. Commonly available northern Pakistani timbers include deodar (*Cedrus deodara*), kail/blue pine (*Pinus wallichiana*), and poplar (*Populus spp.*) (Pakistan Forest Institute, n.d.). Species identity alone does not establish structural suitability; local source, grade/condition, section size, treatment, and connection performance shall be verified for the intended use.

Field acceptance shall include identification of the timber species/local trade name and source; visual grading for sound section, straightness, decay, insect damage, excessive checks or splits, and defects at connection zones; confirmation of dimensions; and a seasoning/moisture condition check. Critical members and joints shall conform to the approved timber schedule or signed project drawing. Visibly green, unstable, decayed, or insect damaged timber shall not be used in primary seismic elements.

Timber shall be seasoned to a stable service condition before installation and stored off the ground, under cover, and with ventilation. Preservative treatment shall be compatible with the timber species and intended exposure. Pressure treatment is preferred where available; otherwise, an approved brush or dip treatment may be used in accordance with the preservative manufacturer's instructions. Cut ends, drilled holes, and notches shall be retreated. Used engine oil, diesel, or unidentified toxic mixtures shall not be specified as preservatives.

Timber near ground level or adjacent to damp masonry shall be separated from soil and persistent moisture by a durable damp proof or capillary break detail while remaining inspectable. Drainage, roof overhangs, leak control, and ventilation shall be used to limit fungal decay. In termite prone locations, treated or naturally durable timber and locally appropriate termite control measures shall be specified and maintained.

At stoves, chimneys, cooking areas, and other heat sources, combustible timber shall be kept clear of ignition hazards and protected by an approved fire-safe detail. This manual

does not assign a fire-resistance rating to timber laced walls; fire performance shall be checked under applicable requirements for the building use.

Metal straps, bolts, nails, washers, and other connectors exposed to exterior or damp conditions shall be hot-dip galvanized, stainless steel, or otherwise provided with an approved durable corrosion-protection system compatible with adjacent materials. Damaged coatings and cut edges shall be repaired before concealment.

A documented visual inspection of timber-stone systems shall be made at intervals not exceeding 2-3 years and after major earthquakes, persistent leaks, flooding/wetting, or evidence of termite/fungal activity. The inspection shall check decay, insect attack, loss of section, checking/splitting at joints, loosened fasteners, corrosion, moisture traps, and loss of roof/wall anchorage. Defective primary members or connections shall be repaired or replaced before their structural function is lost.

Timber is structurally valuable because it is light, flexible, and capable of sustaining tension and repeated deformation. Its effective use is nevertheless constrained by:

- Reduced availability of mature structural timber;
- Increasing cost;
- Use of immature or unseasoned members;
- Dimensional variation;
- Poor joinery;
- Biological attack;
- Moisture exposure; and
- Absence of maintenance.

Timber embedded near ground level is particularly vulnerable when the plinth is low, drainage is poor, or roof runoff wets the wall. Decay at the sill plate or lower band can interrupt the primary load path, thereby compromising the structural continuity of the unified system. Timber selection, seasoning, treatment, drainage, and inspection are therefore structural requirements rather than merely durability considerations. Timber acceptance and deterioration indicators are summarized in Figure 3.3.

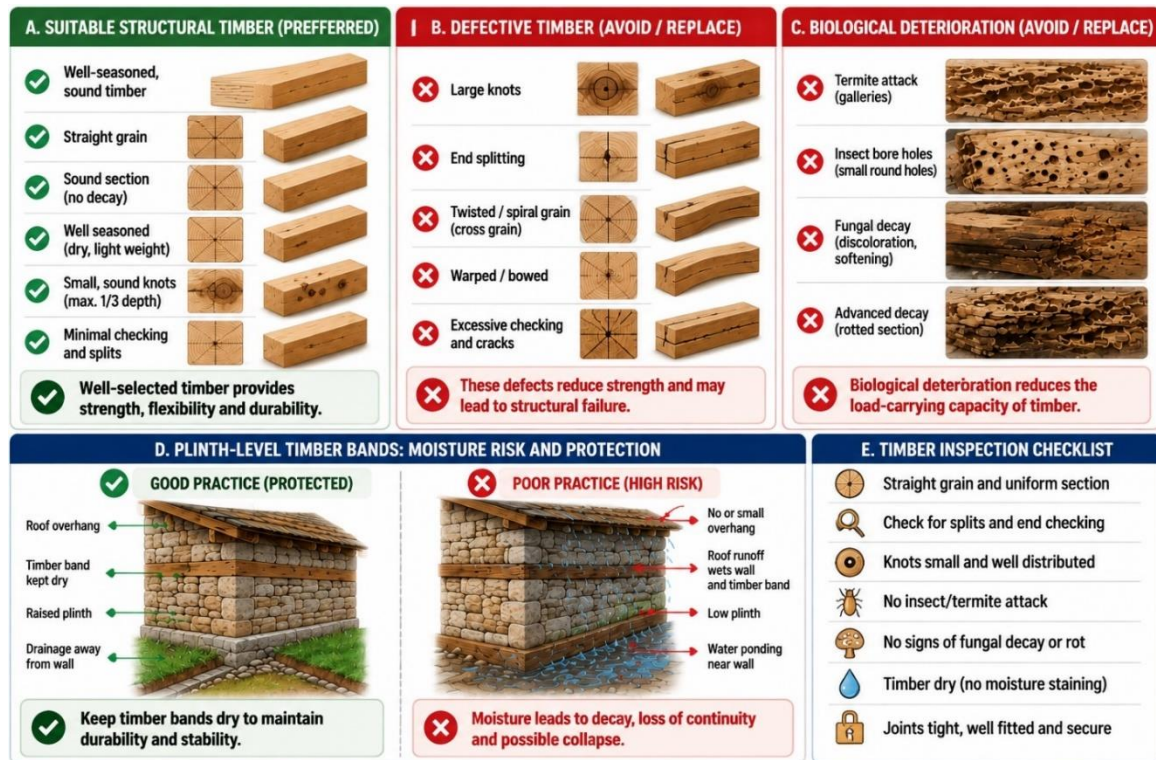


Figure 3.3. Timber quality and deterioration indicators.

3.4 Degradation of Skilled Labor

The performance of traditional systems depended on masons and carpenters who understood stone selection, corner bonding, wall thickness, timber cross-ties, and fitted joints. As these skills decline, superficial replication may replace structural understanding. Examples include decorative timber strips that do not pass through the wall, nail only joints, outer face stones placed without internal bonding, and bands that stop at openings or corners.

A shortage of skilled labor affects both new construction and retrofitting. Installing through-stones in an existing wall, connecting bands at corners, anchoring a roof, or attaching wire mesh through a thick wall requires sequencing and judgment. Training must therefore focus on demonstrable construction operations rather than on written instructions alone.

3.5 Economic Constraints

Economic decisions occur at two different levels: household construction choices and program/agency budgeting. The two should not be combined because the decision maker, available evidence, and acceptable trade-offs differ.

3.5.1 Household Affordability and Construction Choices

At household level, the minimum life-safety package shall not be reduced below the prescriptive requirements merely to lower initial cost. Priority should be given to high benefit, low material measures such as stable site selection, bonded masonry, through-stones or ties, interlocked corners, continuous bands, controlled openings, drainage, and roof anchorage before more expensive strengthening is considered.

Households in remote areas normally prioritize immediate shelter, weather protection and affordability. Seismic risk may appear abstract compared with daily economic needs. A technically superior solution that relies on imported components, specialist labor, complex formwork or prolonged curing will not be implemented consistently. Cost planning shall therefore be based on a local bill of quantities, the latest official provincial Market Rate System where applicable, and at least three current district quotations for timber, transport, and specialist work.

A feasible intervention should:

1. Retain locally available stone;
2. Minimize cement and steel;
3. Use repetitive details;
4. Be constructible by trained local masons;
5. Permit visual inspection;
6. Avoid specialized machinery; and
7. Allow staged upgrading.

The highest economic efficiency is obtained by placing reinforcement at structural discontinuities: corners, wall intersections, opening jambs, sill and lintel levels, roof levels, wall to roof interfaces, and through the wall thickness.

3.5.2 Program and Agency Budgeting

At program or agency level, budgets should report the incremental cost of verified seismic improvements separately from the base shelter cost and should include training, inspection, treatment, transport, and maintenance provisions. High-cost reinforced concrete confinement should not be adopted automatically where simpler verified measures satisfy

the intended scope; conversely, cost reduction shall not remove elements required to maintain the minimum seismic safety load path.

For program budgeting, the implementing agency shall publish an “incremental life safety package” for a reference house and update it at least every six months. A national fixed Pakistani rupee (PKR) figure is intentionally not prescribed because remote valley transport, timber species and access conditions create large price differences. Appendix D provides a mandatory bill of quantities (BOQ) and cost reporting template; adoption documents shall populate that template with dated district rates before funds are approved. The relative cost effectiveness of the intervention hierarchy is shown in Figure 3.4.

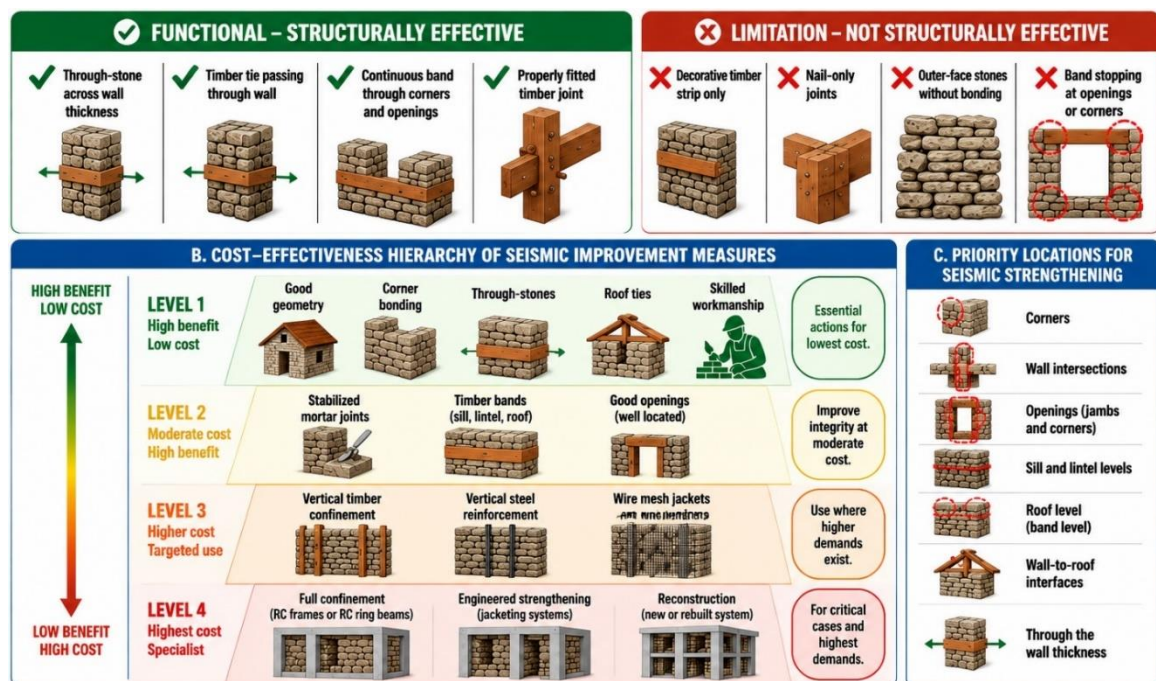


Figure 3.4. Cost effectiveness hierarchy of seismic measures.

3.6 Community Perception

The collapse of stone houses during the 2005 earthquake damaged community confidence in traditional construction. At the same time, the survival of well-maintained Dhajji and Bhatar buildings created evidence that local materials can perform safely when arranged correctly (Bothara & Hıçyılmaz, 2008).

Community acceptance is likely to depend on visibly understandable improvements. A homeowner can observe a full width through-stone, a continuous timber band, a bolted corner strap, or a tied roof beam. Demonstration buildings and repairable test panels can therefore communicate structural principles more effectively than abstract instructions.

The aim should not be to present tradition and engineering as opposing choices. Modern engineering can identify, standardize, and improve effective indigenous mechanisms while rejecting unsafe practices that have become normalized.

CHAPTER 4

SITE SELECTION, SLOPE SAFETY AND STRUCTURAL VULNERABILITIES

SITE-SAFETY WARNING: No superstructure detail in this manual can compensate for an unstable site, active landslide or rockfall exposure, uncontrolled fill, unsafe cut and fill platform, or an inadequately designed retaining system. These construction details shall not be used to justify building on a hazardous site.

4.1 Why Site Safety Governs Building Safety

In hilly terrain, a well detailed superstructure can still be lost if the foundation platform slides, the cut slope collapses, a retaining wall overturns, rockfall strikes the roof, or drainage saturates the ground. Site selection is therefore the first structural intervention. ERRA reconstruction guidance emphasizes avoidance of landslide prone areas, unstable slopes, and unsafe filled sites (Earthquake Reconstruction and Rehabilitation Authority, 2006). No masonry detail in Chapters 6 or 7 shall be used to justify construction on an unapproved hazardous site.

4.2 Mandatory Pre-Construction Site Screening

Before excavation, a competent person shall complete the site screening checklist in Appendix C. Construction shall stop and a geotechnical review shall be obtained where any of the following is observed: active or recent landslide scarps; tension cracks; tilted trees or poles; bulging or displaced ground; recurring rockfall; debris flow channels; undercut river or stream banks; springs emerging from a slope; saturated or soft fill; uncontrolled dumping; settlement of nearby buildings; or a proposed building platform that depends on an nonengineered retaining wall.

The site screening outcomes and corresponding prescriptive decisions are summarized in Table 4.1.

Table 4.1. Site screening conditions and prescriptive decisions.

Site condition	Prescriptive decision
Competent level or gently sloping natural ground; no hazard indicators	Proceed after recorded foundation inspection
Minor regular slope requiring stepped footings; no fill or instability	Proceed only with verified stepped foundation detail

Site condition	Prescriptive decision
Uncontrolled fill, spring/seepage, tension cracks, active erosion, or nearby distress	STOP - geotechnical assessment required
Building depends on a retaining wall or lies in its failure zone	STOP - engineered retaining system and building foundation design required
Rockfall, debris flow, flood, avalanche, or landslide runoff exposure	Relocate or undertake specialist hazard assessment and protection design
Seasonal spring, monsoon only seepage, wet season staining/soft ground, or a history of temporary wetness not visible during dry season inspection	STOP - review wet season evidence and drainage; obtain geotechnical assessment where stability or foundation support may be affected

4.3 Slope Edges, Toes and Rockfall Zones

A building shall not be placed directly at the crest or toe of an unsupported steep cut, natural slope or retaining wall. The safe offset depends on geology, slope height, inclination, groundwater, erosion, and surcharge; it shall be determined by a competent geotechnical professional where failure could affect the building. As an interim screening rule only, the horizontal separation from a nonengineered cut or retaining wall should not be less than its exposed height, and any smaller distance requires engineered verification. This screening rule is not a stability calculation.

4.4 Cut and Fill Platforms

The whole foundation should bear on competent natural ground or on a designed, compacted and retained platform. A building shall not straddle rock or dense natural ground on one side and uncontrolled fill on the other. Benching, fill selection, layer thickness, moisture control, compaction and toe support shall be specified and inspected. Existing household fill or loose excavated spoil shall not be accepted as competent support merely because it has remained in place for one dry season.

4.5 Surface and Subsurface Drainage

Water is a primary trigger for slope movement, foundation softening, mortar erosion and timber decay. Uphill runoff shall be intercepted and safely conveyed around the site. Roof water shall be collected and discharged through stable, erosion resistant outlets away from foundations, fills and retaining wall toes. Soak pits, leaking water tanks and wastewater outlets shall not be located where they can saturate a slope or backfill. Drainage paths shall remain inspectable and maintainable.

4.6 Retaining Walls and Building Separation

A retaining wall that supports an occupied building, or whose failure could endanger it, shall be treated as structural work requiring appropriate investigation, design, drainage provisions, and approval. A residential load bearing masonry wall shall not be used directly as a retaining wall. Soil retention shall be provided by a separate designed retaining system with a defined load path and safe relationship to the building foundation.

4.7 Foundations on Sloping Ground

Foundations on slopes shall be stepped on competent material; they shall not follow the slope as an inclined strip. Each step shall be level and positively connected to adjacent steps. Excavation shall not undercut neighboring buildings or destabilize the uphill slope. Foundation trenches shall be protected from rain and shall not be left open long enough to soften, loosen or fill with runoff. Any spring, seepage, cavity, unconsolidated deposits, or loose fill exposed during excavation is a hold point requiring review before concrete or masonry is placed.

4.8 Absence of Structural Integrity

A stone masonry building may appear massive and stable under gravity loading yet remain highly vulnerable under horizontal acceleration (Ahmad et al., 2018; Gautam et al., 2021). Gravity primarily compresses the wall. Earthquake motion introduces cyclic shear, tension, bending, rocking, and force reversal. The most serious deficiency is not always low material strength; it is the absence of connections that permit the building to act as a unit.

