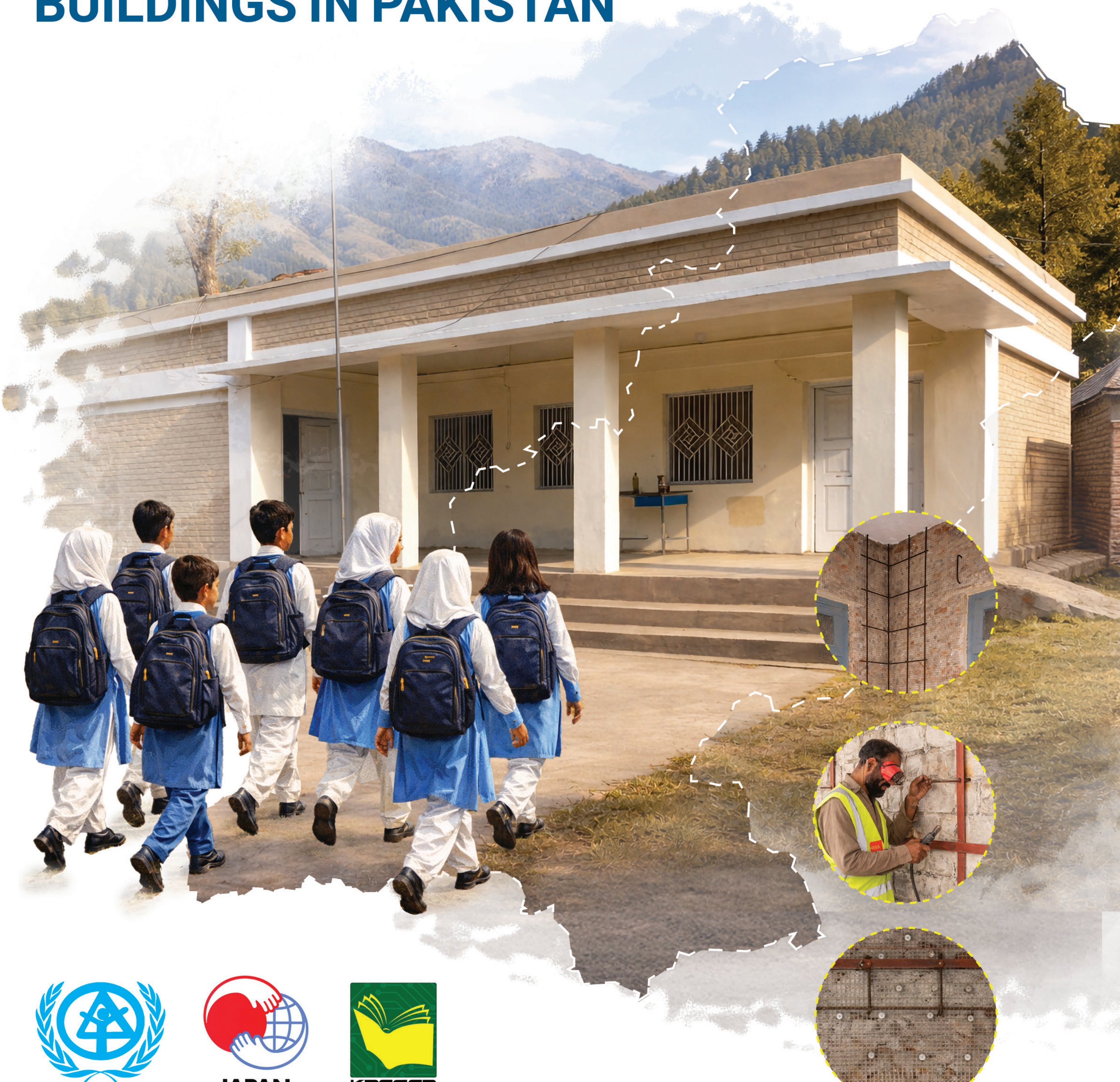
Guidelines for

SEISMIC RETROFITTING
OF MASONRY SCHOOL BUILDINGS IN PAKISTAN



UN-HABITAT

JAPAN
Official Development Assistance

KPESED
Khyber Pakhtunkhwa Elementary & Secondary Education Department

Guidelines for Seismic Retrofitting of Masonry School Buildings in Pakistan
First edition, January 2026

United Nations Human Settlements Programme (UN-Habitat),
1st Floor, UNMOGIP Building,
Plot 5–11, Diplomatic Enclave,
Islamabad, Pakistan.

These guidelines were produced by UN-Habitat Pakistan under the Disaster Resilient School Infrastructure project, with support from the Japan International Cooperation Agency (JICA). The guidelines were prepared based on field experience, technical assessments, design work, implementation learning, and engineering review undertaken during the seismic retrofitting of school buildings in Khyber Pakhtunkhwa, Pakistan.

Photo credits: UN-Habitat
Design and layout: Sardar Hasan Raza
Formatting by: M. Zain ul Abideen
Printed by: Al-Noor Printers, Islamabad.

Guidelines for Seismic Retrofitting of Masonry School Buildings in Pakistan

UN-HABITAT

JAPAN
Official Development Assistance

KPESED
Khyber Pakhtunkhwa Elementary & Secondary Education Department

Message from,

The Secretary

Education Department

Ensuring the safety of school buildings remains a foremost priority for the Education Department of Khyber Pakhtunkhwa. In a province exposed to significant flood and seismic risk, particularly in earthquake-prone districts, many existing masonry structures remain highly vulnerable. Strengthening and retrofitting these buildings is therefore not only a technical necessity but a moral responsibility to safeguard students, teachers, and surrounding communities.

These guidelines, prepared by UN-Habitat with the generous financial support of the Japan International Cooperation Agency (JICA), provide practical, evidence-based, and resource-efficient recommendations for assessing structural vulnerabilities, prioritizing interventions, and implementing seismic retrofitting measures. The approach aligns with national standards and contributes directly to the objectives of the Pakistan School Safety Framework, which promotes a comprehensive, multi-hazard strategy encompassing safe learning facilities, school disaster management, and risk reduction education. By focusing on structural safety improvements, these guidelines strengthen the "Safe Learning Facilities" pillar of the Framework and support the Government's broader commitment to resilient education infrastructure.

The Education Department recognizes that the true value of these guidelines lies in their effective application. We therefore encourage engineers, planners, district authorities, and development partners to integrate these recommendations into ongoing and future rehabilitation initiatives. Through coordinated implementation, standardized practices, and sustained institutional commitment, we can significantly reduce disaster risk in our schools.

By working collectively, we will not only enhance the safety and functionality of school buildings but also reinforce community resilience and preparedness for future emergencies.

I extend my sincere appreciation to UN-Habitat and the Japan International Cooperation Agency (JICA) for their technical and financial support, as well as to the engineers, field teams, and partner institutions whose expertise and dedication contributed to the development of these guidelines.

Sincerely,
Muhammad Khalid Khan
Secretary, Elementary & Secondary Education Department
Government of Khyber Pakhtunkhwa

Foreword

The Asia-Pacific region continues to face some of the world's highest levels of earthquake risk, with Pakistan among the countries most exposed to recurrent, damaging seismic events. Past disasters have shown with devastating clarity that children are disproportionately affected when school buildings fail. Ensuring the safety and continuity of education in hazard-prone areas is therefore not only an infrastructural priority, but a profound development imperative for governments, communities, and partners across the region.

UN-Habitat has long supported countries in strengthening their built environment to protect lives and enhance resilience. Yet one of the persistent challenges in Pakistan and much of the region has been the lack of practical, field-tested guidance for improving the seismic performance of existing masonry buildings which are both the most common and among the most vulnerable building types. These new retrofitting guidelines help fill that critical gap for masonry school buildings.

A particularly innovative feature of these guidelines is their typology-based, pre-engineered approach to retrofitting, which translates complex engineering principles into standardized, repeatable, and affordable solutions for field engineers. The "surgical retrofitting" philosophy, focusing on critical structural weaknesses rather than full reconstruction, allows for cost effective upgrades at scale, enabling safer schools even in resource-constrained environments. Equally important is the transparent, attribute-based Rapid Visual Screening (RVS) and prioritization framework, which integrates technical vulnerability, hazard levels, occupancy exposure, and social equity factors. This ensures that the most at risk and socially important schools can be identified and strengthened first, supporting evidence-based and defensible decision making.

The development of these guidelines draws on valuable lessons from the Disaster-Resilient School Infrastructure (DRSI) project in Khyber Pakhtunkhwa, whose practical field experience, combined with international best practice and alignment with Pakistan's updated Building Code, provides a robust foundation for nationwide application. The result is a document that is not only technically sound, but also highly operational, shaped by real conditions on construction sites, local materials, and the ingenuity of engineers and craftsmen working in challenging environments.