Bothara and Hiçyılmaz (2008) estimated that more than 95% of buildings in the 2005 earthquake affected area were likely non-engineered and lacked seismic features. Such buildings frequently had no reliable links between:

- The inner and outer wall wythes;
- Perpendicular walls;
- Walls and roofs;
- Masonry and timber frames;
- Bands at corners; or
- The superstructure and foundation.

4.9 Multi-Leaf Wall Construction and Delamination

The same delamination mechanism is relevant to gravity stone masonry retaining walls. Two outer faces may appear straight, plumb, and well-dressed while the intervening core contains small, loose, or poorly bonded stones. Such a wall can lose composite action internally even before obvious face distress develops. Where a retaining wall supports or can endanger an occupied building, through bonding, core quality, drainage, foundation support, and overall stability shall be verified through appropriate engineering assessment rather than judged from the visible faces alone.

Thick rubble stone walls are commonly formed from an outer face, an inner face, and a core filled with small stones or loose rubble. If no stones or ties extend through the full wall thickness, the two faces behave as separate thin walls.

During earthquake shaking, the outer and inner faces experience different accelerations, bending demands, and support conditions. The loose core settles and exerts outward pressure. Repeated transverse motion reduces friction and opens vertical separation planes. This process is known as delamination.

Once delamination begins, each wall face has a smaller effective thickness and a much greater slenderness ratio than the original composite wall. Its out of plane capacity consequently falls sharply. One wythe may bulge or overturn, followed by loss of the core and collapse of the remaining face. Bothara and Brzev (2011) identify through-stones as a principal means of stitching the wythes together and reducing this failure risk. The delamination sequence is illustrated in Figure 4.1. The role of through-stones in tying the wall leaves is illustrated in Figure 4.2.

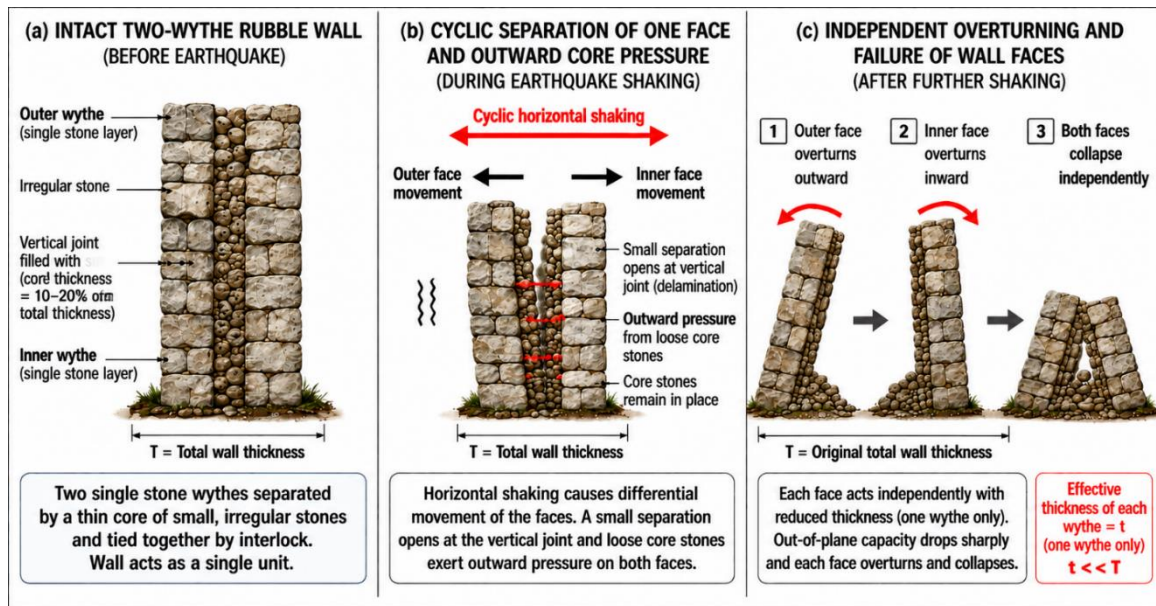


Figure 4.1. Delamination of a multi-leaf stone wall.

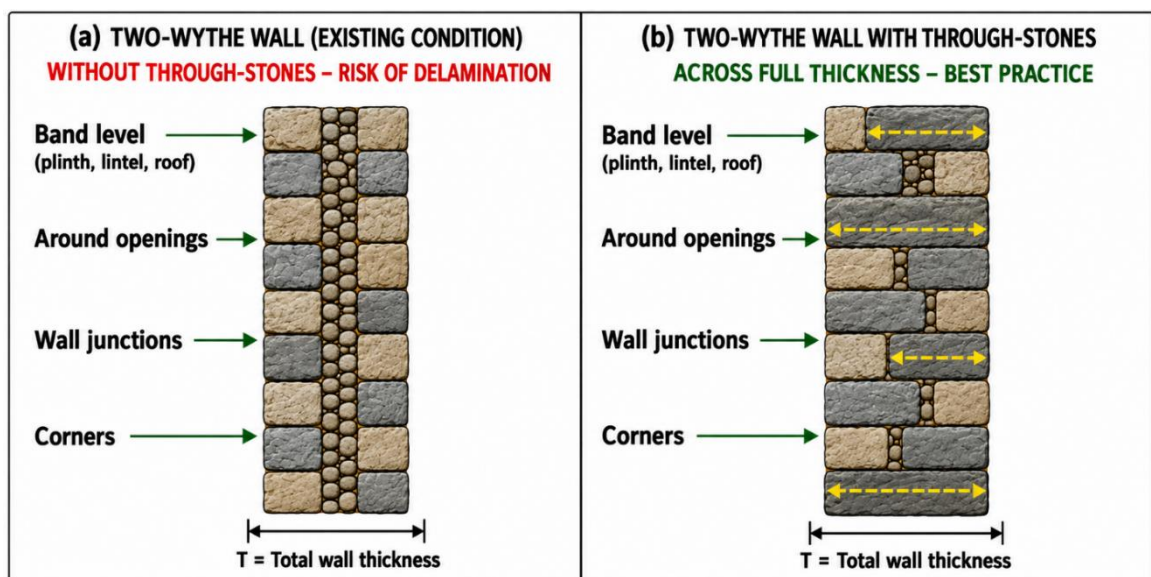


Figure 4.2. Unconnected and through-stone bonded wall sections.

4.10 Lack of Through-Stones

Through-stones are large stones extending through the full thickness of the wall. Their structural role is to transfer transverse forces between the wall faces, restrain bulging, and preserve composite action.

In many newer buildings, through-stones have been omitted because they are difficult to obtain, heavy to handle, or considered unnecessary when cement mortar is used. This omission is hazardous. Mortar alone may not reliably transfer repeated transverse tension across a rubble filled core, particularly where joints are thick or incompletely filled.

Where full length stones are unavailable, overlapping stones or engineered ties may be used, but they must create genuine through thickness connection. Short facing stones that terminate near the core do not perform this function.

4.11 Poor Stone Geometry and Coursing

Rounded stones have limited stable contact surfaces. When placed in thick mortar or loose earth, they may rotate under cyclic movement. Irregular course heights can also create inclined load paths, localized bearing, and continuous vertical joints.

Poor coursing produces:

- Unstable stone seating;
- Excessive dependence on mortar;
- Concentration of stress at small contact points;
- Weak vertical planes;
- Separation between facing and core;
- Poor bonding at corners; and
- Difficulty integrating horizontal bands.

Coursed appearance alone is insufficient. Stones must extend into the wall body, vertical joints must be staggered, voids must be filled with well-placed spalls, and each lift must remain stable before the next is constructed. Field variability in stone masonry workmanship is shown in Figure 4.3.



Figure 4.3. Field examples of variable stone masonry workmanship (Location: Diamir (a) & Chitral (b); Photos Credit: Engr. Noshad Khan & Engr. Faheem Ul Jalal).

4.12 Out of Plane Bending and Overturning

A wall subjected to earthquake acceleration perpendicular to its surface behaves approximately as a vertical plate or cantilever, depending on its connections. The self-weight of the wall produces inertia force through its center of mass. If the wall is not restrained at its top and sides, the force creates an overturning moment at the base.

Cracking commonly develops near the wall base, at corners, around openings, or along poorly bonded joints. Once the wall separates from perpendicular return walls, its unsupported length increases and it becomes more vulnerable to rocking or overturning. Heavy roofs may not restrain the wall if roof beams are unanchored; instead, beam movement may push the wall outward. The out of plane failure mechanism and its restraints are illustrated in Figure 4.4.

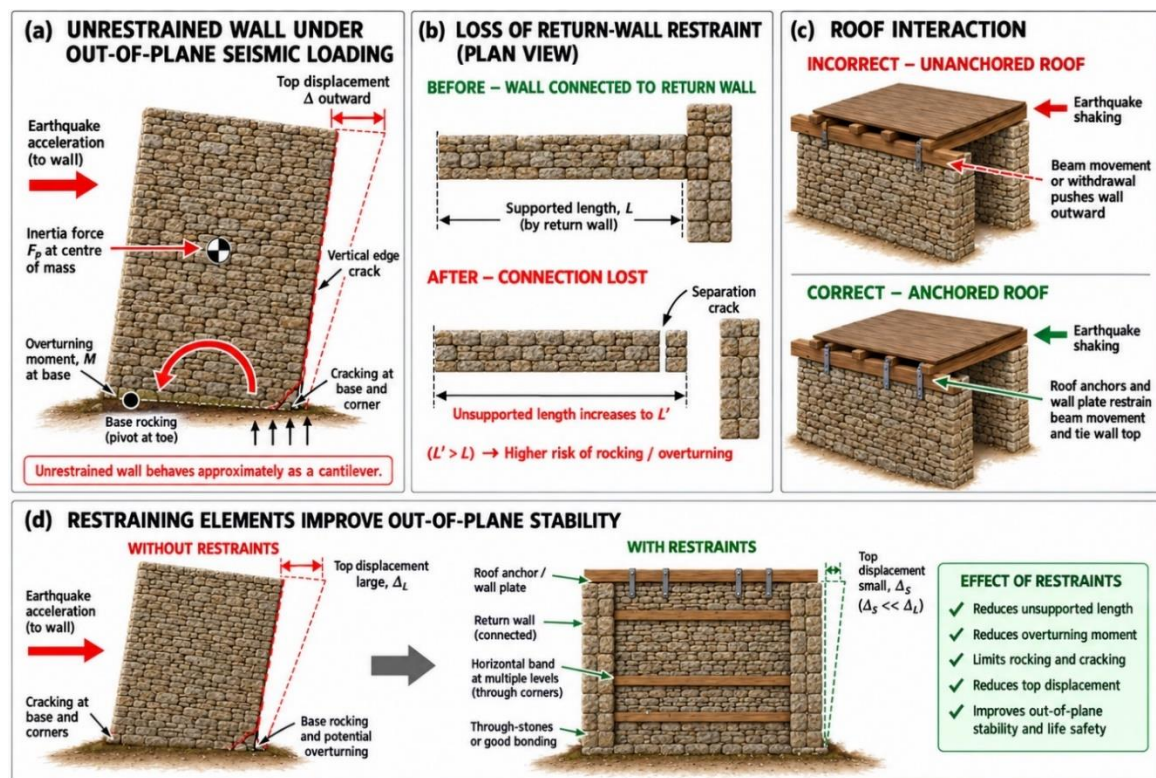


Figure 4.4. Out of plane wall failure and restraint.

4.13 Corner and Junction Weakness

Corners and T-junctions are essential to box action. When the stones of intersecting walls are not alternately interlocked, a vertical construction joint is created. During shaking, the walls move in different directions and a vertical crack opens at the junction.

After separation, one wall may lose its side support and fail out of plane. The adjoining wall may remain standing temporarily, giving the appearance of a local defect, but the overall structural system has already lost continuity.

Corner vulnerability is increased when:

- Walls are constructed at different times without toothing;
- Long facing stones do not cross the junction;
- Timber bands terminate at the corner;
- Openings are located close to the junction; or
- Roof forces are not distributed between the walls. Bonded and unbonded corner arrangements are compared in Figure 4.5.

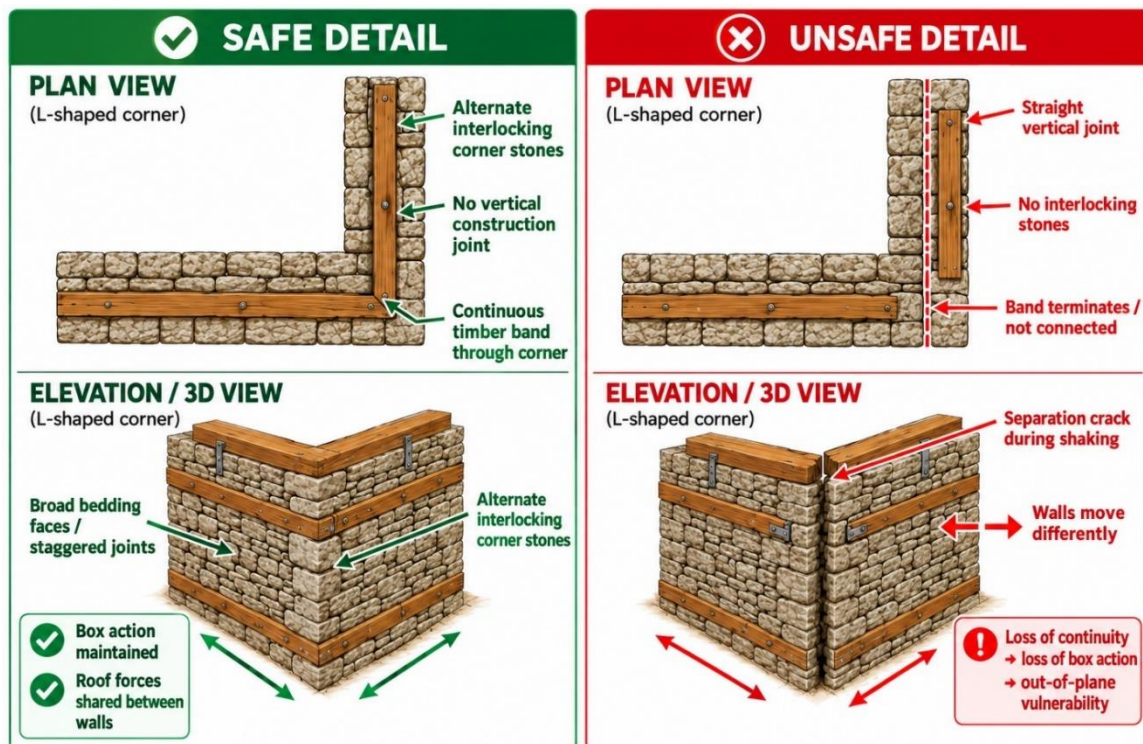


Figure 4.5. Bonded and unbonded masonry corners.

4.14 Openings and Reduced Wall Piers

Doors and windows interrupt the wall and concentrate stress at their corners. Large openings, closely spaced openings, and openings located near building corners leave narrow masonry piers that may rock, crack diagonally, or separate from the adjoining wall.

Unequal opening arrangements can also produce torsional response by creating different stiffnesses on opposite sides of the building. Lintels with inadequate bearing may fall, while discontinuous bands cannot distribute forces around the opening.

4.15 Roof and Floor Deficiencies

Roofs and floors should collect inertial forces and transfer them to the supporting walls. In many rural buildings, beams simply rest in shallow pockets without straps, wall plates, or continuous roof bands. Under lateral movement, beams can slide from their seats. Roof collapse may then occur even when portions of the walls remain standing.

Heavy earth roofs are particularly demanding because seismic inertia is proportional to mass. They also impose high gravity load on walls already weakened by cracking. Pitched lightweight roofs reduce mass but still require anchorage to prevent sliding, separation, and outward thrust. A field example of roof to wall continuity is shown in Figure 4.6.



Figure 4.6. Roof to wall connection in timber laced masonry (Location: Diamir; Photo Credit: Engr. Noshad Khan).

4.16 Material Deterioration

Water erodes mud mortar, enlarges voids, softens wall cores, and promotes timber decay. Freeze–thaw action may worsen cracking in exposed joints and weathered stones. A low

plinth, leaking roof, blocked drainage, or inadequate roof overhang can therefore reduce seismic capacity long before an earthquake occurs.

Deterioration is structurally significant because an earthquake tests the building in its existing condition, not in its original condition. A well-conceived timber laced system can lose its continuity when lower bands decay or connections corrode. Maintenance must consequently be treated as part of earthquake risk reduction.

CHAPTER 5

EARTHQUAKE INDUCED STRUCTURAL FAILURE MODES

5.1 Purpose of Post-Earthquake Classification

This chapter focuses primarily on earthquake induced failure modes of building superstructures. Ground, foundation, platform, and retaining structure failures are included in Section 5.9 for recognition and referral, but detailed geotechnical stability analysis lies outside the prescriptive scope of this manual.

Failure classification converts earthquake damage into design knowledge. The objective is not merely to catalogue cracks but to identify the interrupted load path, the component that lost stability, and the construction deficiency that allowed the mechanism to occur.