UN-Habitat extends its deep appreciation to the Government of Pakistan, the Education Department of Khyber Pakhtunkhwa, JICA for its financial support contributing to Human Security and the many experts, institutions, and practitioners whose commitment made this work possible. These guidelines represent an important step toward reducing seismic risk for children and communities by equipping practitioners with practical and scalable solutions that advance our shared commitment to safer schools, resilient communities, and a more secure future for the next generation.

Kazuko Ishigaki
Regional Director
Regional Office for Asia and the Pacific- UN-Habitat

Authors' Note...

Earthquakes continue to pose a significant threat to communities, and the majority of casualties result not directly from ground shaking but from the collapse of vulnerable structures and falling objects. School buildings, as critical community assets - given their high occupancy, the presence of young children, and their potential role as post-disaster facilities   are particularly at risk. Strengthening these structures through seismic retrofitting is an effective approach to safeguarding the lives of students, staff, and surrounding communities. These guidelines address a critical gap in guidance for practitioners and officials involved in retrofitting of Unreinforced Masonry (URM) school buildings in earthquake-prone districts of Pakistan. Existing references provide general principles but do not systematically address the broad spectrum of typical one- and two-storey masonry school buildings found across the region. The present guidelines are therefore structured to cover the wide range of recurring school typologies, including variations in wall materials, plan configurations, floor systems, and roof types commonly encountered in practice. The guidelines reflect international best practices and are aligned with the Pakistan Building Code. While general retrofit measures are provided for a wide range of typical school buildings, buildings with specific or complex vulnerabilities require detailed engineering solutions.

Through the dissemination of practical knowledge, these guidelines aim to empower field engineers to implement retrofitting interventions efficiently and effectively. Beyond improving individual school safety, these efforts contribute to broader community resilience and disaster risk reduction. More importantly, the guidelines help bridge the gap between engineering knowledge and its implementation in practice, supporting the delivery of seismic safety at scale.

The development of these guidelines draws on lessons learned from current and previous projects, international best practices, and the technical expertise of engineering and education professionals. They reflect authoritative technical standards and complement existing academic and governmental publications, contributing to safer learning environments for students and staff across the region. While providing standardized procedures, tools, and illustrative examples, the guidelines also allow flexibility for adaptation to local conditions and specific school contexts. By facilitating practical and safe retrofitting interventions, they aim to reduce vulnerability, protect lives, and enhance the resilience of the communities served by these schools.

Efforts have been made to make the guidelines clear, practical, and easy to follow, enabling broad replication and effective implementation according to the level of vulnerability of each school building. By disseminating practical knowledge and promoting field-level applications, the guidelines aim to make school buildings safer for children, while also contributing to wider community disaster risk reduction through the spread of retrofitting practices.

Jitendra Kumar Bothara, PhD and Prof. Dr. Mohammad Ashraf

Acknowledgments

The Disaster Resilient School Infrastructure (DRSI) project provided an excellent opportunity to identify critical gaps, validate design approaches, and translate structural theory into practical solutions for the seismic retrofitting of unreinforced masonry (URM) buildings. This work was made possible through the generous financial support of the Japan International Cooperation Agency (JICA) and the strong commitment of the Elementary and Secondary Education Department (E&SED), District Education Officers, school administrations, and Parent Teacher Councils across eight districts of Khyber Pakhtunkhwa.

I extend my sincere appreciation to the experts who contributed through technical consultations and discussions, thereby strengthening these guidelines beyond their initial draft: Eng. Shiraz Shahid, Ms. Maryam Durrani, Ms. Candida Maria Vassallo, Mr. Raza Ali Shah, Haji Parveen, Ms. Sehar Taimoor, Mr. Irfan Durrani, Mr. Farahan Ahmed, Eng. Faiz ul Sibtain, Dr. Waheed, Mr. Abrar Khan, Eng. Azam Babar, Eng. Imran, Eng. Babar Tanweer, Eng. Zeshan, Ms. Faiqa Aziz, Arch. Faseeha Waheed, and Arch. Amna Qayyum, Intern. I am also grateful to the technical staff of UN-Habitat and the Education Department, particularly Syed Shiraz Ali Shah, Safi Ullah Khan, Ajab Khan, Maqbool Ilahi, Irfan Uddin, and Muhammad Hafeez, for their dedicated role in implementing the DRSI project from which the experience, and lessons were drawn to develop these guidelines.

Deep appreciation is extended to the distinguished reviewers whose expertise and professional insight greatly strengthened this document. I gratefully acknowledge the contributions of David Delgado; Prof. Dr. Qaisar Ali, Vice Chairman (KP) Pakistan Engineering Council; Mr. Amjad Naseer, Chairman, Department of Civil Engineering, University of Engineering and Technology Peshawar; Dr. Muhammad Usman, Head of Structures and Survey Department, NUST Institute of Civil Engineering (NICE); Dr. Azam Khan, Professor, Institute of Civil Engineering, NICE, School of Civil and Environmental Engineering (SCEE), National University of Sciences and Technology (NUST); and Dr. Muhammad Salman, Lecturer, Department of Civil Engineering, University of Engineering and Technology Peshawar. I also extend sincere appreciation to Maggie Stephenson for her valuable guidance in strengthening the layout, technical clarity, and editorial quality of this publication.

My special thanks go to Dr. Jitendra Kumar Bothara and Prof. Dr. Muhammad Ashraf for preparing these guidelines and translating technical analysis into practical, context-responsive guidance aligned with recognized best practices and national building codes. Appreciation is also extended to Sardar Hasan Raza of Koko Studio for preparing the layout and graphics for these guidelines.

The successful development of these guidelines owes much to the leadership, commitment, and technical contribution of Mr. Hamid Mumtaz Khan. He identified important gaps in existing knowledge, helped define the performance objectives, and guided the development of the guidelines from concept to completion. His close coordination, technical input, editorial support, and consistent oversight were invaluable throughout the process.

Finally, I express my gratitude to Bruno Dercon, Senior Human Settlements Officer, UN-Habitat Regional Office for Asia and the Pacific (ROAP), for his guidance and encouragement in bringing these comprehensive guidelines to completion.

With sincere appreciation,

Jawed Ali Khan
Habitat Programme Manager
UN-Habitat Pakistan

Table of Content

Executive Summary

The 2005 Kashmir earthquake, which resulted in the tragic loss of approximately 19,000 schoolchildren, starkly exposed the vulnerability of existing school infrastructure in Pakistan. The widespread collapse of unreinforced masonry school buildings during school hours demonstrated the urgent need for systematic strengthening of educational facilities in seismically active regions. Despite improvements in building regulations, a substantial proportion of school buildings, particularly unreinforced masonry structures constructed prior to the Building Code of Pakistan 2007, continue to face significant seismic risk.

These Guidelines for Seismic Retrofitting of Masonry School Buildings in Pakistan have been developed to provide technically sound, scalable, and resource efficient solutions for strengthening vulnerable school v infrastructure. Grounded in the experience of the Disaster Resilient School Infrastructure project implemented in Khyber Pakhtunkhwa, aligned with the Building Code of Pakistan 2021, and informed by established engineering practice, the document translates structural engineering principles into practical and implementable guidance.

The guidelines provide a structured framework for identifying vulnerable buildings, prioritizing retrofitting interventions, selecting strengthening techniques, and addressing key implementation considerations. A distinct feature of this document is its prescriptive, typology based retrofitting approach. Rather than requiring a fully customized structural design for each individual school building, the guidelines present pre-engineered strengthening solutions for commonly occurring unreinforced masonry school typologies across Pakistan.

The majority of government school buildings constructed over past decades follow standardizedt layouts, similar construction materials, comparable structural systems, and consistent geometric proportions. When analyzed individually, such buildings often require broadly similar strengthening measures. Requiring full structural design calculations for each typical low rise masonry school can therefore lead to duplication of engineering effort, increased cost, and delays in implementation without proportionate improvement in safety outcomes.

The prescriptive methodology presented in these guidelines is firmly grounded in engineering analysis, observed seismic behavior, and field validation. Buildings are categorized according to structural typology, and validated strengthening packages are defined for each category. This provides a technically defensible alternative to repetitive building specific design, while maintaining alignment with the Life Safety performance objective under the Design Basis Earthquake. For senior decision makers, these guidelines enable efficient allocation of limited resources. For practitioners, it provides clear design direction supported by engineering logic.

The document focuses on one and two-storey unreinforced masonry school buildings constructed in brick or stone masonry with reinforced concrete slabs, inverted T iron, or lightweight trussed roofs. A structured Rapid Visual Screening and prioritization framework integrates building typology, observed deficiencies, seismic hazard level, occupancy exposure, and selected social considerations. This framework supports transparent, evidence-based decision making and helps ensure that the most vulnerable and high-risk schools are addressed first. Exclusion criteria are also defined to identify buildings that require specialized structural engineering beyond the scope of typology-based retrofitting.

Retrofitting measures are designed to prevent collapse under the Design Basis Earthquake (DBE) and significantly reduce life safety risk. The strengthening philosophy addresses critical structural vulnerabilities including inadequate wall to wall and wall to roof connections, insufficient anchorage, excessive wall slenderness, absence or discontinuity of seismic bands, poor bonding in stone masonry, and falling hazards such as parapets and gable walls. The guidelines clearly distinguish between repair and rehabilitation measures, which restore structural condition, and seismic retrofitting measures, which enhance earthquake performance.

To demonstrate the practical application of the methodology, three detailed case studies have been included in the guidelines. These comprise one brick masonry building with a flat reinforced concrete roof and two stone masonry buildings with sloping roofs. In each case, retrofitting was implemented in accordance with the design provisions contained in this document. These schools were strengthened under the Disaster Resilient School Infrastructure project, supported financially by the Japan International Cooperation Agency (JICA) and implemented by UN Habitat.

Each case study includes school building data, assessment results, deficiency-based vulnerability scores, prioritization scores, exclusion screening, and complete retrofitting drawings and design details. These implemented examples provide practitioners with clear reference models and demonstrate how the assessment and prescriptive design framework translate into executed strengthening works. These case studies provide evidence that the methodology is practical, implementable, and grounded in real project experience.

Beyond technical design provisions, the document addresses key implementation considerations including logistical planning, sequencing of works, quality control procedures, construction safety measures, documentation requirements, and incremental strengthening options where full retrofitting may not be immediately feasible. This integration of engineering guidance with operational considerations ensures that the guidelines are not only technically credible but also practically applicable.

While developed through experience in Khyber Pakhtunkhwa, the methodology is applicable to similar unreinforced masonry school buildings in other regions of Pakistan with comparable construction practices and seismic exposure. By combining engineering validity, operational feasibility, and scalability, these guidelines provide a structured and defensible pathway for reducing seismic risk in school buildings and enhancing the safety of students, teachers, and communities. These guidelines emphasize capacity building of engineers, contractors, and local authorities to ensure quality of retrofitting measures. Community awareness and stakeholder engagement are also encouraged to promote ownership and understanding of seismic safety interventions.

Chapter 1

Background and Rationale

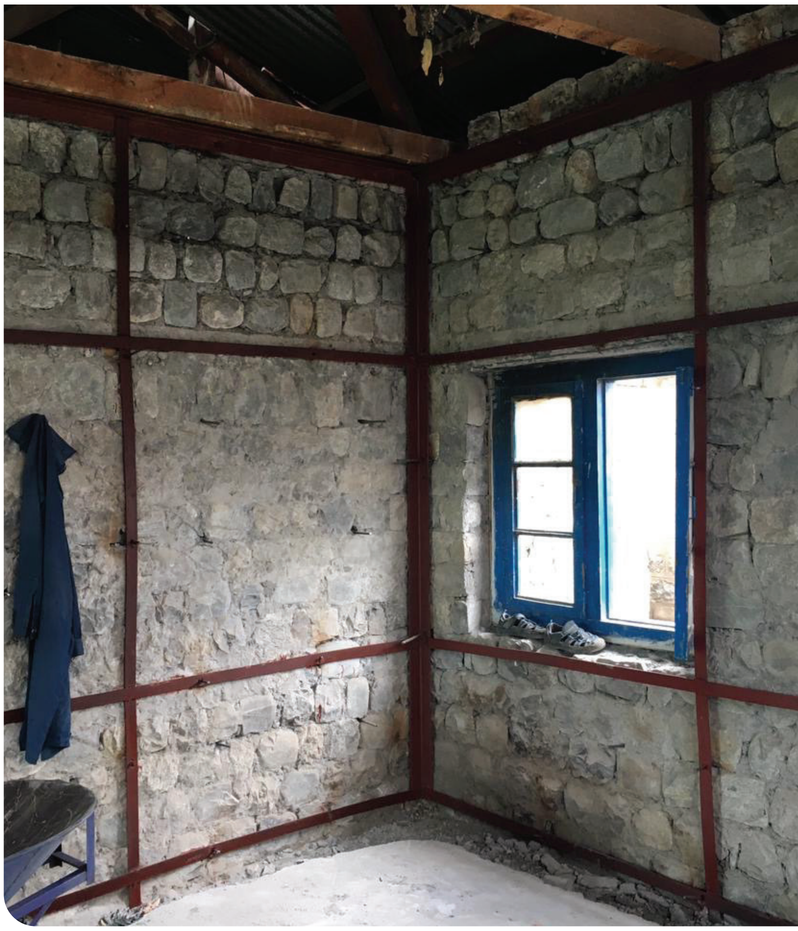
Pakistan is one of the most earthquake-prone countries in the world due to the presence of the Himalayas in the north, the Hindu Kush in the northwest, and the Chaman and Makran fault systems in the west. These regions have produced many damaging earthquakes, including the 2005 Kashmir earthquake, which caused over 73,000 deaths. Among them were approximately 19,000 schoolchildren who died when school buildings collapsed during class hours. This tragedy highlighted the urgent need to make school buildings safer for children. In line with Pakistan's commitment to providing safer learning environments for children and communities, UN-Habitat has been actively involved in retrofitting vulnerable school buildings and has successfully completed several projects across the country. These guidelines draw upon the lessons learned and best practices from those initiatives. They offer practical, affordable and context-specific procedures for field engineers and construction practitioners working in Khyber Pakhtunkhwa (KP), while remaining applicable to other earthquake-prone areas of Pakistan. The approach is designed not only to improve individual buildings, but to enable the delivery of seismic safety across large numbers of schools under real-world constraints.

1.1 Objectives of the Guidelines

The ultimate goal of these guidelines is to enhance the seismic resilience of school buildings by reducing project implementation time and cost, timely mitigation of other hurdles and cutting carbon footprint. Although developed for Khyber Pakhtunkhwa (KP), it is equally applicable to other parts of Pakistan and to the areas with similar socio-economic and hazard conditions.

The main objectives of these guidelines are:

- Provide unified and standardized methods for assessing and retrofitting typical Unreinforced Masonry (URM) school buildings, reducing the need for customized designs for each individual building.
- Offer simple, ready-to-use pre-engineered procedures for retrofitting school buildings.
- Promote practical, affordable, and locally adaptable techniques that use available materials and skills.
- Identify common logistical challenges and outline practical strategies for managing them to ensure project success in difficult conditions.



1.2 Scope and Applicability

These guidelines apply to the most common types of small Unreinforced Masonry (URM) school buildings constructed of brick or stone in mud or cement–sand mortar. It covers single and two-storey buildings with:

- Reinforced concrete (RC) slabs,
- Reinforced brick (RB) slabs,
- Steel girder and inverted T-iron floor/roof systems,
- Lightweight trussed roofs made of steel or timber.

These guidelines are intended for field engineers, technicians and implementing agencies working in medium to high seismic zones of Pakistan, as defined by the Building Code of Pakistan (2021). The engineering basis of the retrofitting provisions is presented in Appendix 3.

Although the guidelines focus primarily on seismic risk, the proposed retrofitting measures will also enhance performance against other hazards such as floods and cyclones. By addressing key structural deficiencies, including roof-to-wall anchorage, splints and bandages, and plinth protection, overall building resilience is improved. Users are encouraged to assess additional local hazards and incorporate complementary measures where necessary. Application of these guidelines outside the defined building typologies and limits may lead to unreliable performance and therefore requires detailed engineering assessment.These guidelines should be used alongside site-specific structural assessments to ensure appropriate interventions. They promote cost-effective, scalable, and locally adaptable solutions for improving the safety and resilience of school buildings in line with local conditions.

1.3 Seismic Hazard and Risk in Pakistan

Seismic risk arises from the combination of seismic hazard, building vulnerability, and human exposure. In Pakistan, the main sources of seismic hazard are the Himalayas in the north, the Hindu Kush in the northwest, and the Chaman and Makran fault systems in the west (Fig-1). Major earthquakes such as the 1935 Quetta, 2005 Kashmir, 2013 Awaran, have demonstrated the destructive potential of these sources. The destruction of 7,489 school buildings and the deaths of 19,000 children during the 2005 Kashmir earthquake served as a wake-up call for Pakistan to strengthen school safety and resilience measures. Past earthquakes in Pakistan and neighboring regions have also shown that most buildings, especially Unreinforced Masonry (URM) building structures in Pakistan, are highly vulnerable and that communities are generally unprepared for strong shaking. This combination of high hazard, deficient construction practices and limited preparedness places school buildings at an unacceptably high level of seismic risk, making urgent action necessary to improve their safety.