The cited literature provides detailed quantitative consequences and building observations for the 2005 earthquake but a less complete building by building record for the 2015 event. Accordingly, the 2005 event is discussed quantitatively, while statements about 2015 are limited to cited official and published assessments.

5.2 Out of Plane Wall Collapse

Out of plane failure was among the most dangerous mechanisms observed in non-engineered masonry. It typically developed through the following sequence:

1. Cracking at wall corners or wall to roof interfaces;
2. Separation of the wall from perpendicular return walls;
3. Loss of top restraint;
4. Bulging or delamination of wall wythes;
5. Rocking or overturning of a large wall portion; and
6. Roof collapse following loss of support.

The mechanism is dangerous because a large mass can fall suddenly over the full length of a wall. Interior occupants may be struck by the inner wythe and roof, while exterior occupants may be struck by the outer face. The progressive out of plane collapse sequence is shown in Figure 5.1.

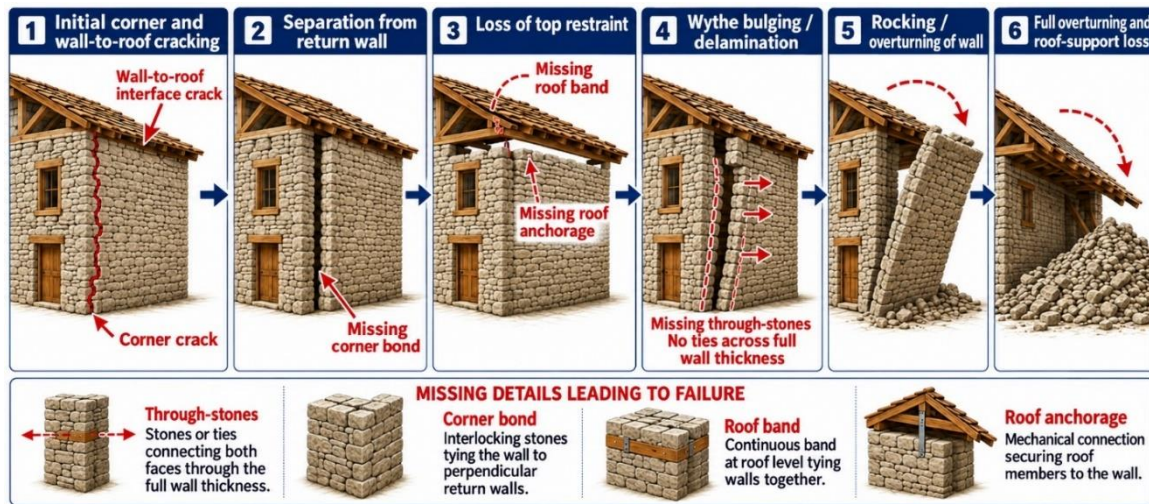


Figure 5.1. Progressive out of plane wall collapse.

5.3 Delamination and Stone Expulsion

Delamination may occur before global overturning. The outer face can detach and fall while the inner face temporarily supports the roof. Alternatively, stones may be expelled locally from the wall core, leaving voids, and reducing the effective section.

In walls constructed using face stones and loose internal chips, cyclic acceleration can progressively rearrange the core. This is not simply a surface failure. It represents loss of through thickness composite behavior and may lead to subsequent collapse under an aftershock.

5.4 Corner Separation

Corner separation is identified by vertical cracking at L-junctions, diagonal cracking extending from the junction, or complete detachment of one wall from another. It destroys box action and changes the boundary conditions of the affected walls.

A wall that originally benefited from support on two or more edges may become a free-standing cantilever after corner separation. It's out of plane demand remains, but its restraint is greatly reduced. Corner failure is therefore both a local damage pattern and a trigger for global instability. The development of corner separation is illustrated in Figure 5.2.

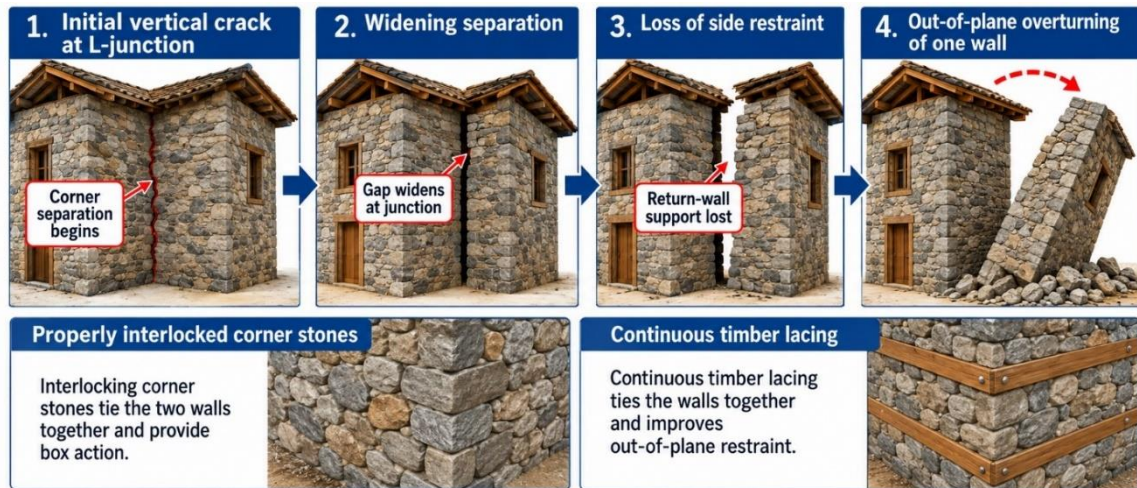


Figure 5.2. Corner separation and loss of wall restraint.

5.5 In-Plane Shear and Rocking Failures

Walls parallel to the direction of shaking resist in-plane forces. Depending on wall dimensions, axial load, mortar, openings, and connections, damage may appear as:

- Diagonal cracking;
- Bed joint sliding;
- Rocking at the wall base;
- Crushing at wall toes;
- Cracking from opening corners;
- Failure of narrow piers; or
- Separation of spandrels from piers.

In-plane damage is not necessarily catastrophic if the wall remains connected to the building and retains gravity load capacity. However, an in-plane wall cannot stabilize a perpendicular wall if their junction has failed.

5.6 Roof Support and Diaphragm Failure

Roof failure may occur through loss of bearing support, wall top spreading, collapse of gable walls, or failure of the wall supporting the beam ends. An unbraced roof may also distort in its own plane and transfer irregular forces to the walls.

The wall to floor and wall to roof connections are considered as essential components of improved seismic performance (Bothara and Brzev, 2011). Roof anchorage should prevent

beam withdrawal, while roof plane bracing or an effective diaphragm should transfer forces to walls oriented to resist them. Typical roof failure mechanisms are summarized in Figure 5.3.

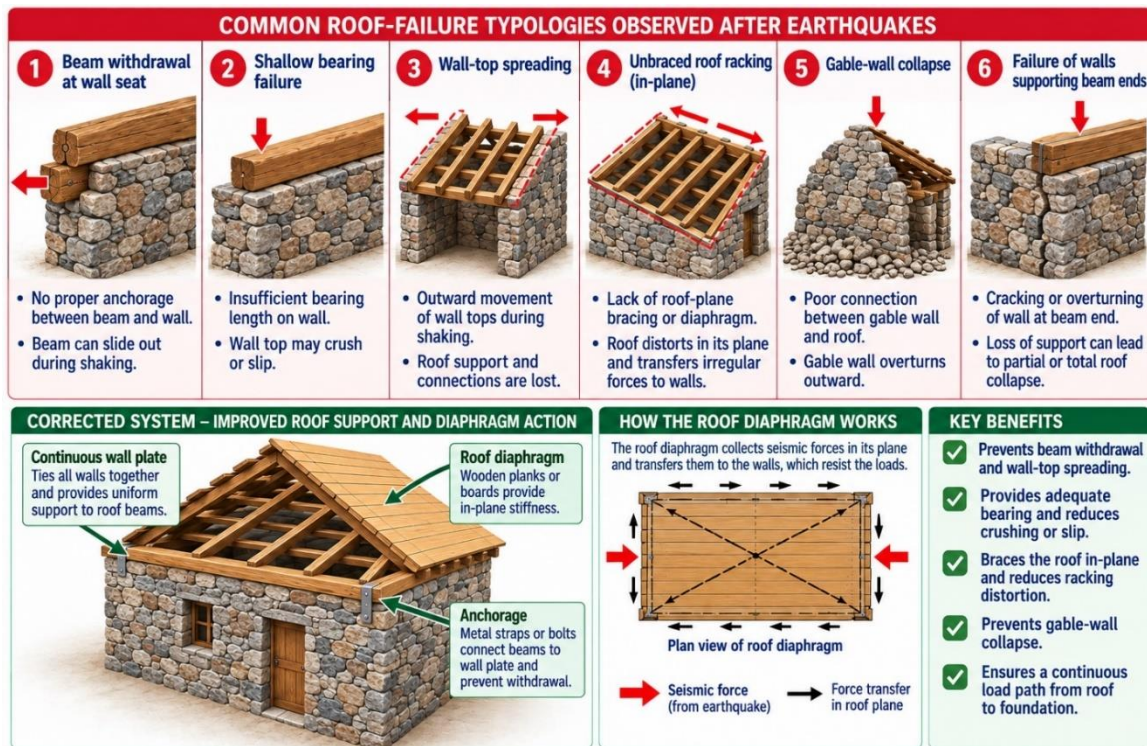


Figure 5.3. Common roof failure mechanisms.

5.7 Failure of Bhatar Construction

Bhatar buildings can fail when the timber lacing is incomplete or degraded. Reported weaknesses in the supplied source material include:

- Missing transverse cross-ties;
- Weak timber;
- Excessive vertical spacing between bands;
- Weak corner joints;
- Long unsupported walls;
- Unreinforced rear walls;
- Openings near corners; and
- Poor wall to roof connections.

Without cross-ties, horizontal runners on the two wall faces may act independently and cannot prevent delamination. Without continuity at corners, the bands do not create box action. The presence of timber is therefore not sufficient; the timber must form a connected three-dimensional system.

5.8 Failure of Dhajji Dewari

Dhajji structures generally demonstrated resilient behavior, but damage can arise from:

- Post to sill pullout;
- Opening or separation of brace connections;
- Weak nail only joints;
- Decayed sill plates;
- Inadequate anchorage to the plinth;
- Loss of infill;
- Failure of supporting platforms or retaining walls; and
- Absence of maintenance.

The post to bottom plate connections controlled the tested wall response. The global strength and deformation capacity of a timber frame may be limited by a small number of critical joints (Ali et al., 2012). Critical Dhajji connection failures are illustrated in Figure 5.4.

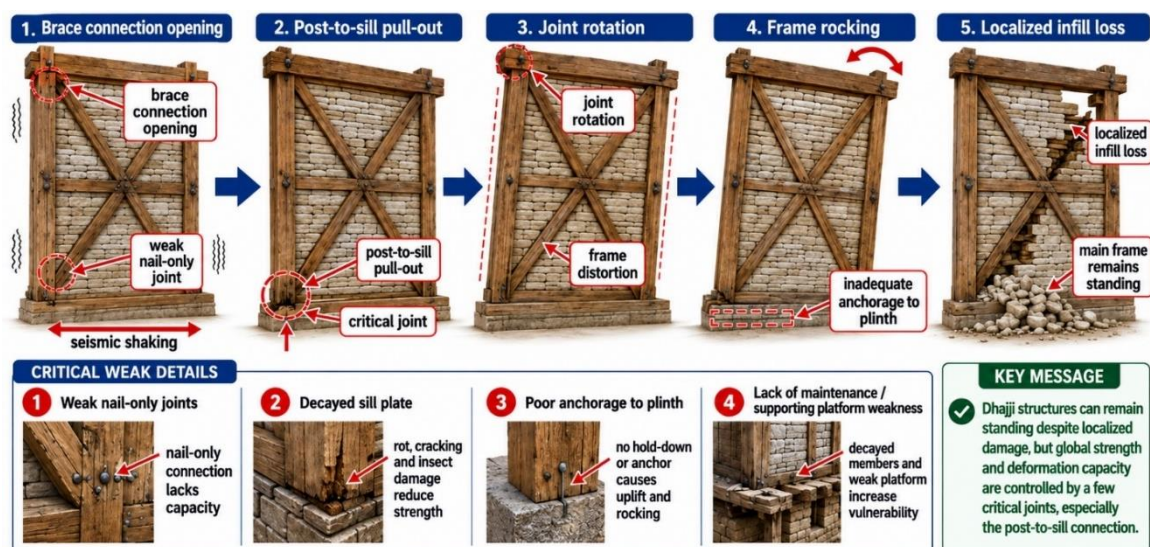


Figure 5.4. Connection failure in Dhajji Dewari.

5.9 Slope, Platform and Retaining Wall Failure

In hilly settlements, building damage may begin below the superstructure. Typical mechanisms include downslope translation of a cut and fill platform, rotation or bulging of an unreinforced retaining wall, settlement of uncompacted fill, toe erosion, rockfall impact and foundation separation across a stepped site. These mechanisms can produce severe distortion even when masonry details are comparatively good. Post-earthquake classification shall therefore record ground movement, drainage, retaining wall condition and foundation displacement separately from wall cracking.

5.10 Comparative Lessons from 2005 and 2015

Cited post-earthquake assessments indicate a recurring pattern across the two earthquakes:

- Rural unreinforced masonry remained the most vulnerable stock;
- Building collapse, rather than ground shaking alone, caused the principal life safety consequences;
- Out of plane wall failure and roof support loss were recurring mechanisms;
- Poor workmanship magnified material weakness;
- Traditional seismic details had often been abandoned in newer construction;
- Surviving timber reinforced buildings demonstrated the value of confinement and continuity; and
- Economic pressure caused communities to continue using the same materials after disasters.

An important lesson is that “new” does not necessarily mean “safer.” A recently constructed stone building may perform worse than an older timber laced building when it replaces traditional bands and interlocking with weak cement mortar, unconnected wythes, and heavy reinforced concrete roofing. Representative slope support and retaining wall conditions are shown in Figure 5.5.



Figure 5.5. Field examples of slope support and retaining wall conditions (Location: Diamir & Chitral;
Photos Credit: Engr. Noshad Khan & Engr. Faheem Ul Jalal).

CHAPTER 6

PRESCRIPTIVE REQUIREMENTS FOR SIMPLE SINGLE-STORY BUILDINGS

6.1 Performance Objective

The prescriptive objective is Life Safety at the BCP-2021 design earthquake for the applicable seismic zone and site conditions. Significant cracking and repairable damage may occur, but sudden wall collapse, wall leaf separation, corner opening, roof loss and loss of a survivable space are to be prevented. This objective applies only when every mandatory measure in this chapter is completed; no single band, mortar mix, through-stone or roof strap compensates for omitted requirements.

The eligibility limits that must be satisfied before applying the prescriptive provisions are summarized in Table 6.1.

Table 6.1. Prescriptive eligibility limits for simple single-story dwellings.

Prescriptive eligibility check	Limit/decision
Building use	Ordinary private dwelling only
Stories	One story; a second story requires engineered design
Plan	Compact and regular; no unresolved re-entrant corners or major offsets
Story height	Maximum 3.0 m
Random rubble wall thickness	380-450 mm excluding plaster, unless engineered
Wall slenderness	$h/t \leq 8$
Unsupported wall length	$l/t \leq 12$ and not more than 5.0 m
Through-stone spacing	Maximum 600 mm vertical and 1.2 m horizontal
Site	Approved under Chapter 4; no unresolved slope/fill/retaining hazard
Roof	Lightweight and positively anchored
Any non-compliance	Project specific structural/geotechnical design
<i>Note - Status of limits: The numerical values in this table are prescriptive empirical/project limits for the stated scope; they do not replace project specific code checks. Projects in high seismic zones, on adverse ground, or with poor/uncertain geology require qualified engineering review before the table is applied. Governing BCP provisions and approved project specific design take precedence.</i>	

This objective can be achieved only through a sequence of complementary measures. No single band, mortar mix, through-stone, or roof strap can compensate for all other deficiencies.

6.2 Simple and Symmetrical Configuration

Buildings shall have compact, regular plans with direct load paths in both principal directions. Square and moderately rectangular plans are preferred (International Association for Earthquake Engineering, 1986/2004). Re-entrant L-, T- and U-shaped plans, large offsets, split levels, and major eccentric roof masses require structural separation or engineering design. Instead of relying on an unsupported universal 3:1 plan ratio, this guideline controls wall panel dimensions, symmetry, cross wall continuity and torsional irregularity. Any elongated plan shall be subdivided by bonded cross walls so that every wall panel meets Section 6.3.

Opposite walls should have reasonably balanced lengths and opening arrangements. Sudden changes in wall height, offset walls, unsupported projections, and large eccentric roof masses should be avoided because they increase torsional response. Preferred and irregular plan configurations are compared in Figure 6.1.