1.4 Typical School Building Typologies

The vast majority of school buildings, particularly those constructed before 2007 in KP, follow a largely standardized form. They are simple one-to two-storey rectangular or L-shaped masonry structures, typically constructed with brick or stone load-bearing walls in cement- or mud-mortar, supporting either reinforced concrete (RC) slabs, inverted T-iron slabs, or lightweight roofs supported by trusses (See Figure 2c).

Field surveys confirm that most of these schools were built using uniform design templates and similar construction practices. Their common characteristics can be broadly summarized as follows:

1.4.1 Foundation

Foundations of these masonry school buildings are typically shallow strip footings, provided including under openings. Foundation is typically wider than the walls and commonly constructed of both brick and stone masonr.

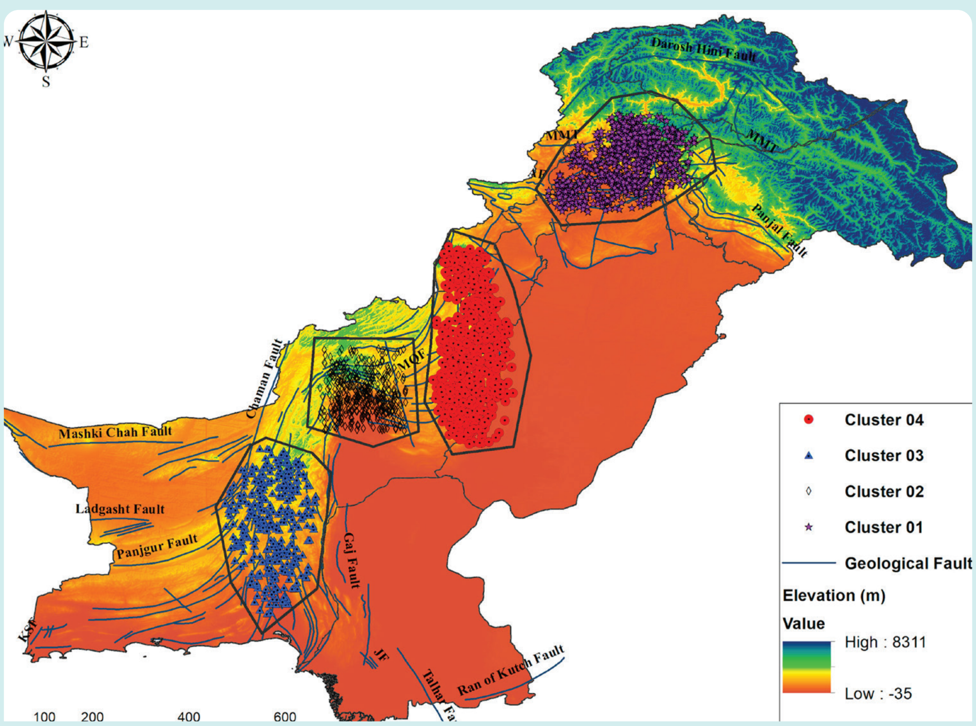


Fig-1: Seismotectonic settings and fault systems of Pakistan (Ahmed, et al., 2019)

1.4.2. Masonry Walls

The walls of these buildings are typically constructed from brick or stone masonry set in mud or cement-based mortar. The use of both mud and cement-based mortar was common until the 1960, however, buildings constructed after 1960 are generally built using cement-based mortar. In some cases, concrete block masonry has been used in subsequent extensions or repair works to the same building. It should be noted that, right proportioning, mixing, handling and curing of cement-based material was often not well practiced, resulting in weak mortar and low-quality concrete.

Fig-2a: Typical school building typologies

Fig-2b:Two-storey high brick masonry building

Fig-2c: Stone masonry building with light metal roof

Fig-2d: A brick masonry building with RC slab roof

Brick Masonry Walls: The typical wall thicknesses for brick masonry constructed with cement mortar are:

13.5” (350 mm) at the ground floor and 9” (230 mm) at the upper floor of two-storey buildings, and 9” (230 mm) for single-storey buildings.

Stone Masonry Walls: For stone masonry walls, construction typically consists of random rubble masonry to semi-dressed stonework, with wall thickness generally ranging between 18–20” (450 mm and 500 mm). However, as per the government design, coursed rubble masonry is recommended, with a wall thickness of 15 inches (375 mm) in cement mortar.

Field observations and evidence from past earthquakes indicate that many stone masonry walls lack through-stones and proper interlocking between the inner and outer wythes, significantly reducing their integrity, shear strength, and overall seismic performance.

1.4.3. Flooring

The floors of these buildings are typically constructed of cement concrete flooring; however, terrazzo/chip flooring and marble flooring has also been observed in few cases.

1.4.4. Roofing

The roofs of these school buildings are typically constructed using reinforced concrete (RC) slabs, inverted T-iron (Girder and T-Iron) slabs supported by steel or RC beams, or light metal sheets roof supported by timber or steel trusses (See Fig-3). Where the roof is an RC or inverted T-iron slab, it is usually finished with waterproofing treatment, followed by a 100 mm (4 in) layer of compacted soil, and finally covered with brick tiles laid and pointed in cement-sand mortar.

The school building typologies discussed above can be broadly classified as follows:

- Brick masonry with cement concrete flooring and roof slab
- Brick masonry with steel girder and inverted T-iron roof
- Brick masonry with cement concrete flooring and steel/timber truss roof
- Stone masonry with cement concrete floor and roof slab.
- Stone masonry with steel girder and inverted T-iron roof

1.5 Masonry Buildings With Earthquake Resistant Features

Field observations suggest that at least some masonry school buildings, likely constructed under earlier programmes, were provided with lintel bands or similar horizontal elements (See Fig-4b). However, complete design records, reinforcement details, and construction specifications are unavailable, making it difficult to verify whether these bands meet the requirements for effective seismic performance. In several cases, 3 to 4" high plain concrete

bands appear to have been constructed mainly as architectural features rather than structural components, creating additional uncertainty.

Fig-3: Iron Girder and T-iron roof

RC slabs are considered rigid diaphragms; inverted T-iron slabs are considered semi-rigid diaphragms; and metal roofs are considered flexible diaphragms. Flexible diaphragms require stronger wall-to-roof connections and do not provide effective load distribution between walls

Where reinforcement is present, the quality of bars, anchorage length, hooks, and overall detailing are expected to vary significantly between buildings. Therefore, reinforcement must be confirmed through removal of the concrete cover and checked for proper anchorage. Even if reinforcement exists, these bands will still require upgrading to meet the requirements of this Guideline. If no reinforcement is found or if the presence of reinforcements could not be investigated, the bands should be treated as unreinforced and assumed not to contribute to seismic resilience.

1.6 Performance Objectives and Retrofitting Philosophy

The primary purpose of seismic retrofitting is to enhance a building's structural behavior so that it remains stable during an earthquake, preventing catastrophic failure, safeguarding lives, and allowing safe evacuation. Life Safety implies that widespread structural collapse is prevented, although significant damage and localized failures may occur.

For school buildings, these guidelines adopt the Life Safety performance objective at Design Basis Earthquake (DBE). This objective requires that occupants are adequately protected at DBE and that the building does not collapse under the most credible earthquake (MCE) event (See Fig-1).

This performance target aligns with the engineering framework defined in the Building Code of Pakistan 2021 (Appendix 4) for retrofitting of school buildings.

Retrofitting philosophy recognizes that seismic strengthening does not provide absolute

Fig-4a: A masonry building with seismic band at lintel level

Fig-4b. Stone masonry building apparently with a discontinued reinforced concrete

protection but a risk-reduction strategy. The level of strengthening achievable in practice depends on several interconnected factors, including:

- Expected seismic hazard at the site
- Building typology, its structural form, and inherent structural limitations
- Practicality and cost of interventions
- Appetite for level of intervention
- Availability of skills, materials, and construction technology

As illustrated in Fig-5, seismic retrofitting is a balance between desired performance at a given level of shaking, available funds including human resources and construction technologies. The goal is to achieve the greatest possible life-safety improvement within these constraints, ensuring that school buildings perform reliably during major earthquakes while retrofitting remains affordable and practical to implement across large portfolios of structures. In this context, retrofitted buildings are expected to maintain overall stability and box action, with damage distributed rather than concentrated in single critical elements. This Life Safety performance level has been agreed upon by practitioners, the engineering community, and government, with the aim of preventing building or component collapse and minimizing loss of life during strong earthquakes Note that 'immediate occupancy' and 'operational' indicate a higher level of performance than Life Safety.

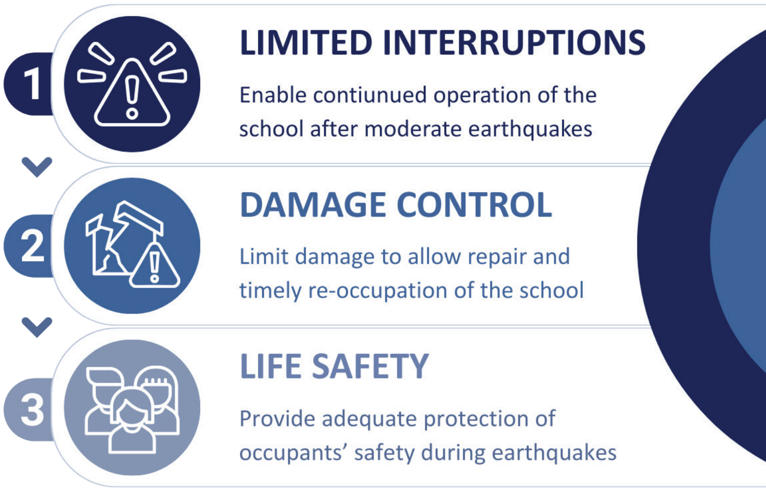


Fig-5: Performance objectives for retrofitting

In practice, performance depends significantly on construction quality and workmanship. It should be noted that, seismic strengthening improves life-safety performance but does not eliminate all risks. Masonry buildings, due to their intrinsic vulnerabilities, remain particularly susceptible to damage during strong earthquakes, although no building system is entirely immune to severe ground shaking. Even after retrofitting, limited cracking, localized damage, or falling debris may occur. The objective of retrofitting is to reduce risk and prevent collapse so that buildings remain stable enough to protect occupants. Residual risks may persist due to earthquakes exceeding the design level, existing material deterioration or construction defects, weak soil or foundation conditions, and the quality of workmanship and materials used.

Surgical Retrofitting: Rather than targeting strengthening of each building elements, these guidelines follow a simplified and targeted "surgical" strengthening approach, focusing on the most critical parts of a structure that influence its stability and life-safety performance. This method minimizes disruption while significantly reducing the risk of collapse of the building during an earthquake, still ensuring cost-effectiveness of the retrofitting process.

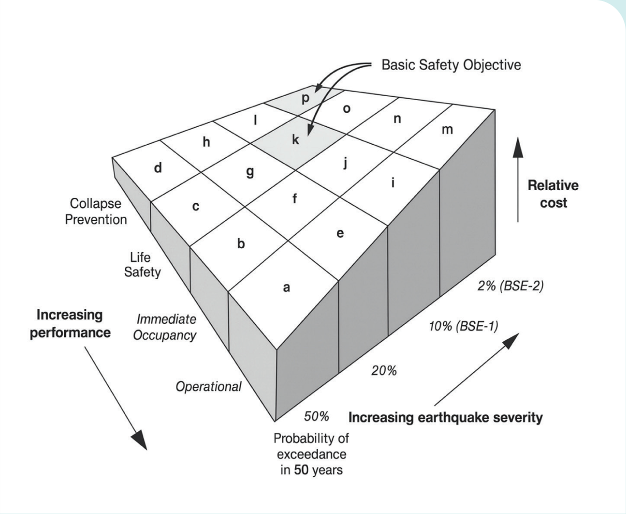


Fig-6: Surface showing relative costs of various retrofitting objectives (source: (FEMA 274)

These guidelines further encourage a phased retrofitting strategy, allowing strengthening works to be planned and executed in manageable stages based on priority and available resources. Critical interventions can be addressed first to reduce immediate risks, while less urgent measures can be implemented over time. This approach supports continuity of building use, reduces disruption to occupants, and ensures that retrofitting remains practical and adaptable to funding and operational constraints. It also allows lessons learned from initial phases to inform subsequent works. Regular monitoring during each phase helps ensure quality and effectiveness. This flexibility makes the approach suitable for diverse building types and contexts.

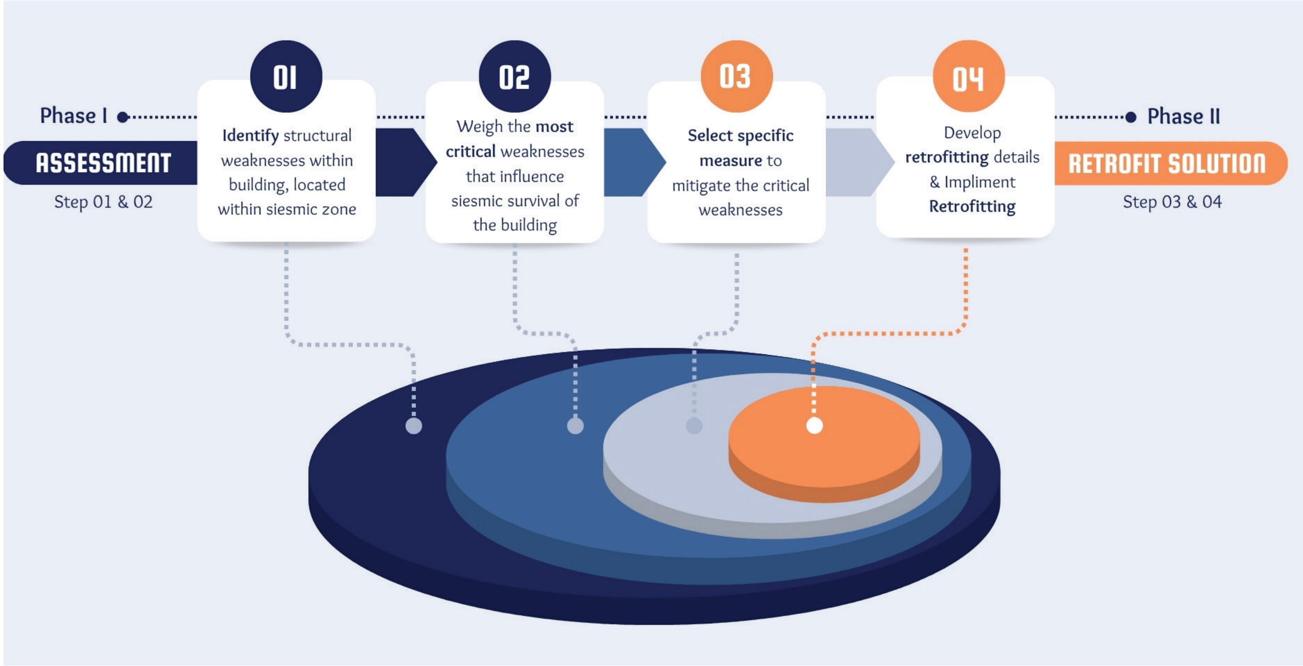


Fig-7: Surgical retrofitting approach

1.7 Basis Of This Guideline

These guidelines are based on the widely accepted principle that simplified, typology-based seismic assessment and retrofitting methods are appropriate and effective for standard, low-rise masonry buildings. International documents, including FEMA 154, FEMA 306, FEMA 547 and related guidance, explicitly recommend simplified, pattern-based approaches for simple, repetitive building types, precisely the condition of most school buildings assessed under the UN-Habitat project. Field surveys in KP show that these schools share similar plans, materials, and construction practices, resulting in comparable seismic behavior. Preparing a customized engineered design for each building is therefore unnecessary, resource-intensive, and incompatible with project timelines.

These guidelines compile practical, pre-engineered strengthening techniques adapted from international references and research, refined through local field experience and construction practices. While performance may vary due to existing deterioration and earthquake uncertainty, when these measures are correctly applied, the retrofitted buildings can be expected, with high confidence, to meet the Life Safety objective of the Building Code of Pakistan (2021) for existing buildings. The guidance is intended to support standardized implementation across similar building typologies.

1.8 How To Use These Guidelines

These guidelines follow a sequential approach, investigation and assessment, prioritization, engineering design, logistical planning and implementation, as outlined below. The overall process is summarized in Fig-8.

Investigation and prioritization: Assess school buildings to identify seismic vulnerabilities and determine retrofit priority using the attribute-based framework. Evaluate structural deficiencies, site conditions, occupancy exposure, and contextual factors to support transparent and defensible selection of buildings for retrofitting.