Plan-Shape Comparison for Seismic Performance

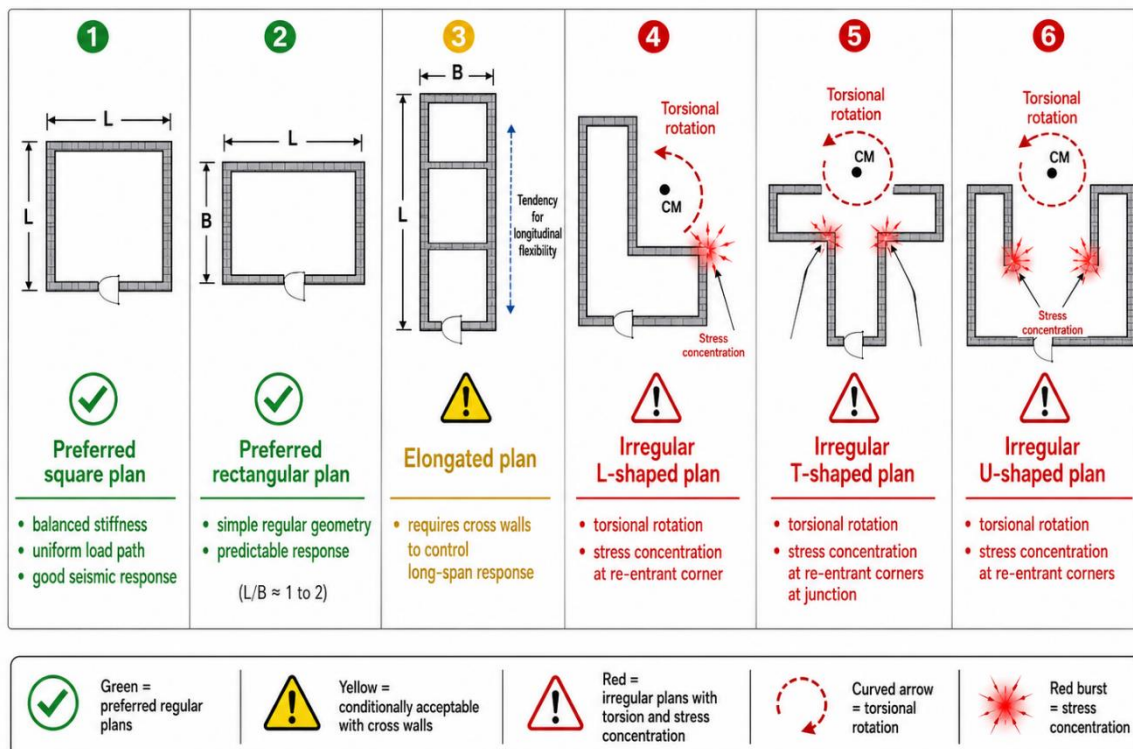


Figure 6.1. Preferred and irregular building plans.

6.3 Box Effect and Cross Wall Arrangement

Cross walls reduce unsupported wall length and provide out of plane restraint. For the prescriptive route, the clear wall height divided by the effective wall thickness, h/t , shall not exceed 8, and the unsupported wall length divided by thickness, l/t , shall not exceed 12. In addition, clear unsupported wall length shall not exceed 5.0 m and story height shall not exceed 3.0 m. The most restrictive limit governs. The h/t , l/t and story-height limits are consistent with Nepal NBC 203 (Department of Urban Development and Building Construction, 2015); the 5.0 m absolute length is a conservative project cap adopted by this guideline. All limits shall be reviewed against BCP-2021 requirements and local hazard. A panel outside any limit requires engineering design.

Cross walls must be bonded into external walls. A cross wall built later against a finished external wall without toothing, anchors, or interlocking cannot provide reliable restraint.

Buttresses may be used where internal cross walls are impractical. They must have sufficient width, projection, foundation support, and connection to the wall. A decorative surface projection does not constitute a structural buttress. Cross wall and buttress arrangements are illustrated in Figure 6.2.

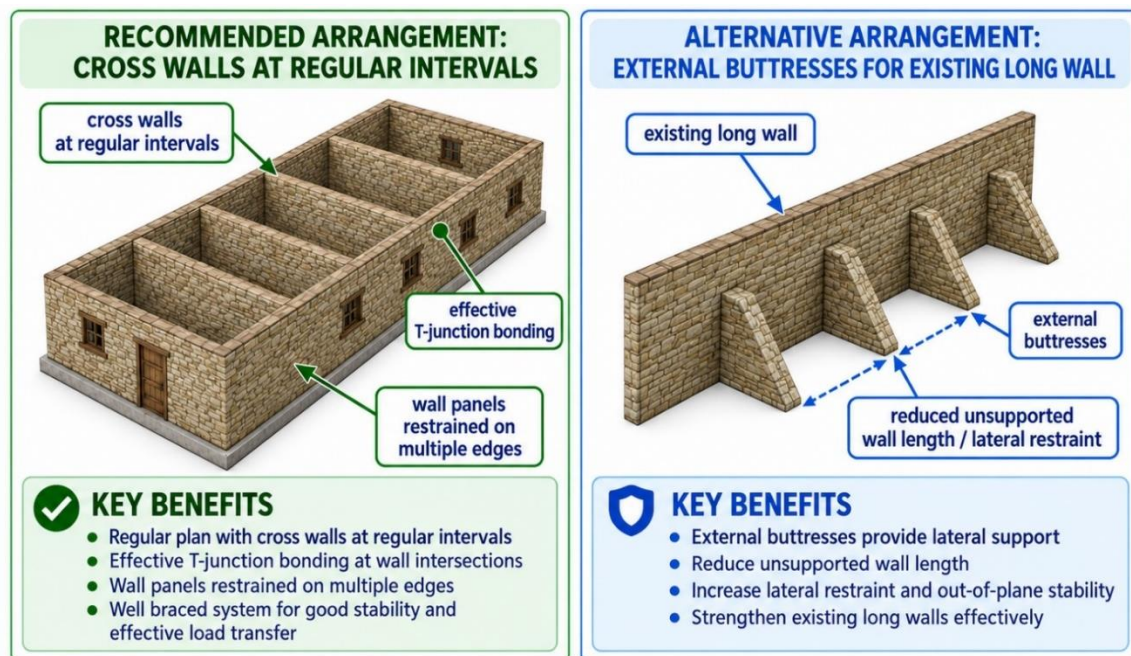


Figure 6.2. Cross wall and buttress arrangements.

6.4 Foundation and Plinth Continuity

The foundation shall be continuous beneath load bearing walls, stepped level by level on slopes and founded on competent ground. Differential support across natural ground and fill, weak platforms, unstable retaining walls, or active drainage paths invalidates the prescriptive route. Chapter 4 site approval is a mandatory hold point before foundation work.

A continuous plinth level tie shall connect the wall bases. Timber supported wall construction shall be kept above persistent ground moisture. As a minimum field durability measure, the finished wall/plinth interface should be at least 300 mm above adjacent finished ground; higher levels are required where snow, splash, flood, or drainage conditions demand. The 300 mm value is a moisture protection minimum, not a flood design elevation and not a retaining wall dimension.

Finished ground shall fall away from the building or drain to a stable lined outlet. Roof and surface water shall not discharge onto fill, at a foundation corner, behind a retaining wall or onto a slope face. Timber at or near plinth level shall be seasoned, protected, inspectable and isolated from direct soil contact. Field examples of foundation and plinth construction on sloping ground are shown in Figure 6.3.



Figure 6.3. Foundation and plinth construction on sloping ground (Location: Chitral & Diamir; Photos Credit: Engr. Faheem Ul Jalal & Engr. Noshad Khan).

6.5 Mortar Stabilization

The mortar strategy has three controlled levels:

1. **Ordinary mud mortar**, which should not be relied upon as the sole stabilizing mechanism in large unreinforced load bearing walls;
2. Tested stabilized earth mortar, selected by dry mass trial batching and Appendix B acceptance tests;
3. Cement sand mortar, nominally 1:6 by measured loose volume where specified at critical nodes or in an approved standard detail.

No universal cement or lime percentage is prescribed. Cement stabilized earth mortar shall be selected from local trial batches, initially 5%, 7% and 9% cement by dry mass of screened soil unless a laboratory recommends another range. Lime dosage shall be based on soil suitability and trial testing. The adopted mix shall be the lowest dosage that passes Appendix B. Cement sand mortar specified as 1:6 means one measured loose volume of cement to six measured loose volumes of clean sand. Water shall be controlled for workability, and curing shall follow the binder requirements. The 5%, 7%, and 9% cement contents are starting trial proportions only; they are not mandatory design mixes and shall not be used unless the adopted field mix passes the Appendix B acceptance protocol.

All mortar joints should be fully filled. Face pointing over an empty internal joint does not create a bonded wall. Mortar should be mixed consistently, protected from contamination, and cured according to the binder used. The field mortar trial and acceptance process is summarized in Figure 6.4.



Figure 6.4. Field mortar trial and acceptance process.

6.6 Stone Selection and Coursing

Applicability to rubble masonry: the provisions in this chapter may be used for coursed rubble or random rubble masonry only where individual stones can be seated stably, vertical joints can be broken, the core can be tightly packed and bonded, the specified wall-thickness range can be maintained, and through-stones or approved transverse ties and continuous seismic bands can be installed. Walls with loose continuous core layers, severe existing delamination, highly unstable rounded stone, or workmanship that cannot achieve these conditions require corrective reconstruction or project specific engineering.

Safer stone masonry should use:

- Durable stones free from severe weathering;
- Broad bearing surfaces;
- Angular or semi dressed units where possible;
- Large stones at corners and junctions;
- Headers extending into the wall;

- Staggered vertical joints;
- Well packed hearting; and
- Stable, approximately horizontal courses.

Stones should not be placed solely to produce a smooth façade. Long stones should extend into or through the wall, and small spalls should fill local voids without creating continuous loose layers (Khadka et al., 2023). Each stone should be stable before mortar is placed around it.

For random rubble load bearing walls under the prescriptive route, nominal wall thickness shall be not less than 380 mm and not greater than 450 mm unless a signed design states otherwise. Thickness shall be measured excluding plaster. Very thick walls are not automatically safer: loose cores increase mass and delamination risk. The wall shall be bonded through its thickness and shall meet both h/t and l/t limits. A field example of bonded flat stone masonry is shown in Figure 6.5.



Figure 6.5. Bonded flat stone masonry with a timber band (Location: Chitral; Photo Credit: Engr. Faheem Ul Jalal).

6.7 Through-Stones and Alternative Ties

Through-stones are among the most economical and important anti delamination measures. In random rubble stone masonry, full thickness bond stones or approved overlapping alternatives shall be installed at maximum spacing of 600 mm vertically and 1.2 m

horizontally, in a staggered arrangement. These limits are consistent with Nepal NBC 203 and the World Housing Encyclopedia stone masonry guidance and are summarized in Appendix A.

- 600 mm vertically; and
- Horizontal spacing shall not exceed 1.2 m.

A through-stone should extend across the full wall thickness and bear adequately on both wall faces. It must not protrude excessively from the façade or be supported solely by loose rubble infill.

Where a single full width stone is unavailable, alternatives may include:

- Paired overlapping stones extending substantially into the wall;
- Durable timber cross-ties;
- Protected steel links; or
- Other engineered transverse connectors.

Alternative ties shall transfer tension across the full wall thickness and prevent separation of the masonry wythes. Timber ties shall receive the seasoning, moisture isolation, and preservative treatment required by Section 3.3. Steel ties shall be hot-dip galvanized, stainless steel, or otherwise protected by an approved corrosion system and shall have positive end anchorage. Where a small steel tie (nominal diameter not greater than 16 mm) is cast into concrete that is exposed to weather or earth contact, clear concrete cover shall be at least 40 mm for weather exposure and at least 75 mm where concrete is cast against and permanently exposed to earth, unless the governing BCP/American Concrete Institute (ACI) provisions or approved design require more (ACI 318-05, as incorporated by reference in BCP-SP-2007; American Concrete Institute, 2005). Where a tie is embedded only in masonry, “concrete cover” is not applicable; the connector shall instead be fully bedded in compatible mortar/grout, protected against corrosion, and detailed for the actual exposure condition. The required through-stone distribution is illustrated in Figure 6.6.

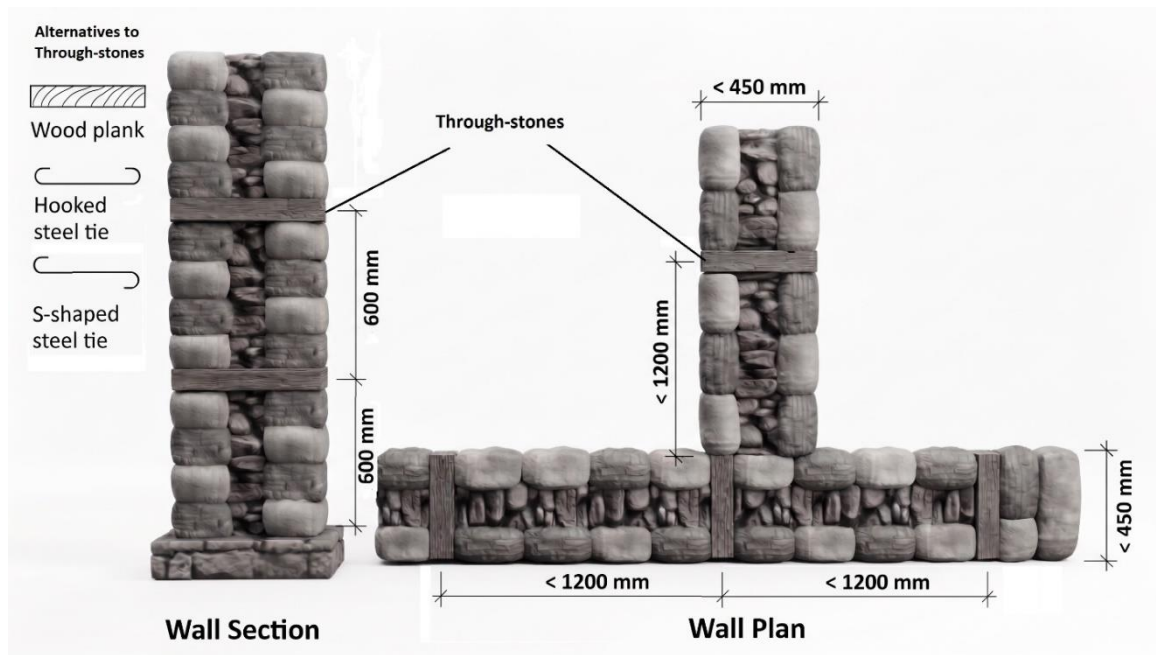


Figure 6.6. Through-stone arrangement in a multi-leaf wall.

6.8 Corner and Junction Interlocking

Corner stones should alternately extend into each intersecting wall. The bond should continue through the wall height rather than being limited to isolated decorative stones. At T-junctions, the cross wall should be toothed or mechanically tied into the main wall.

Horizontal timber or reinforced concrete bands must remain continuous through the junction. Where timber members meet, the joint should transfer axial tension, compression, and shear. Overlapping members, fitted joints, straps, bolts, or equivalent connections may be used depending on timber availability and workmanship. Continuity of timber bands around a masonry corner is shown in Figure 6.7.



Figure 6.7. Continuous timber bands at wall corners (Location: Diamir; Photo Credit: Engr. Noshad Khan).

6.9 Openings

Openings should be:

- Limited in width and total area;
- Positioned away from corners;
- Separated by adequate wall piers;
- Aligned where practicable;
- Supported by properly seated lintels; and
- Integrated with sill and lintel bands.

The masonry beside door and window openings should be carefully interlocked because jambs are locations of stress concentration. Timber posts or other vertical confinement elements at jambs can reduce cracking and prevent local disintegration.

For the prescriptive route, opening dimensions and pier widths shall comply with a verified standard drawing prepared for the selected wall thickness and seismic zone. In the absence of that drawing, no opening shall be placed within 600 mm of an external corner, and no masonry pier between openings shall be narrower than 600 mm or one quarter of the clear

story height, whichever is greater. These are interim project criteria requiring validation against the adopted standard drawing and BCP requirements. A field example of timber framed openings is shown in Figure 6.8. The 600 mm minimum corner clearance value is an interim project criterion of this guideline, not a mandatory national code requirement, and shall not be transferred into local bylaws without appropriate validation and formal adoption.



Figure 6.8. Timber framed openings in stone masonry (Location: Chitral; Photo Credit: Engr. Faheem Ul Jalal).

6.10 Roof Mass and Anchorage

Reducing roof mass reduces seismic inertia. Lightweight pitched roofing is generally preferable to a heavy unreinforced earth or concrete roof where the wall system has limited capacity. A lightweight roof is not safe, however, unless it is anchored.

Roof rafters, joists, or trusses shall be anchored to a continuous roof band or wall plate. The roof diaphragm must be adequately braced to facilitate the transfer of lateral loads. Furthermore, all connections shall be designed to resist uplift and shear displacement along

both principal orthogonal axes. Figure 6.9 illustrates the internal roof framing configuration and the requisite load path continuity.

Lightweight metal roofing reduces seismic mass but does not reduce the need for reliable anchorage. Roofing screws, clips, straps, bolts, washers, and other metal connectors shall be corrosion resistant or protected by a compatible anti-corrosion system, especially where exposed to rain, condensation, or dissimilar metal contact. Corroded or loosened roof connectors shall be replaced during maintenance.