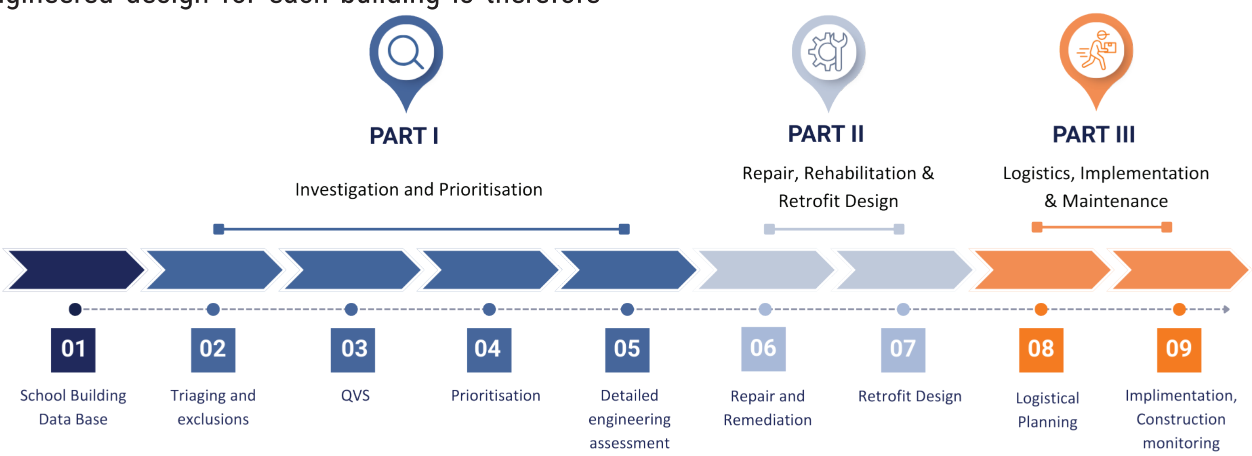


Fig-8: Overall flow of the Guidelines' document

Repair, rehabilitation and retrofitting design: Design repair and rehabilitation work prior to strengthening. Select and apply appropriate pre-engineered retrofitting solutions from this guideline, based on building typology and identified deficiencies, to enhance structural integrity and life-safety performance.

Logistics, Implementation and Maintenance: Plan and manage logistics, including material supply, workforce mobilization, and coordination with local stakeholders. The effectiveness of retrofitting measures ultimately depends on construction quality, supervision, and adherence to detailing requirements The guidelines are broadly divided into three interconnected parts as shown in Fig-8.

Part-i

Chapter 2

Assessment and Prioritization

This section provides practical guidance for assessing and prioritizing school buildings for seismic retrofitting. It introduces qualitative, attribute-based methods suitable for one- to two-storey Un-reinforced Masonry (URM) school buildings. The process aims to help engineers identify vulnerabilities, evaluate risks, and prioritize schools for intervention in a consistent and transparent manner.

The work starts with the collection of school data from relevant agencies (District Education Offices) and moves towards prioritization in a sequential order.

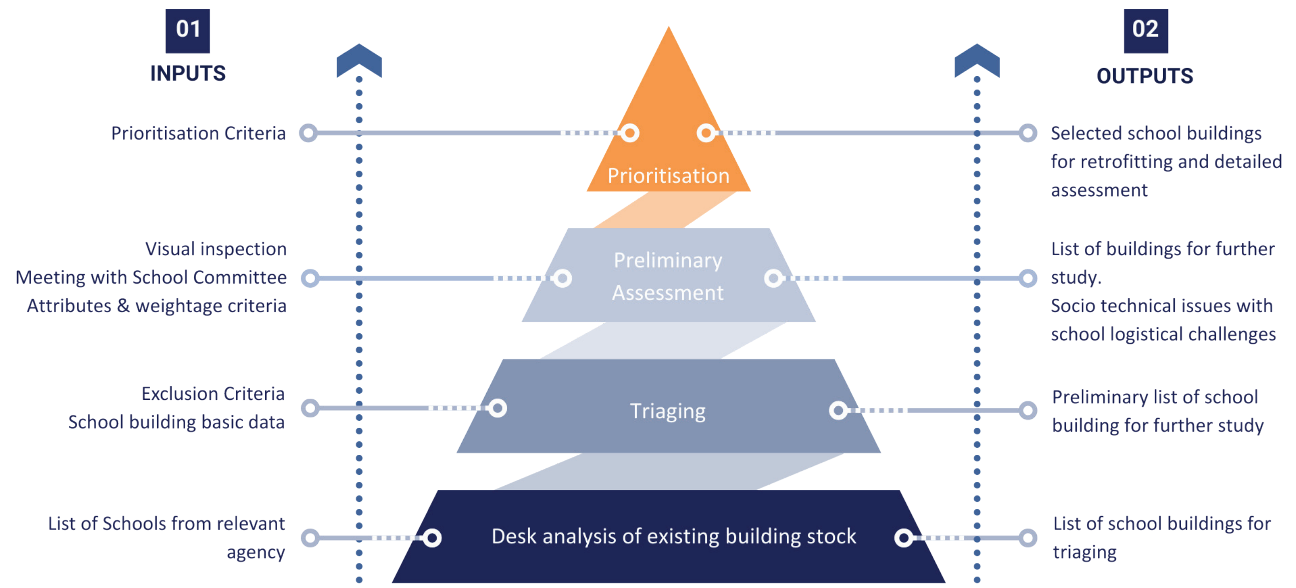


Fig-9: Assessment & prioritization

2.1 Principles of Assessment

The assessment of school buildings is guided by the 'Life Safety' performance objective, which defines the minimum acceptable level of safety a building must achieve during Design Basis Earthquake (DBE) for existing buildings, corresponding to 225-years return period, and ultimately achieve under a significant earthquake, corresponding to 975-years return period, by preventing collapse. During assessment, the building is examined to determine how far its current condition is from meeting the Life Safety objective. The focus is on identifying elements that could compromise stability, lead to collapse, or endanger occupants during strong earthquake shaking.

Given the practical realities of rural and resource-constrained environments and recognizing that these guidelines are intended primarily for field-level engineers and technicians, the assessment relies on qualitative, attribute-based indicators rather than detailed numerical analyses. The proposed method is informed by a substantial body of engineering calculations, published literature, observed performance of buildings during earthquakes and professional engineering judgement. This approach balances engineering rigor with field practicality, emphasizing visible construction attributes, deterioration, connection failures, and irregularities that influence seismic

In alignment with international best practice, return periods of 225 years and 975 years have been adopted, as DBE and MCE respectively, for the retrofitting of existing school buildings. These levels reflect the principle that retrofit objectives are calibrated and staged, rather than requiring full equivalence with new-build standards. For existing buildings, performance-based retrofit targets are generally adopted to achieve meaningful and proportionate risk reduction within practical technical and financial constraints, while prioritizing Life Safety. This approach recognizes that upgrading existing structures differs fundamentally from designing new buildings and that substantial improvements in safety can be achieved without requiring full new-build compliance.

performance and may prevent the building from achieving Life Safety without intervention. Fig-9 shows assessment and prioritization steps.

2.2 Understanding Vulnerabilities Of Urm School Buildings

When assessing and retrofitting existing Unreinforced Masonry (URM) buildings, it is essential to understand their seismic deficiencies and the hierarchy of potential failure mechanisms. Experience from recent earthquakes shows that URM school buildings are particularly vulnerable because of weak materials, poor construction practices, and lack of proper connections.

The most hazardous weaknesses are typically inadequately restrained elements at height, such as parapets and gable-end walls. These are often the first to fail during an earthquake and pose serious risks to people beyond the building perimeter. Therefore, out-of-plane wall

failures are the most critical life-safety concern and must be addressed as the first priority in all retrofitting interventions.

The next critical vulnerabilities are face-loaded walls and their connections to diaphragms and Return (cross) walls. Although failure of these elements may not cause total collapse, it still represents a significant life-safety hazard.

When building components are properly tied together and out-of-plane wall failures are restrained, the structure behaves as an integrated system, and the in-plane walls are engaged to resist lateral forces. This reflects the need for a continuous and reliable load path, so that seismic forces can be transferred safely through the structure.

Failures of URM buildings-as shown in Figure-11 are generally classified as:

- **Local failures** - such as the toppling of parapets, out-of-plane collapse of unsupported walls, or detachment of materials from in-plane walls. While the building may remain standing, these failures can seriously endanger occupants and passers-by. can seriously endanger occupants and passers-by.
- **Global failures** - involving total or near-total collapse due to loss of load path, poor configuration, or inadequate interconnection between elements.