Figure 6.9. Roof framing and internal load path continuity (Location: Diamir; Photo Credit: Engr. Noshad Khan).

CHAPTER 7

ADVANCED REINFORCEMENT TECHNIQUES

7.1 Reinforcement Strategy

Figure control requirement: every figure in this chapter that shows a connection, dimension, reinforcement layout or construction sequence shall be assigned a drawing number, revision, scale/status, and checker. Before field issue, a registered professional engineer shall sign the drawing register in Appendix F. Concept illustrations shall remain marked “NOT FOR CONSTRUCTION.”

Advanced reinforcement shall be selected according to building importance, BCP-2021 seismic zone, site conditions, local materials, labor capacity, durability, and the level of engineering supervision. No advanced system is permitted to compensate for an unsafe site, unstable foundation or unbonded wall core. The systems range from verified timber lacing to engineered reinforced concrete confinement and mesh retrofit.

The objective is to establish a continuous confining system in three dimensions. Horizontal elements tie the building around its perimeter; vertical elements restrain corners, junctions, and openings; transverse elements connect wall faces; and roof/foundation anchors complete the load path.

7.2 Horizontal Timber Lacing

7.2.1 Band Locations

Continuous horizontal timber bands should be considered at the following levels:

- Plinth;
- Window sill;
- Lintel; and
- Roof.

Additional intermediate bands may be required for taller walls or where the traditional Bhatar arrangement is adopted. Sill and lintel bands limit cracking around openings. The roof band ties the wall tops and distributes roof forces. The plinth band connects the base of the walls. The overall timber lacing layout is illustrated in Figure 7.1.

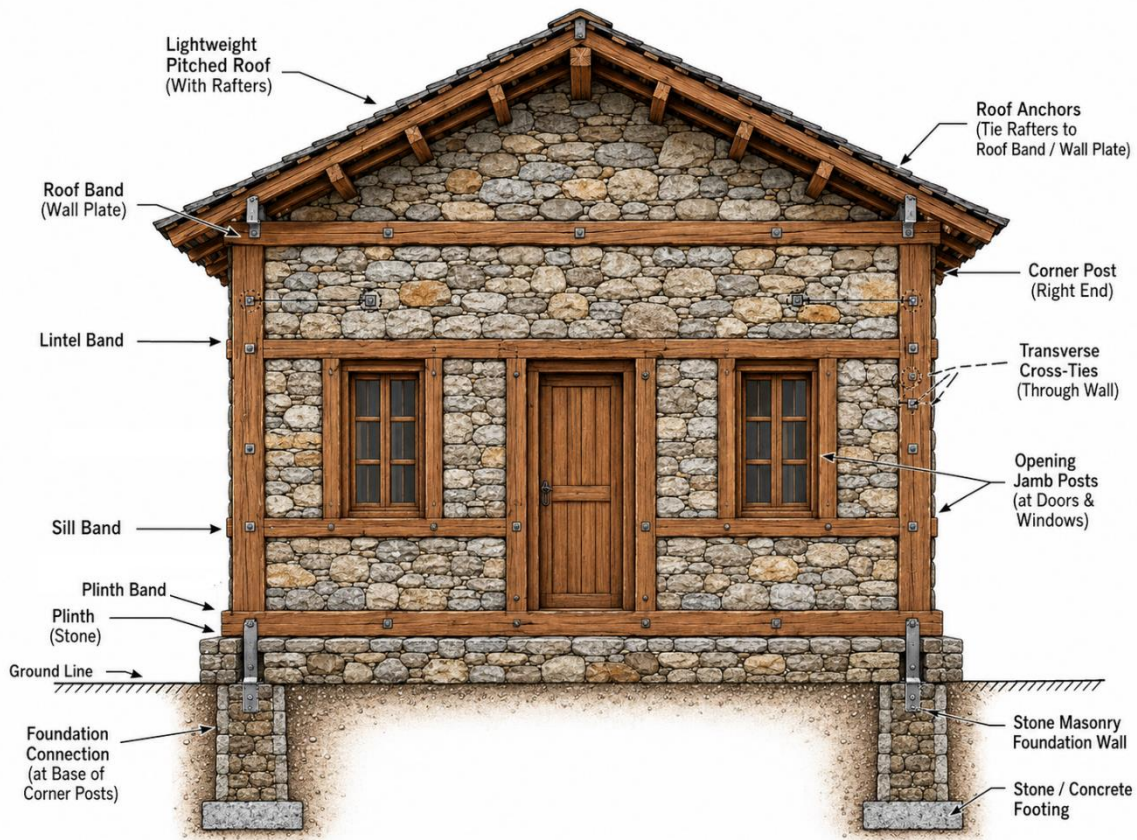


Figure 7.1. Timber laced stone house reinforcement layout.

7.2.2 Paired Runners and Cross-Ties

In thick stone masonry, timber runners should be placed along both wall faces and connected by transverse timber pieces. The cross-ties restrain delamination and enable the paired runners to function as one band.

A single timber embedded only near the outer wall face may improve local continuity but cannot adequately restrain the inner wythe. Cross-ties should therefore be treated as integral components rather than optional accessories. Paired runners and transverse ties are illustrated in Figure 7.2.

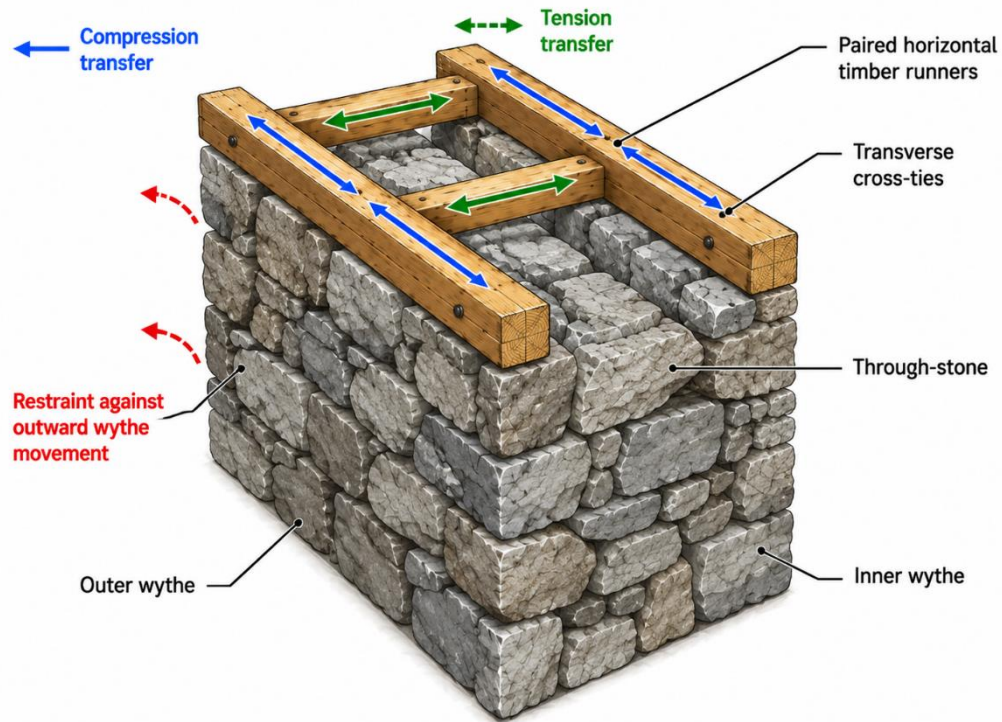


Figure 7.2. Paired timber runners and transverse ties.

7.2.3 Continuity and Splices

Bands should be continuous around the building. Where timber length is insufficient, splices should be staggered and detailed to transfer axial force. Simple end to end butt joints provide limited tensile continuity and should not be relied upon without straps, laps, bolts, or fitted carpentry.

At corners, the connection should engage both wall directions. Metal straps, bolted angle plates, lap joints, or wooden knee braces may be used when compatible with the timber and workmanship. These details create continuity; they should not automatically be classified as rigid moment connections unless structurally designed and verified as such. Representative splice and corner joint options are shown in Figure 7.3.

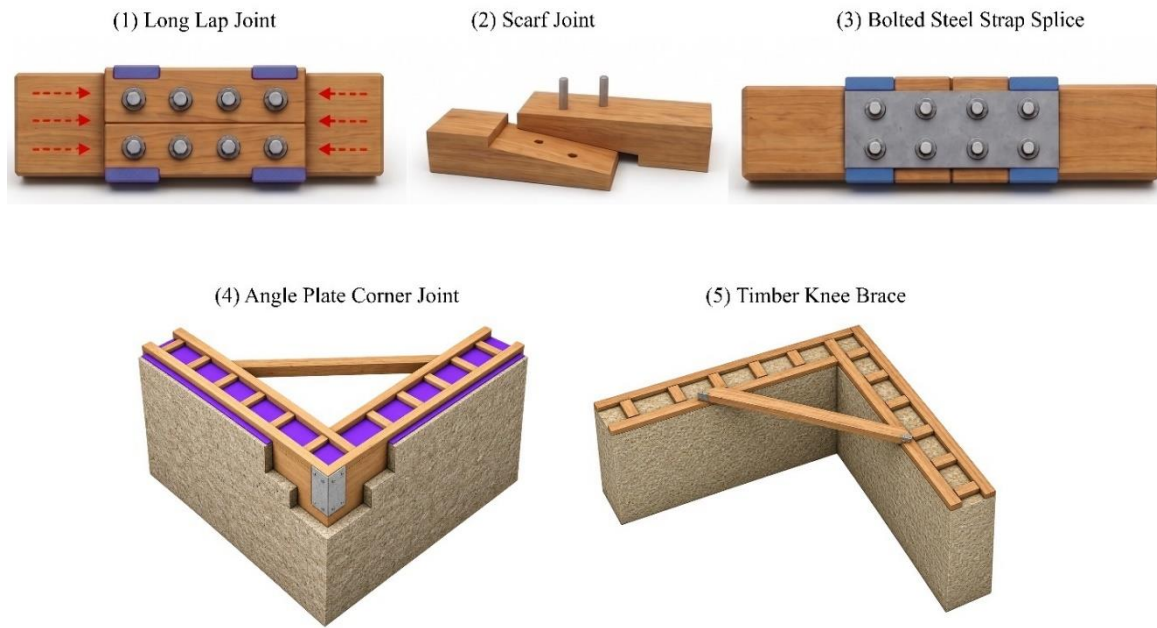


Figure 7.3. Timber band splice and corner joint options.

7.3 Vertical Timber Reinforcement

Vertical timber members may be used at corners, wall intersections, selected opening jambs and intermediate locations as part of a continuous timber cage. No universal 100-150 mm diameter is adopted in this edition. The required section depends on species, grade, effective length, roof load, post spacing, joint geometry, moisture exposure and seismic demand. Prescriptive member sizes shall be issued only in a species specific, tested and engineer signed standard drawing.

- Typical locations include building corners;
- Wall intersections;
- Selected opening jambs; and
- Intermediate positions required by the verified drawing.

Until a prescriptive timber sizing schedule is officially established, the dimensioning of vertical posts shall require site specific structural design. Every post shall be anchored to the foundation or plinth system and mechanically connected to each horizontal band. An unconnected or decorative post shall not be counted as reinforcement.

Vertical timber posts should be anchored at the foundation or plinth and connected to every horizontal band they cross. An unconnected vertical member cannot form a confining cage.

Posts should be plumb, sound, treated where exposed to moisture, and protected from direct soil contact.

At corners, the arrangement must connect both wall directions. At openings, posts should support and restrain lintels and reduce disintegration of jamb masonry. Recommended locations for vertical timber reinforcement are shown in Figure 7.4.

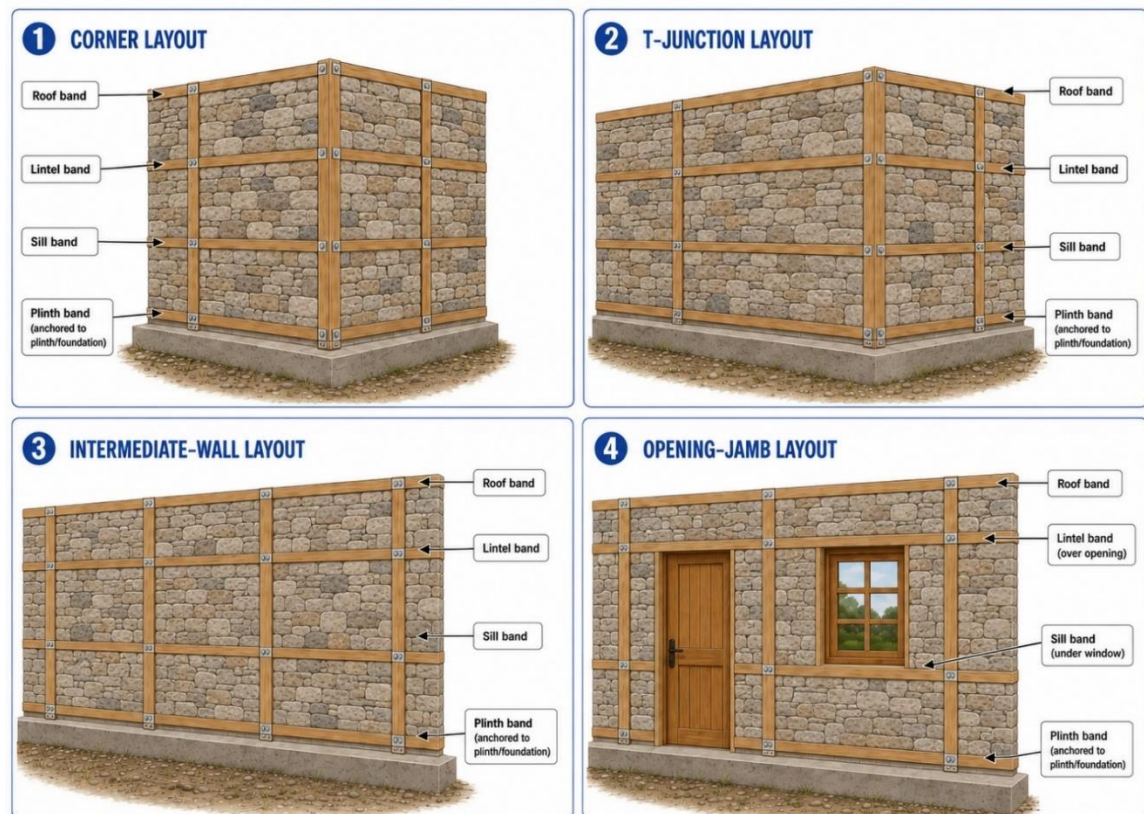


Figure 7.4. Locations of vertical timber reinforcement.

7.4 Timber to Timber and Timber to Masonry Connections

Ali et al. (2012) demonstrated that timber connections can control the lateral response of Dhajji walls. Connection design should therefore address:

- Axial tension and compression;
- Shear;
- Withdrawal;
- Rotation;
- Cyclic load reversal;
- Timber splitting;

- Fastener corrosion; and
- Ease of inspection.

Bolts and straps can improve reliability where fitted carpentry skills are limited. However, over tightening bolts may crush timber fibers, while insufficient washers may cause local embedment. Nails alone may be inadequate for major primary joints, particularly where withdrawal governs.

Connections should allow the system to deform without immediately disengaging. A connection that is extremely stiff but brittle may transfer damaging force into adjacent timber or masonry. Deformable and brittle timber joint responses are compared in Figure 7.5.

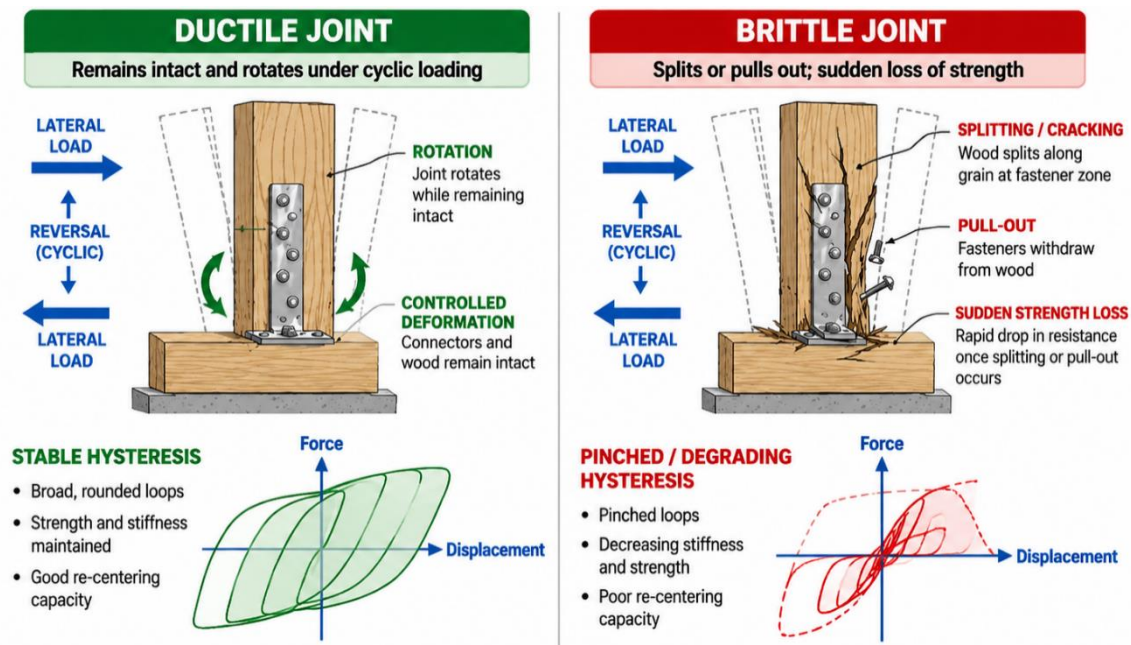


Figure 7.5. Deformable and brittle timber joint response.