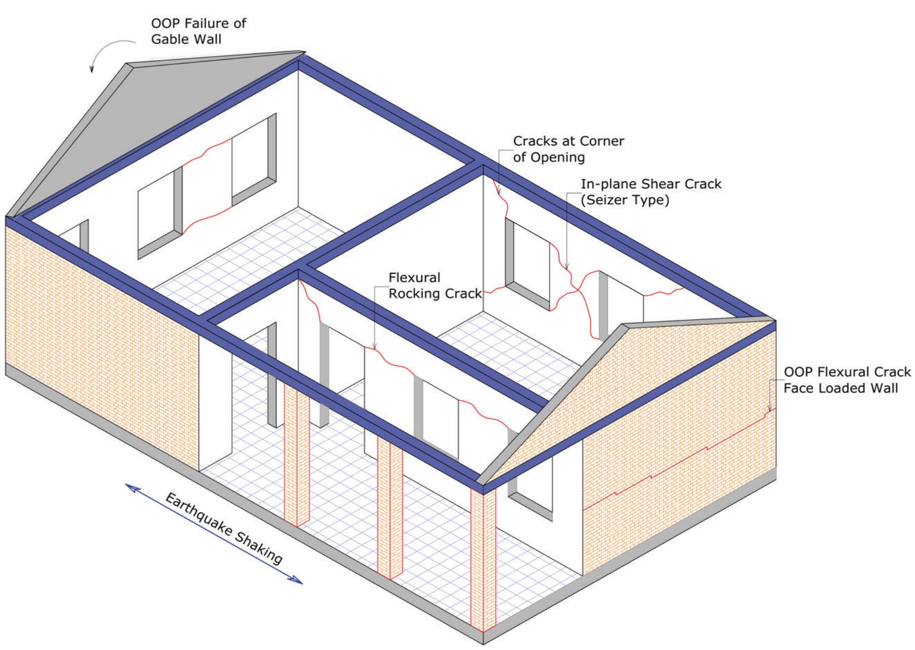


Fig-10: Typical failure modes of URM buildings

Fig-11: Common observed earthquake-induced damages to URM buildings

a.Destruction of school building during the Kashmir earthquake

b.Collapse of parapet during the Kashmir earthquake

c.A stone masonry building with delaminated wall. Also note collapse of gable

d.Vertical crack at wall junction

e.Toppling of face-loaded wall

f.Collapse of timber roof

g.Diagonal shear cracks

h. Rocking and crushing of piers

i. Crushing of masonry pier

Commonly observed failure modes to URM buildings are presented in Fig-11 and discussed below:

- Collapse of gable walls, parapets, partition walls and appendages
- Topping of out-of-plane walls due to lack of restraints, delamination etc.
- Failure of roof and floor diaphragm connections
- Failure of wall-to-roof and wall-to-floor anchorage
- In-plane shear cracking including rocking, sliding, toe crushing and diagonal failure of in-plane walls.

Stone masonry buildings often experience failures unique to their construction type, mainly due to irregular stone shapes and the absence of through-stones. These weaknesses cause outward displacement of stones and delamination of wall wythes. Many government-built schools in Khyber Pakhtunkhwa use Coursed Rubble (CR) masonry, which frequently lacks proper interlocking and bonding between wythes, reducing wall integrity. Field observations also indicate that some schools classified as CR masonry are built with round river stones, where only the visible faces are dressed and the inner stones remain rounded or irregular and loosely packed, further increasing the risk of instability of masonry units and delamination.

2.3 Triaging and Exclusion

Before starting the preliminary assessment, a triaging step is essential to exclude buildings that either do not require retrofitting or fall outside the scope of these guidelines. This process ensures that available resources are focused on buildings that are both feasible and critical for retrofitting. The exclusion criteria are summarized in Table-1. Some of these criteria can be applied during the desktop review of the school list provided by E&SED, while others can only be confirmed through on-site inspection. It is also recommended to consult the district-level Education Department to verify if any additional criteria or local classification systems should be considered during the triage process.

These exclusion criteria do not imply that the excluded buildings are safe or do not require intervention. Rather, they identify buildings that;

- Already comply with current standards,
- Are scheduled for demolition and reconstruction, or
- Require specialized engineering assessment beyond the scope of this guideline.

Table-1: Exclusion criteria

S/ No	Criteria	Reason of Exclusion	Exclusion Phase
1	*Post 2007 buildings (for Pakistan only)	Likely constructed following the BCP 2007.	Desk study phase
2	Buildings that have exceeded or are near the end of their service life (cutoff year to be set with E&SED) or are planned for demolition and reconstruction by E&SED.	Such buildings are structurally and economically unsuitable for retrofitting and should be replaced instead	Desk study phase
3	Buildings which have been retrofitted by any other agencies. OR which have been included in PSDP/ Donor supported programme	Already retrofitted or funded under other programmes	Desk study phase
4	Located in very high seismic zone	Requires specific engineering assessment and retrofitting design by suitably qualified structural engineer because of the structural complexities involved	Following field visit for RVS
5	Reinforced concrete or steel frame buildings		
6	More than 2-storey high URM buildings in cement-sand mortar		
7	More than 1-storey high unreinforced stone masonry buildings in mud mortar		
8	Two-storey high building with ground floor wall less than 13.5” (350 mm) thick walls		

9	Located in highly geotechnical hazard susceptible areas such as landslide, rockslide, flood (river/Nala bed), liquefaction, sinking land, Schools situated in low-lying areas where drainage is blocked by local conditions.	Consultation required with geotechnical engineer because of the structural and geotechnical complexities involved	Following field visit for RVS
10	Highly complex or irregular buildings, such as: Buildings with load-bearing walls that are not vertically aligned, Buildings with wings with length-to-width ratio > 2.2 (Fig-12)	Requires specific engineering assessment and retrofitting design by suitably qualified structural engineer because of the structural complexities involved	Following field visit for RVS
11	**Significant structural damage (severe cracks, foundation settlement, or wall tilting)		

* Some buildings constructed after 2007 may still lack proper seismic strengthening measures and therefore require assessment and possible retrofitting.

** These buildings may not be economically feasible to remediate and retrofit and may be suitable for demolition and reconstruction.

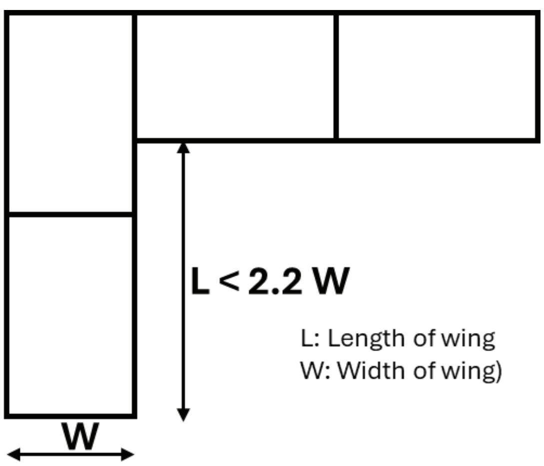


Fig-12: An L-shaped building layout

Any building meeting the exclusion criteria shall be assessed by a qualified engineer. Retrofitting design for such buildings shall be carried out by a qualified structural engineer following detailed engineering assessment.

2.4 Seismic Zones of Pakistan

In the Building Code of Pakistan 2007 (BCP 2007), seismic hazard is characterized using peak ground acceleration (PGA) values assigned to five seismic zones (1, 2A, 2B, 3, and 4), corresponding to a 10% probability of exceedance in 50 years (approximately 475-year return period). In contrast, the Building Code of Pakistan 2021 (BCP 2021) defines seismic hazard through spectral accelerations[1] for short period and 1 sec period structures (S_2 and S_1) for different return periods as shown in Fig-13. For new buildings, the Maximum Considered Earthquake (MCE) corresponds to a 2% probability of exceedance in 50 years (2475-year return period), with the design-level earthquake taken as two-thirds of the MCE values. For existing buildings, the MCE corresponds to a 5% probability of exceedance in 50 years (975-year return period), and the design-level earthquake is taken as two-thirds of the MCE, which is equivalent to a 20% probability of exceedance in 50 years (equivalent to 225 years return period).

According to the Building Code of Pakistan 2021, the maximum limit for existing short-period structures ranges from 0.18 seconds to 0.46 seconds. Since the natural period of one to two-story buildings generally falls in this range, their seismic assessment is primarily governed by the short-period spectral acceleration (S_2). Consequently, the seismic hazard map of Pakistan, based on short-period acceleration for a 975-year return period, is used to classify the country into four seismic zones (refer to Fig-13): low ($S_2 < 0.35g$), medium ($0.35g \leq S_2 \leq 0.64g$), high ($0.64g \leq S_2 \leq 1.21g$), and very high ($S_2 > 1.21g$). Refer to Appendix 4 for location-specific zonation.