7.5 Reinforced Concrete Confinement

7.5.1 Structural Function

Reinforced concrete tie columns and horizontal bands may confine stone masonry panels, improve wall to wall continuity, restrain out of plane displacement and create defined load paths. Their design shall comply with BCP-SP-2007, BCP-2021 and an approved confined masonry or structural design. Stone infill, concrete elements and reinforcement shall be detailed as a compatible system rather than as disconnected frames cast beside a completed wall.

Tie-column and band dimensions shall not be treated as universal. Their dimensions, reinforcement, anchorage, lap lengths, concrete strength and connection to stone masonry shall be calculated and shown on signed drawings for the specific building. A small concrete strip without adequate reinforcement, continuity or masonry interlock shall not be described as confinement.

7.5.2 Construction Sequence

For effective confined masonry behavior, masonry and reinforced concrete elements must be securely connected. Smooth concrete columns cast independently beside a completed stone wall may separate unless mechanical or geometric interlock is provided.

The confinement system should connect continuously into the foundation and roof level. Reinforcement continuity, lap lengths, concrete compaction, cover, curing, and joint preparation require supervision. Poorly constructed reinforced concrete may add cost and weight without delivering reliable ductility. Field examples of hybrid stone timber buildings supported on reinforced concrete plinths are shown in Figure 7.6. These photographs do not, by themselves, demonstrate code compliant confined masonry. Reinforced concrete components are not inherently safe if construction quality is poor. Common field defects such as inadequate curing, unsuitable or poorly graded aggregate, insufficient compaction, incorrect bar position or lap, and inadequate reinforcement cover can negate the intended confinement action; these items require inspection before concrete placement and during curing.



Figure 7.6. Hybrid stone timber buildings with reinforced concrete plinths (Location: Chitral; Photos Credit: Engr. Faheem Ul Jalal).

7.5.3 Appropriate Use

Reinforced concrete confinement may be justified for:

- Schools and other important community buildings;
- Sites where timber is scarce;
- Buildings requiring higher durability;
- Structures with controlled material supply and supervision; or
- Locations where qualified design and construction are available.

It is generally more expensive than timber lacing because it requires cement, steel, aggregate, formwork, curing, and trained labor. It should therefore be selected where its additional reliability can be achieved in practice, not merely specified on paper.

7.6 Wire Mesh Retrofitting

7.6.1 Two-Sided Mesh Confinement

For existing multi leaf walls, galvanized wire mesh may be fixed to both wall faces and connected through the wall by transverse ties. This creates a confining sandwich that restrains stone expulsion and holds cracked masonry together.

The system is effective only when:

- Mesh is continuous;
- Overlaps are adequate;
- Transverse ties genuinely connect the two faces;
- Corners and openings are wrapped or anchored;
- The wall substrate is prepared;
- Corrosion protection is maintained; and
- The mesh is integrated with a compatible plaster or mortar layer where required.

Mesh fixed only to deteriorated surface plaster cannot restrain the wall core. The principal components of a two-sided mesh retrofit are shown in Figure 7.7.

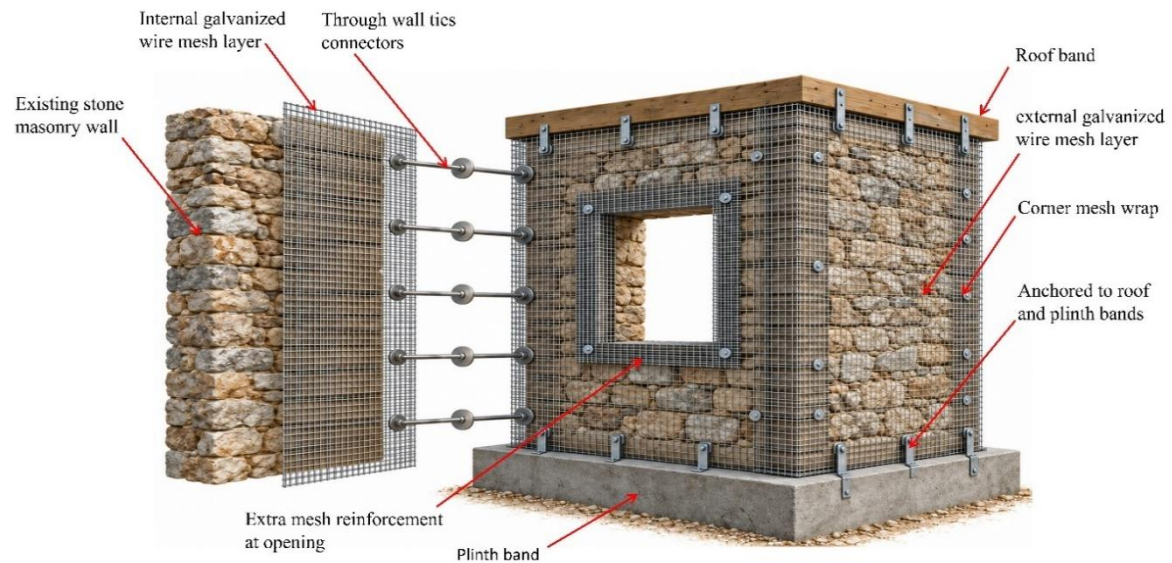


Figure 7.7. Two-sided wire mesh retrofit.

7.6.2 Limitations

Wire mesh shall not be used as the sole rehabilitation measure for a wall that is severely bulged, has a loose or collapsing inner core, has lost gravity load stability, or has extensive delamination. Unstable portions shall be locally dismantled and rebuilt, or otherwise stabilized through a designed repair, before any mesh confinement is installed.

Wire mesh may conceal deterioration if applied without prior investigation. Existing wall stability, voids, foundation condition, moisture, and roof anchorage should be assessed first. Mesh should not be used to justify retention of a wall that has already lost gravity load stability.

Corrosion is a significant long-term concern. Mesh exposed to rain or embedded in permeable, cracked plaster may lose section. Maintenance and material compatibility are therefore necessary.

7.7 Gabion Construction

Gabions consist of stone contained within wire cages. Their principal advantages are that irregular local stone can be used, confinement is provided by the cage, and limited deformation can occur without immediate loss of the fill. Gabions can be constructed with comparatively modest masonry skills.

They are well established for retaining, erosion control, and non-building applications. Their use as primary walls in habitable buildings requires careful evaluation of:

- Cage durability;
- Wire corrosion;
- Wall thickness;
- Vertical load capacity;
- Lateral stability;
- Connections between baskets;
- Roof anchorage;
- Fire and weather protection;
- Thermal requirements; and
- Local building regulations.

Gabion construction should therefore not be assumed equivalent to code compliant reinforced masonry. The gabion assembly sequence is illustrated in Figure 7.8.

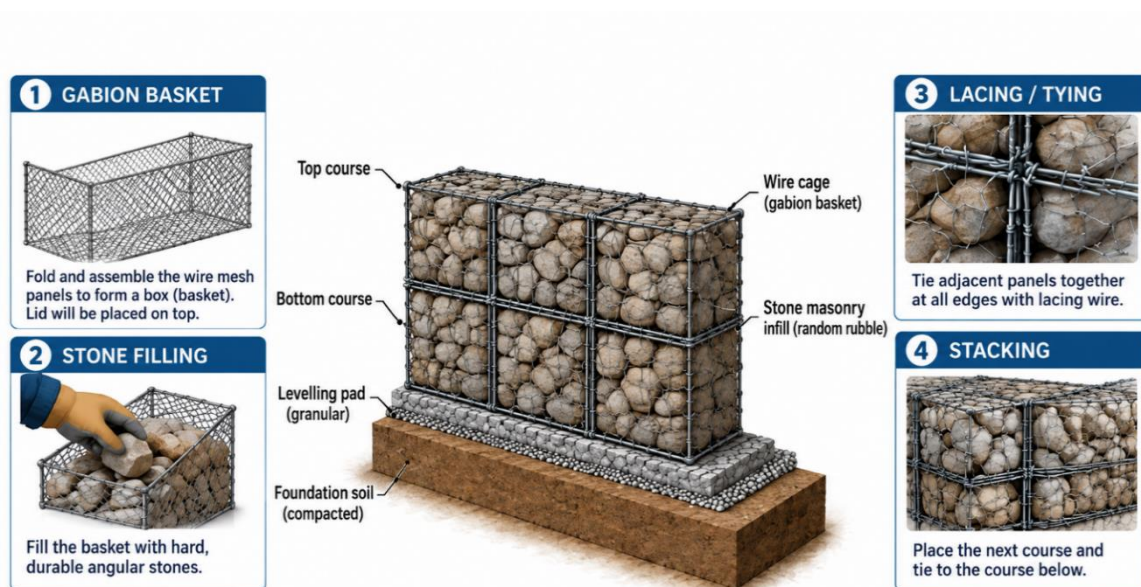


Figure 7.8. Gabion wall assembly.

7.8 Hybrid Gabion and Timber Laced System

WARNING - RESEARCH PROTOTYPE ONLY: The gabion timber hybrid is not part of the prescriptive residential package and shall not be used for routine or

large-scale dwelling construction. Its use is limited to controlled research or demonstration projects supported by signed engineering design, defined test/monitoring criteria, independent review, and formal approval.

A hybrid system using gabion construction at foundation or lower wall level and timber laced masonry above has been suggested as a possible research concept. It is not included in the prescriptive construction package. Its economic rationale is potentially attractive, but the transition between flexible wire cages and the upper timber masonry system, global stability, durability, and roof/foundation load paths remains unverified.

Structurally, the transition between the systems is critical. The lower gabion component and upper timber frame must not behave as separate blocks. A continuous sill or transition beam would be required, anchored to the gabion cages, and connected to the vertical and horizontal timber system.

Possible anchorage concepts include heavy gauge galvanized wire loops, bolted U-shaped anchors, or a designed transition frame. However, no universal detail can be prescribed from the cited literature and the applicable Pakistani code framework. The hybrid structural system shall remain designated as a research prototype, necessitating comprehensive structural analysis, material characterization, full-scale connection validation, durability assessments, and monitored demonstration construction prior to widespread policy adoption. The unverified gabion to timber transition concept is shown in Figure 7.9.

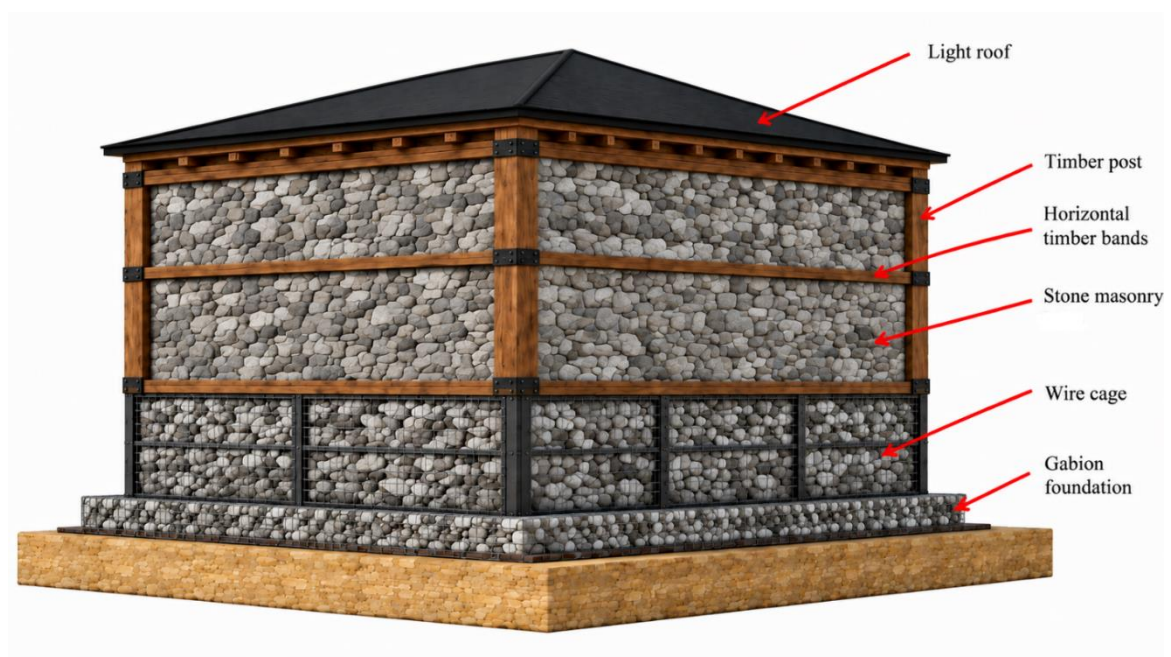


Figure 7.9. Unverified gabion to timber transition concept.

7.9 Comparative Selection of Reinforcement Systems

A pragmatic hierarchy of structural interventions can be established as follows:

- **Minimum essential system:** improved geometry, interlocked corners, proper coursing, through-stones, roof anchorage, and compatible mortar.
- **Timber laced system:** minimum measures plus continuous horizontal lacing, cross-ties, and selected vertical posts.
- **Confined system:** minimum measures plus designed reinforced concrete tie columns and beams.
- **Retrofit system:** existing wall assessment followed by through-stones, anchors, bands, mesh, or other compatible strengthening.
- **Pilot hybrid system:** gabion lower construction with engineered timber laced upper construction, subject to validation.

Selection should be based on total life cycle reliability rather than initial material cost alone.

The system selection framework is summarized in Figure 7.10.

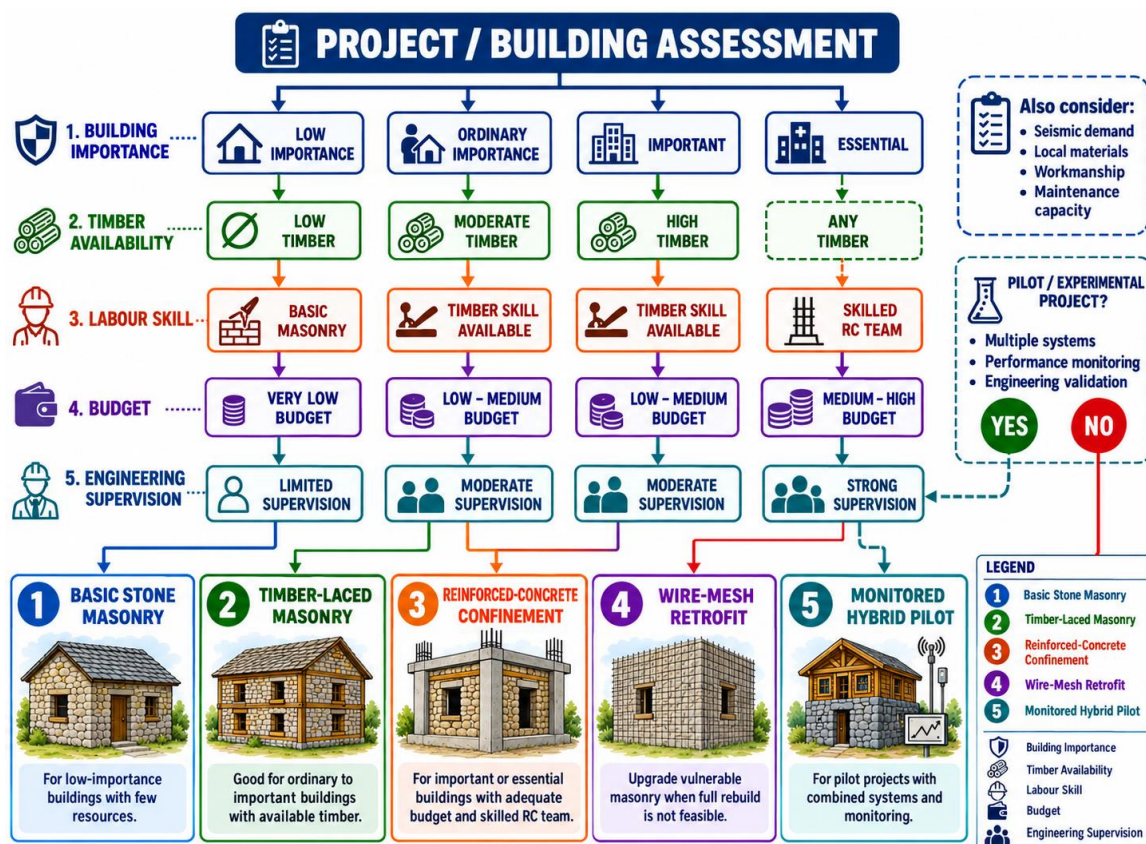


Figure 7.10. Selection of reinforcement systems.

CHAPTER 8

IMPLEMENTATION, QUALITY ASSURANCE AND POLICY

8.1 Principal Findings

The principal finding is that life safety depends on continuity from stable ground to the roof. Increasing wall thickness or adding cement mortar does not correct an unstable site, unbonded wall leaves, open corners, discontinuous bands, or an unanchored roof. The implementation package shall therefore be audited as one load path rather than as isolated material items.

The principal vulnerabilities are:

- Unconnected inner and outer wythes;
- Loose rubble cores;
- Missing through-stones;
- Weak wall intersections;
- Unanchored roofs;
- Heavy superstructure mass;
- Poor opening configuration;
- Degraded mortar and timber;
- Discontinuous seismic bands; and
- Inadequate workmanship.

The corresponding core interventions are:

1. Use a compact and regular building plan;
2. Limit unsupported wall lengths;
3. Provide cross walls or structural buttresses;
4. Prioritizing structural interlock over visual aesthetics during stone bedding;
5. Stagger vertical joints;
6. Provide through-stones or equivalent transverse ties;
7. Interlock corners and junctions;

8. Use tested stabilized mortar where appropriate;
9. Provide continuous horizontal bands;
10. Add vertical confinement at corners, junctions, and openings;
11. Anchor lightweight roofs to the wall system; and
12. Protect timber and masonry from moisture.

8.2 Hybridization of Indigenous and Modern Engineering

The evidence from Bhatar, Taq, Dhajji Dewari, and analogous hımış construction demonstrates that timber can provide tensile continuity, confinement, subdivision, and deformation capacity to masonry. Bothara and Hiçyılmaz (2008) documented the comparatively favorable earthquake performance of maintained traditional systems. Ali et al. (2012) experimentally demonstrated the lateral resilience and energy dissipation mechanisms of Dhajji walls. Gülkan and Langenbach (2021) place these systems within a wider family of timber frame masonry traditions.

Contemporary engineering principles contribute essential standardization, robust connection design, rigorous quality assurance, material testing protocols, and continuous load paths. Therefore, the most effective policy framework avoids both the unmodified retention of vernacular methods and the ubiquitous imposition of reinforced concrete. Instead, it advocates for the controlled hybridization of empirically validated local mechanisms with verifiable modern detailing. Completed field applications of this hybrid stone timber typology are depicted in Figure 8.1.



Figure 8.1. Completed hybrid stone timber houses (Location: Kohistan; Photo Credit: Engr. Ayub Khan).

8.3 Recommended Implementation Hierarchy

8.3.1 Immediate Mandatory Measures

For eligible single-story dwellings, the following measures shall form the minimum construction package:

Recorded BCP-2021 seismic zone and approved project scope;

Site and foundation approval in accordance with Chapter 4;

- Regular building configuration;
- Competent foundation and drainage;
- Stable stone coursing;
- Full wall bonding;
- Through-stones;
- Corner interlocking;
- Controlled openings;
- Roof anchorage; and
- Continuous roof level tying.

These measures provide high structural benefit with limited industrial material.

8.3.2 Timber Lacing Program

Where durable timber is locally available, a standardized Bhatar type package should be developed. It should specify:

- Band levels;
- Paired runners;
- Through wall cross-ties;
- Splice details;
- Corner joints;
- Vertical posts;
- Roof connections;
- Timber treatment; and
- Inspection procedures.

The details should be presented through full-scale drawings and demonstration panels rather than text alone.

8.3.3 Engineered Confinement for Important Buildings

Schools, health facilities, community halls, and other high occupancy buildings should not rely solely on prescriptive rural details. They require site specific engineering and enhanced quality control. Designed reinforced concrete or engineered timber confinement may be appropriate, depending on material access and construction capability.

8.3.4 Existing Building Retrofit

A retrofit program should begin with condition assessment. Buildings with unstable foundations, severely bulged walls, advanced delamination, decayed primary timber, or lost gravity load capacity require professional evaluation before strengthening. The existing building retrofit workflow is summarized in Figure 8.2.

Retrofit measures may include:

- Installation of through wall ties;
- Repair and repointing;
- Corner stitching;

- Roof anchorage;
- Horizontal bands;
- Local rebuilding;
- Mesh confinement; and
- Replacement of decayed timber.



Figure 8.2. Existing building retrofit workflow.

8.4 Mason and Carpenter Training

Training should reproduce actual construction conditions. Each trainee should demonstrate the ability to:

- Distinguish suitable and unsuitable stones;
- Construct a bonded corner;
- Place a through-stone;
- Build a stable wall lift;
- Prepare a measured mortar batch;
- Install paired timber bands;
- Connect cross-ties;
- Form a timber splice;
- Anchor a roof member; and

- Identify moisture and decay.

Certification should be based on practical performance. A register of trained local masons and carpenters would support post-disaster reconstruction and routine rural construction.

Training programs should actively accommodate women who participate in house construction, repair, and maintenance, where this is relevant to the local community. Training schedules, venues, demonstration work, and safety arrangements should support practical participation without changing the competency requirements for certification.

8.5 Demonstration Buildings

Community scale demonstration houses should be constructed in representative districts. The structural system should remain partly exposed so that homeowners can see through-stones, timber bands, straps, mesh, and roof ties before plastering.

Demonstration programs should also include a clearly marked “do not build this way” display area showing common defective practices, such as face only timber lacing, unbonded corners, loose wall cores, missing through-stones, inadequate roof ties, and improperly drained retaining conditions. Defective demonstration specimens shall be physically separated or marked so that they cannot be mistaken for approved construction.

Demonstration buildings should include cost records, construction time, local labor requirements, maintenance observations, and post-construction inspections. Where feasible, representative wall and connection specimens should be tested cyclically before a detail is promoted at regional scale. The proposed demonstration and training layout is shown in Figure 8.3.



Figure 8.3. Community demonstration and mason training layout.

8.6 Quality Assurance

The inspection checklists in Appendix C shall be used at defined hold points. Work shall not proceed beyond a hold point until the responsible supervisor signs “Pass,” records an approved corrective action, or refers the work for engineering review (Earthquake Reconstruction and Rehabilitation Authority, 2008).

1. Site and foundation approval;
2. Plinth and drainage inspection;
3. First masonry lift;
4. Through-stone verification;
5. Corner and junction inspection;
6. Sill and lintel band inspection;
7. Opening and vertical post inspection;
8. Roof band and anchorage inspection; and
9. Final moisture protection inspection.

Critical details should be photographed before they are concealed. Inspection should focus on structural continuity rather than surface appearance.

Acceptance is binary for concealed life-safety details: through-stones, band continuity, cross-ties, corner joints, roof anchors and reinforcement cannot be accepted as “mostly complete.” Photographs shall include a scale and location reference. The final completion certificate shall identify the drawing revision, material trial record and persons responsible for inspection.

8.7 Economic and Institutional Strategy

Financial support shall prioritize verified high benefit components rather than material quantities without quality control. The project cost plan shall separate: (a) base shelter work; (b) incremental seismic life-safety items; (c) site, drainage and retaining works; (d) training and inspection; and (e) contingencies for remote transport. Rates shall be dated and sourced from the latest applicable provincial Market Rate System and current district quotations. Incremental life-safety cost means only the additional expenditure required for the seismic safety measures, testing, supervision, and associated durability provisions; it excludes the cost of the basic shelter that would have been constructed without those improvements.

- Pre-cut and treated timber band kits;
- Standardized straps and bolts;
- Measured cement or lime for stabilization;
- Through-tie components;
- Roof anchor kits;
- Mason training vouchers; and
- Inspection linked to staged financial assistance.

Local authorities, engineering institutions, disaster management agencies, universities, community organizations, and timber suppliers should coordinate standard details and terminology. Conflicting guidance can lead to partial implementation and false confidence.

Local authorities shall not extend the prescriptive single-story provisions in this manual to two-story or multistory buildings, schools, hospitals, community buildings, or other excluded occupancies without dedicated project specific engineering design and review.

Before public issue, the implementing agency shall publish one completed example for a 30-40 m² reference house in each target district. This guideline does not invent a national PKR range because available official Market Rate System (MRS) data, local timber prices and remote transport costs must be combined for the actual location. A blank template is provided in Appendix D so that donor and government budgets remain transparent and updateable.

The required basis for reporting key incremental life safety cost items is summarized in Table 8.1.

Table 8.1. Required basis for reporting incremental life-safety costs.

Budget item	Required reporting basis
Through-stones/through-ties	Number, type, wall thickness and installed unit rate
Timber bands and posts	Species/grade, treated volume, connectors, fabrication, and installation
Roof anchorage	Number and type of straps/anchors plus labor
Mortar stabilization	Dry soil mass, binder dosage, binder bags and testing cost
Drainage/site works	Measured drains, outlets, platform preparation and retaining works
Training/inspection	Trainee days, supervisor days, travel, and documentation
Reference house total	Base shelter cost and incremental life-safety cost reported separately in PKR; the incremental value includes only additional seismic safety, durability, testing, supervision, and related implementation costs, not the underlying basic shelter cost

8.8 Policy Position on the Gabion–Timber Hybrid

A gabion lower structure combined with a timber laced upper structure may offer economic and logistical advantages where irregular stone is abundant and conventional masonry skills are limited. It may also provide a potentially deformable lower assembly and a lighter, better confined upper wall system.

Nevertheless, its use in occupied buildings should proceed through a controlled research and pilot program. The transition connection, global stability, roof anchorage, wire durability, thermal performance, and vertical load behavior require verification. The system should not be promoted as a universal solution until prototype testing and monitored field performance establish its reliability.

8.9 Final Conclusion

An economical and safer stone masonry house in Pakistan is technically achievable only when the site is stable, the applicable BCP seismic requirements are identified, the building remains within the prescriptive scope, every critical connection is inspected and all non-prescriptive conditions are referred for engineering design.

The economically rational strategy is to retain local stone while correcting the discontinuities responsible for collapse. Through-stones prevent wall leaf separation; interlocked corners and continuous bands create box action; verified timber or reinforced concrete elements provide confinement; roof anchors preserve gravity support; tested mortar improves integrity and durability; and drainage protects both the ground and the construction materials. None of these measures can compensate for an unstable slope or foundation.

The resulting approach is neither purely traditional nor purely modern. It is a controlled, code aware hybrid based on observed earthquake performance, experimental evidence, local affordability, and explicit structural mechanics. Adoption requires a signed standard drawing set, local material trials, a district cost schedule, mason and carpenter certification, construction hold points, independent technical review and monitored demonstration buildings.

REFERENCES

- Ahmad, N., Ali, Q., Adil, M., & Khan, A. N. (2018). Developing seismic risk prediction functions for structures. *Shock and Vibration*, 2018, 4186015. <https://doi.org/10.1155/2018/4186015>
- Ali, Q., & Muhammad, T. (2011). Stone masonry residential buildings, Pakistan (World Housing Encyclopedia Report 138). Earthquake Engineering Research Institute and International Association for Earthquake Engineering.
- Ali, Q., Schacher, T., Ashraf, M., Alam, B., Naeem, A., Ahmad, N., & Umar, M. (2012). In-plane behavior of the Dhajji-Dewari structural system (wooden braced frame with masonry infill). *Earthquake Spectra*, 28(3), 835-858. <https://doi.org/10.1193/1.4000051>
- American Concrete Institute. (2005). Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05). Farmington Hills, Michigan: American Concrete Institute.
- Bothara, J., & Brzev, S. (2011). A tutorial: Improving the seismic performance of stone masonry buildings (WHE-2011-01). Earthquake Engineering Research Institute/World Housing Encyclopedia.
- Bothara, J. K., & Hiçyılmaz, K. M. (2008). General observations of building behaviour during the 8th October 2005 Pakistan earthquake. *Bulletin of the New Zealand Society for Earthquake Engineering*, 41(4), 209-233.
- Chandra, U. (1975). Fault-plane solution and tectonic implications of the Pattan, Pakistan earthquake of December 28, 1974. *Tectonophysics*, 28(3), T19-T24. [https://doi.org/10.1016/0040-1951\(75\)90032-3](https://doi.org/10.1016/0040-1951(75)90032-3)
- Carabbio, R., Pieraccini, L., Silvestri, S., & Schildkamp, M. (2018). How can vernacular construction techniques sustain earthquakes: The case of the Bhatar buildings. *Frontiers in Built Environment*, 4, 18.
- De Berardinis, P., Rotilio, M., Marchionni, C., & Friedman, A. (2014). Improving the energy-efficiency of historic masonry buildings. A case study: A minor centre in the Abruzzo region, Italy. *Energy and Buildings*, 80, 415-423.
- Department of Urban Development and Building Construction, Government of Nepal. (2015). Nepal National Building Code NBC 203: Guidelines for earthquake resistant building construction - Low strength masonry.

- Earthquake Reconstruction and Rehabilitation Authority. (2006). Building back better: Rural housing reconstruction strategy for earthquake hit districts in NWFP (North-West Frontier Province) and AJK (Azad Jammu and Kashmir). Government of Pakistan.
- Earthquake Reconstruction and Rehabilitation Authority. (2008). Compliance catalogue: Rural housing reconstruction programme. Government of Pakistan.
- Gautam, D., Rupakhety, R., Adhikari, R., Shrestha, B. C., Baruwat, R., & Bhatt, L. (2021). Seismic vulnerability of Himalayan stone masonry: Regional perspectives. In *Masonry Construction in Active Seismic Regions* (pp. 25-60). Elsevier. <https://doi.org/10.1016/B978-0-12-821087-1.00014-4>
- Gülkan, P., & Langenbach, R. (2021). Traditional timber laced masonry construction in Turkey known as himiş. In *Masonry Construction in Active Seismic Regions* (pp. 61-97). Woodhead Publishing.
- Hiçyılmaz, K., Bothara, J. K., & Stephenson, M. (2011). Dhajji Dewari, Pakistan and India (World Housing Encyclopedia Report 146). Earthquake Engineering Research Institute and International Association for Earthquake Engineering.
- International Association for Earthquake Engineering. (1986/2004). Guidelines for earthquake resistant non-engineered construction. Tokyo.
- Ismail, N., & Khattak, N. (2016). Building typologies prevalent in Northern Pakistan and their performance during the 2015 Hindu Kush Earthquake. *Earthquake Spectra*, 32(4), 2473-2493.
- Ismail, N., & Khattak, N. (2015). Reconnaissance report on the Mw 7.5 Hindu Kush earthquake of 26th October 2015 and the subsequent aftershocks. *United Arab Emirates University: Al Ain, United Arab Emirates*.
- Khadka, S. S., Acharya, S., Acharya, A., & Veletzos, M. J. (2023). Enhancement of Himalayan irregular stone masonry buildings for resilient seismic design. *Frontiers in Built Environment*, 9, 1086008. <https://doi.org/10.3389/fbuil.2023.1086008>
- Manandhar, V., Alexander, N., Shrestha, H., Marasini, N., Prajapati, R., Chaulagain, R., ... & Sextos, A. (2026). Affordable seismic strengthening of stone masonry walls: experimental validation using an in-situ testing approach. *International Journal of Disaster Risk Reduction*, 106204.

- Pakistan Forest Institute. (n.d.). Important Pakistani timbers. Peshawar, Pakistan.
<https://www.pfi.gov.pk/cipt/htdocs/CIPT/timbers.php>
- Pakistan Engineering Council. (2007). Building Code of Pakistan - Seismic Provisions 2007 (BCP-SP-2007). Government of Pakistan.
- Pakistan Engineering Council. (2008). Statutory Regulatory Order (S.R.O.) 971(I)/2008: Application of Building Code of Pakistan (Seismic Provisions-2007). Gazette of Pakistan.
- Pakistan Engineering Council. (2021). Building Code of Pakistan 2021. Government of Pakistan.
- Schacher, T., & Ali, Q. (2009). Dhajji Dewari: A guidebook for technicians and artisans for one and two storey earthquake resistant houses. United Nations Human Settlements Programme (UN-Habitat) / Earthquake Engineering Center, University of Engineering and Technology (UET) Peshawar.
- Schildkamp, M., Silvestri, S., & Araki, Y. (2020). Rubble stone masonry buildings with cement mortar: Design specifications in seismic and masonry codes worldwide. *Frontiers in Built Environment*, 6, 590520. <https://doi.org/10.3389/fbuil.2020.590520>
- Sharaf, F. (2020). The impact of thermal mass on building energy consumption: A case study in Al Mafraq city in Jordan. *Cogent Engineering*, 7(1), 1804092.
- United Nations Development Programme. (2015). Seismic design in Pakistan: The Building codes, Bylaws, and Recommendations for Earthquake Risk Reduction. Islamabad.
- United States Geological Survey. (2015). M 7.5 - 45 km N of `Alaqahdari-ye Kiran wa Munjan, Afghanistan, 26 October 2015. Earthquake event record.

APPENDIX A - PRESCRIPTIVE REQUIREMENT AND SOURCE MATRIX

This matrix provides traceability for numerical values that can influence construction. The “status” column distinguishes national code requirements, cited comparative rules, and interim criteria adopted by this guideline. In this appendix, BCP refers to the Building Code of Pakistan; BCP-SP-2007 refers to the Building Code of Pakistan-Seismic Provisions 2007. Interim criteria are not national standards.

The traceability of each numerical requirement, its source basis, and its applicability is summarized in Table A.1.

Table A.1. Prescriptive requirements, source basis, and applicability.

Requirement	Value in this guideline	Source/basis	Status and applicability
Seismic hazard	BCP zones 1, 2A, 2B, 3 and 4; project zone recorded	BCP-SP-2007	National regulatory basis
Prescriptive stories	One story only	Guideline scope decision; more than one story requires project specific engineering design	Interim scope; more stories require design
Story height	≤ 3.0 m	Nepal NBC 203 (2015), Clause 5.3	Comparative minimum; stricter project rule governs
Wall thickness	380-450 mm, excluding plaster	Bothara & Brzev (2011), WHE-2011-01	Comparative prescriptive range for random rubble
Height/thickness	$h/t \leq 8$	Nepal NBC 203 (2015), Clause 7.4	Comparative prescriptive limit
Unsupported length/thickness	$l/t \leq 12$	Nepal NBC 203 (2015), Clause 7.3	Comparative prescriptive limit
Absolute unsupported length	≤ 5.0 m	Guideline conservative cap informed by Nepal NBC 203 (2015) 12t limit	Comparative cap; lesser of all limits governs
Through-stone spacing	≤ 600 mm vertical; ≤ 1.2 m horizontal	Nepal NBC 203 (2015), Clause 7.1; Bothara & Brzev (2011), WHE-2011-01	Cited comparative requirement
Masonry lift	≤ 600 mm before through bond inspection	Bothara & Brzev (2011), WHE-2011-01	Cited workmanship control
Cement sand mortar	1:6 by measured loose volume where specified	Guideline nominal mix; project-approved specification and field trials govern	Only at locations/details specified
Stabilized earth dosage	Trial 5%, 7%, 9% cement by dry soil mass; adopt lowest passing mix	Guideline interim trial protocol; field and laboratory validation required	Interim trial series; not a universal mix
Raised plinth/moisture separation	≥ 300 mm above adjacent finished ground, higher where exposure requires	Nepal NBC 203 (2015), Clause 5.5; guideline moisture minimum	Moisture minimum, not flood level

Requirement	Value in this guideline	Source/basis	Status and applicability
Opening corner clearance	≥ 600 mm unless verified drawing permits otherwise	Guideline interim criterion	Requires validation before formal adoption
Minimum pier between openings	≥ 600 mm or 1/4 story height, whichever greater	Guideline interim criterion	Requires validation before formal adoption
Timber post size	No universal diameter	Species/grade/load/connection design required	Project specific member design; no universal size is prescribed
Reinforced concrete tie column size	No universal 150 x 150 mm size	BCP and project specific confined masonry design	Project specific confined masonry design; no universal nominal size is prescribed
Slope/retaining wall screening distance	Prefer horizontal separation $\geq$ exposed height for nonengineered cut/wall	Guideline interim screening rule informed by ERRA site safety guidance	Screening only; not a stability calculation

APPENDIX B - FIELD MATERIAL TESTS AND PASS/FAIL CRITERIA

These are interim project quality control criteria for pilot implementation. They create an auditable accept/reject process but shall be calibrated against laboratory testing and local climate before statutory adoption. Every interim threshold in Table B.1 is explicitly marked so it cannot be mistaken for a mandatory national code value.

The field test procedures, pass criteria, and required records are summarized in Table B.1.

Table B.1. Field material tests, pass criteria, and required records.

Test	Procedure	Pass criterion	Record
Soil screening	Remove roots/organic matter; screen the mortar soil; record approximate gravel/sand/fines and source	Uniform material without organic contamination or oversized particles that prevent full joints	Source, date, screen size, photograph
Shrinkage bar	Pack moist mortar in a 600 x 40 x 40 mm oiled mold; cure protected for 7 days; measure total shortening and cracks	INTERIM PROJECT CRITERION - Total linear shrinkage $\leq$ 3%; no single through crack wider than 2 mm	Initial/final length and crack map
Wet brushing/spray	After minimum 7-day cure, wet the specimen and brush 20 double strokes or apply a controlled 10-minute spray from fixed distance	INTERIM PROJECT CRITERION - No disintegration; no continuous channel; average surface loss $\leq$ 3 mm	Photographs before/after and measured loss
Hand cohesion	After cure, press and rub a joint edge using firm thumb pressure and a stiff brush	Joint remains coherent and does not powder through its depth	Pass/fail and observer
Bonded trial panel	Build at least 1.0 m x 1.0 m representative wall panel with actual stones, joints and curing	No rocking stones, open internal joints, delamination, or loss of mortar under controlled handling	Panel identifier, mix identifier, and approval
Cement sand batch	Use gauge boxes/buckets; dry mix to uniform color; add controlled clean water; use within approved time	Correct 1:6 loose volume batching; no retempering of set mortar; full joints and adequate curing	Batch quantities, start/end time
Timber acceptance	Identify species/local trade name and source; visually grade; confirm dimensions and seasoning/moisture condition; inspect decay, insects, checks/splits, and defects at connection zones; verify preservative treatment where specified	Sound, stable section with no active decay/insect attack or critical defect at a connection zone; size and condition match approved timber schedule/drawing; required treatment complete	Species/local name, source, size, condition, treatment, date, and photograph
Metal connector acceptance	Check diameter/thickness, material, hot-dip galvanizing/stainless grade/approved coating, washers, edge distances, damaged coatings, and installation against the drawing	Exact match to approved drawing and exposure requirement; no unapproved substitution, damaged protection, or visible corrosion	Batch/material certificate where available and installed photographs

Note: The 3% shrinkage, 2 mm crack and 3 mm erosion limits are interim criteria introduced by this guideline to create a measurable pilot protocol. They shall be confirmed or revised through comparative laboratory and field testing before nationwide adoption.

APPENDIX C - CONSTRUCTION HOLD POINT CHECKLISTS

C1 Site and platform approval

The site and platform approval hold point is recorded using Table C.1.

Table C.1. Site and platform approval hold point checklist.

No.	Inspection item	Pass	Fail/corrective action	Inspector/date
1	BCP seismic zone recorded	☐	☐	
2	No visible landslide, rockfall, debris flow, flood, or erosion hazard unresolved	☐	☐	
3	Natural ground/fill condition recorded	☐	☐	
4	Retaining walls assessed	☐	☐	
5	Drainage route defined	☐	☐	
6	Geotechnical referral completed where triggered	☐	☐	
7	Drawing compliance verification - completed work matches the current approved drawing/detail and revision	☐	☐	

C2 Foundation and plinth

The foundation and plinth hold point is recorded using Table C.2.

Table C.2. Foundation and plinth hold point checklist.

No.	Inspection item	Pass	Fail/corrective action	Inspector/date
1	Excavation reaches approved competent material	☐	☐	
2	Stepped foundations are level and connected	☐	☐	
3	No spring/seepage or loose fill concealed	☐	☐	
4	Plinth continuity verified	☐	☐	
5	Finished ground/drainage falls away from building	☐	☐	
6	Timber separated from soil and moisture	☐	☐	
7	Drawing compliance verification - completed work matches the current approved drawing/detail and revision	☐	☐	

C3 Masonry wall lift

The masonry wall lift hold point is recorded using Table C.3.

Table C.3. Masonry wall lift hold point checklist.

No.	Inspection item	Pass	Fail/corrective action	Inspector/date
1	Wall thickness within approved range	☐	☐	

No.	Inspection item	Pass	Fail/corrective action	Inspector/date
2	Stones stable on broad beds	☐	☐	
3	Joints fully filled	☐	☐	
4	Vertical joints staggered	☐	☐	
5	Hearting packed without loose continuous layer	☐	☐	
6	Corners and T-junctions bonded	☐	☐	
7	Drawing compliance verification - completed work matches the current approved drawing/detail and revision	☐	☐	

C4 Through-stones/ties

The through-stones and ties hold point is recorded using Table C.4.

Table C.4. Through-stones and ties hold point checklist.

No.	Inspection item	Pass	Fail/corrective action	Inspector/date
1	Maximum 600 mm vertical spacing	☐	☐	
2	Maximum 1.2 m horizontal spacing	☐	☐	
3	Staggered arrangement	☐	☐	
4	Full width bearing or approved overlapping/mechanical alternative	☐	☐	
5	Installed before concealment	☐	☐	
6	Photographic record with scale	☐	☐	
7	Drawing compliance verification - completed work matches the current approved drawing/detail and revision	☐	☐	

C5 Bands, posts, and openings

The bands, posts, and openings hold point is recorded using Table C.5.

Table C.5. Bands, posts, and openings hold point checklist.

No.	Inspection item	Pass	Fail/corrective action	Inspector/date
1	Band level and continuity match drawing	☐	☐	
2	Cross-ties connect both wall faces	☐	☐	
3	Splices/corners match drawing	☐	☐	
4	Opening clearance and pier widths accepted	☐	☐	
5	Jamb posts connected where specified	☐	☐	
6	No decorative/unconnected reinforcement counted	☐	☐	
7	Drawing compliance verification - completed work matches the current approved drawing/detail and revision	☐	☐	

C6 Roof and completion

The roof and completion hold point is recorded using Table C.6.

Table C.6. Roof and completion hold point checklist.

No.	Inspection item	Pass	Fail/corrective action	Inspector/date
1	Continuous roof band/wall plate	☐	☐	
2	Each rafter/joist/truss positively tied	☐	☐	
3	Roof plane bracing installed	☐	☐	
4	Gables restrained	☐	☐	
5	Water discharged to stable outlet	☐	☐	
6	All conceptual details replaced by approved drawings where required	☐	☐	
7	Final file contains photographs and signatures	☐	☐	
8	Drawing compliance verification - completed work matches the current approved drawing/detail and revision	☐	☐	

APPENDIX D - INDICATIVE BILL OF QUANTITIES AND DISTRICT COST SCHEDULE

Complete this schedule using the latest applicable provincial Market Rate System (MRS) and at least three current local quotations. State the district, valley, road head distance, date, tax basis and transport assumptions. Report the base shelter cost separately from the incremental life safety package.

The indicative bill of quantities (BOQ) and district cost schedule to be completed during implementation is provided in Table D.1.

Table D.1. Indicative bill of quantities and district cost schedule.

Item	Unit	Reference quantity	Unit rate (PKR)	Amount (PKR)	Rate source/date
Site investigation/platform approval	lump sum				
Drainage and safe outlets	M				
Additional stone dressing/corner stones	m ³				
Through-stones or approved ties	No.				
Timber plinth/sill/lintel/roof bands	m ³ or m				
Vertical timber posts	m ³ or No.				
Straps, bolts, washers, and anchors	kg/No.				
Mortar trial panels and binder	lump sum/bag				
Roof anchorage and bracing	lump sum				
Mason/carpenter training allowance	Trainee day				
Inspection and documentation	Supervisor day				
Remote transport premium	lump sum				
Incremental life-safety subtotal (additional seismic safety work only; excludes base shelter cost)					
Contingency (%)					
Total incremental life-safety cost (additional seismic safety work only)					

Required program indicator: incremental life safety cost (Pakistani rupees [PKR] and percentage) per reference house, together with verified quantities and inspection cost. The figure shall be updated at least every six months during active programs.

APPENDIX E - GLOSSARY AND LOCAL LANGUAGE TRAINING TERMS

Local terminology varies among Urdu, Pashto, Hindko, Kashmiri, Shina, Balti, Burushaski, and other languages and may differ between neighboring valleys. The following Urdu style explanations are training aids, not authoritative translations. Before each formal training issue or district rollout, terminology shall be checked with experienced local masons and carpenters and revised where needed without altering the technical meaning of the English master text.

The technical terms, plain language meanings, and locally verifiable field wording are provided in Table E.1.

Table E.1. Glossary of technical terms and suggested field wording.

Technical term	Plain language meaning	مقامی اصطلاح (مقامی تصدیق ضروری)
Bhatar/Taq	Thick masonry wall tied by horizontal timber lacing	لکڑی کی پٹیوں سے بندھی پتھر کی دیوار
Dhajji Dewari	Timber frame divided into small panels with masonry infill	لکڑی کا فریم اور چھوٹے بھرائی خانے
Wythe/wall leaf	One face layer of a thick multi-leaf wall	دیوار کی ایک تہہ
Hearting/core	Material between the two wall faces	دیوار کی درمیانی بھرائی
Through-stone/bond stone	Stone tying both faces across the wall thickness	آر پار باندھنے والا پتھر
Horizontal band	Continuous tie at plinth, sill, lintel, or roof level	مسلسل زلزلہ مزاحم پٹی
Plinth	Raised base of wall above ground	کرسی / زمین سے اونچی دیوار کی بنیاد
Jamb	Vertical side of a door or window opening	دروازے/کھڑکی کا عمودی کنارہ
Lintel	Member spanning over an opening	دروازے/کھڑکی کے اوپر افقی سہارا
Buttress	Wall projection that restrains a long wall	دیوار کو سہارا دینے والا پشتہ
Retaining wall	Wall holding back soil or a platform	مٹی روکنے والی پشتہ دیوار
Box action	All walls and roof acting together	دیواروں اور چھت کا ایک ساتھ کام کرنا
Delamination	Separation of wall faces/layers	دیوار کی تہوں کا الگ ہو جانا
Hold point	Work cannot continue before inspection	معائنے کے بغیر اگلا کام نہ کریں

APPENDIX F - STANDARD DRAWING AND FIGURE VERIFICATION REGISTER

The present embedded figures communicate concepts. Before field adoption, the implementing authority shall issue a companion set of scaled, dimensioned and signed drawings. No figure shall be converted into a construction detail merely by adding dimensions after illustration. The embedded image objects in this edition are retained unchanged; reviewer requests concerning graphical redrawing, resolution, or geometric consistency are to be addressed only by the author-controlled drawing set. The required standard drawings, checking responsibilities, and issue status are listed in Table F.1. Standard Drawing (SD) identifiers are used in the register.

Table F.1. Standard drawing and figure verification register.

Drawing No.	Required drawing	Minimum checker/sign-off	Status
SD-01	Eligible building plan, wall panel limits and cross wall layout	Structural engineer + architect	To be prepared
SD-02	Foundation and stepped footing on approved sloping ground	Structural/geotechnical engineer	To be prepared
SD-03	Random rubble wall section, wall thickness, hearting, and through-stones	Structural engineer + experienced mason trainer	To be prepared
SD-04	Bonded L-corner and T-junction sequence	Structural engineer	To be prepared
SD-05	Plinth, sill, lintel, and roof timber band details	Structural/timber engineer	To be prepared
SD-06	Timber splice, corner, cross-tie and post anchorage details	Structural/timber engineer	To be prepared
SD-07	Opening limits, jambs and lintel bearing	Structural engineer	To be prepared
SD-08	Roof anchorage, gable restraint and roof plane bracing	Structural engineer	To be prepared
SD-09	Wire mesh retrofit, through-ties and termination details	Structural engineer + corrosion/durability review	To be prepared
SD-10	Confined stone masonry details	Project structural engineer under BCP	Project specific only
SD-R1	Gabion-timber prototype transition	Research team and independent peer reviewer	Research only - not for construction

Verification certificate: I confirm that the issued standard drawings have been checked for structural action, dimensions, material specifications, connections, durability, buildability, consistency with BCP requirements and compatibility with this guideline.
Name / Pakistan Engineering Council (PEC) registration / signature / date:

APPENDIX G - ONE-PAGE FIELD SHEET: TEN LIFE-SAFETY RULES

For field deployment, this one page sheet should be issued in independently verified Urdu and Pashto versions, and in additional local languages where required. Technical meaning shall be preserved and the translated field wording shall be checked with local masons before printing or training use.

The ten field life safety rules are summarized in Table G.1.

Table G.1. Ten life safety rules for field implementation.

Rule	Action	Field message
1	Choose safe ground	Do not build on active slide, loose fill, rockfall path, stream bank or an unsafe retaining platform.
2	Keep the house simple	Use a compact regular plan and one story under the prescriptive route.
3	Build on a continuous foundation	Step foundations level by level on slopes and inspect the ground before covering it.
4	Bond the whole wall	Use broad bedded stones, staggered joints, packed hearting, and interlocked corners.
5	Tie both wall faces	Provide through-stones/ties at maximum 600 mm vertically and 1.2 m horizontally.
6	Control wall size	Meet $h/t \leq 8$, $l/t \leq 12$, maximum 5.0 m unsupported length and maximum 3.0 m story height.
7	Keep openings controlled	Keep them away from corners, provide adequate piers and use continuous sill/lintel ties.
8	Tie the building at key levels	Provide verified plinth, sill, lintel, and roof bands with continuous corner connections.
9	Use a light, anchored roof	Tie every roof member and brace the roof plane; do not let beams merely rest in pockets.
10	Inspect before covering	Photograph through-stones, bands, anchors, and joints; no signed pass means no next stage.

STOP WORK AND CALL AN ENGINEER if the site moves, a wall bulges or separates, timber is decayed at a primary joint, the roof loses support, a retaining wall cracks/leans, or the building falls outside the prescriptive limits.

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