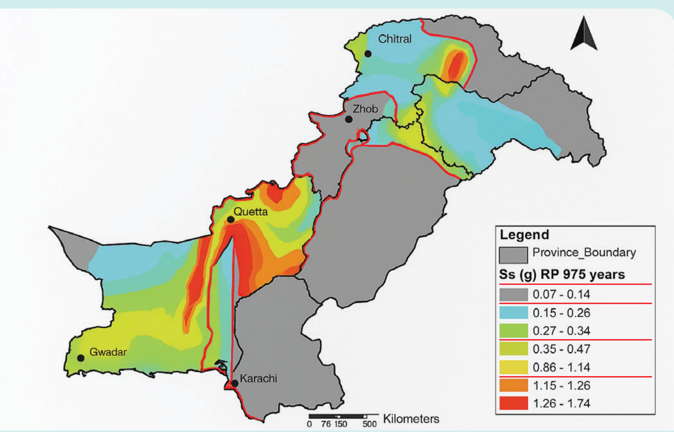


Fig-13: Simplified earthquake zones of Pakistan for short period buildings

[1]**Spectral acceleration** is a measure of how strongly an earthquake shakes a structure, expressed as the expected acceleration of a building with a given height and stiffness during ground shaking. Short, stiff buildings experience higher accelerations during strong shaking, while taller, more flexible buildings experience lower accelerations but larger displacements.

The four seismic zones identified in this section are intended solely for assessment purposes. This approach ensures that low-seismic-zone buildings do not overwhelm the overall assessment and prioritization process. Otherwise, there is a risk that schools located in low seismic zones could be prioritised ahead of those in moderate and high seismic zones, which have a greater need for retrofitting.

Once schools are prioritised, the retrofitting provisions developed for moderate seismic zones can also be applied to those in low seismic zones.

2.5 Rapid Visual Assessment and Prioritization Framework

This chapter presents the methodology for the qualitative assessment and prioritization of Unreinforced Masonry (URM) school buildings in Pakistan. It introduces a transparent scoring system that expresses seismic vulnerability numerically based on observable building deficiencies. The approach combines engineering judgement, past earthquake experience, and simplified quantification to ensure consistent and defensible decisions across varied field conditions.

The framework has two components:

1. Engineering assessment, using an attribute-based method to quantify seismic vulnerability; and
2. Societal factors incorporate social and contextual considerations.

These components are presented separately for clarity and transparency.

After initial triaging, shortlisted buildings undergo Rapid Visual Screening (RVS). This qualitative process documents critical features affecting seismic performance and assigns scores to observed deficiencies. The resulting technical score reflects the relative seismic vulnerability of each building, with higher scores indicating higher risk and greater need for retrofitting.

Following the technical assessment, buildings enter the prioritization stage, where societal and contextual considerations are applied to determine retrofitting priority. The overall framework for assessment and prioritization is shown in Fig-14.

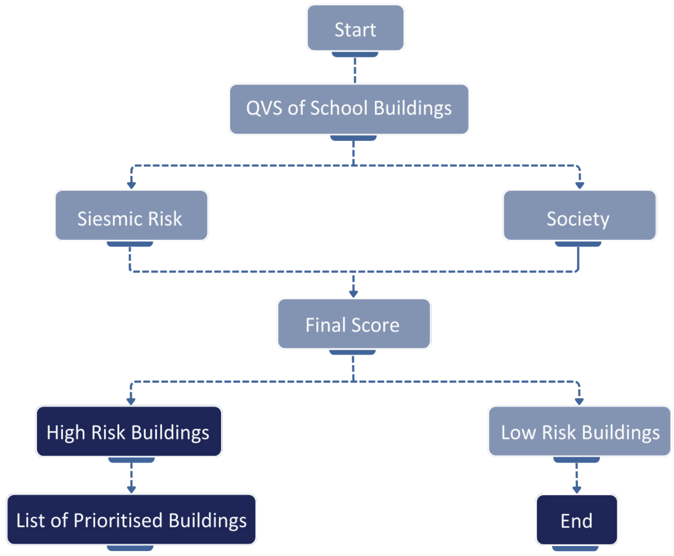


Fig-14: Assessment Process

The framework separates technical assessment from programme-level considerations to ensure clarity and defensibility. The Score, discussed below, is derived solely from structural observations made during the RapidVisual Screening (RVS), providing an objective measure of seismic vulnerability. The programme prioritization layer then applies social, contextual and feasibility factors without influencing the engineering judgment. This structure ensures life-safety remains the core basis for decisions while allowing socially important schools, such as girls' schools or those serving remote communities, to receive elevated priority when justified. The overall approach is risk-based: buildings with high vulnerability, high hazard exposure and large student populations receive the highest priority for retrofitting, while lower-risk buildings may be addressed through phased improvements.

2.5.1. Understanding the framework logic and how it works

The proposed prioritization framework integrates structural vulnerability, seismic hazard, occupancy exposure, and societal considerations into a transparent and defensible structure. The foundation of the system is the risk score (R), which quantifies seismic risk based on observed vulnerabilities, hazards, and exposure. Programme-level refinements such as social priority, classroom density, community interest, and discretionary adjustments allow decision-makers to incorporate contextual realities without compromising engineering reasoning. In below equation-1, the first part of the equation presents seismic risk, and the second part represents a societal factor and discretionary factor.

Prioritization Score (P)=[Risk score(R)]x [Societal factors (S) x Discretionary Factor (D)]...**Equation-1**

P= [B+∑(D x W)](H x E)x[(S) x (D)]

Where,

P = Prioritization score

R = Risk score

B = Building typology score

∑(G x W) = Building specific vulnerability, i.e. combined effect of all observed structural deficiencies identified in a building during the visual assessment. G is grading factor and W is the weightage for a particular attribute

H = Seismic hazard factor

E = Classroom density factor (exposure)

S = Social prioritization factor

D = Discretionary factor

The scoring system provides a relative ranking of buildings and should not be interpreted as an absolute measure of seismic risk.

2.5.2. Risk score (R)

The risk assessment includes vulnerability assessment framework and quantifies the seismic risk the building exposed to. It is based entirely on observable structural attributes and context factors such as seismicity of the area and occupancy of the building.

2.5.3. Building typology score (B-score)

The building typology score (B-score) represents the inherent seismic vulnerability of the certain building typology, structural system and material type before considering individual deficiencies. Different masonry types, such as stone in mud mortar, brick or stone in mud mortar, or brick in cement-sand mortar, have well-established performance patterns in past earthquakes. B-score captures this baseline risk by assigning a predefined score to each construction type, reflecting its expected seismic behavior. This ensures that buildings made from inherently weaker or less reliable materials begin with a higher vulnerability level, while stronger, better-performing systems start with a lower baseline score. B-score therefore provides a consistent and technically defensible system for the overall vulnerability assessment. Refer to Table-2 for B-score.

Table-2: Building typology score (B-Score)

Type	Description	B-score
A	Random rubble / river stone masonry in mud mortar	30
AC	Random rubble / river stone masonry in cement-sand mortar	25
B	Semi-dressed stone masonry in mud mortar	20
BC	Semi-dressed stone masonry in cement-sand mortar	15
BC	Concrete block masonry in cement-sand mortar	15
C	Brick masonry in mud mortar	15
CC	Brick masonry in cement-sand mortar	5
CC	Dressed stone Masonry in cement-sand mortar	5

2.5.4. Deficiency-based vulnerability score

The deficiency score represents the combined effect of all observed structural deficiencies identified during the on-site visual assessment. It is calculated by summing the products of Grading (G) and Weightage (W) for each attribute (Σ W × G). Deficiency-based vulnerability score therefore provides a quantified measure of the actual built condition, incorporating factors such as workmanship quality, material deterioration, wall slenderness, irregularities, roof and floor behavior, and opening configurations. A higher score indicates a greater concentration of vulnerabilities.

2.5.5. Grading score (G-score)

The grading score (G) represents the observed severity of each deficiency in a specific building. While the list of attributes identifies what to look for, the G-value reflects how significantly each deficiency is present, ranging from minor to severe. This enables field engineers to capture real, on-site variation in construction quality, detailing and deterioration observed on site. Applying G-values ensures that deficiencies with greater structural significance contribute more to the overall vulnerability score, supporting consistent and transparent comparison across different schools. Refer to Table-3 for grading criteria and for attribute-specific G-score.

2.5.6. Weightage score (W)

The weightage (W-score) reflects the relative importance of each deficiency type, such as missing seismic bands, weak connections, or out-of-plane instability, in affecting seismic performance of individual building. Some deficiencies have a much greater impact on building performance than others and therefore receive higher weightage. The W-score ensure that the scoring system aligns with established engineering understanding and past earthquake evidence, allowing critical weaknesses to influence the technical priority more than secondary ones. Refer Table-4 for Weightage score.

The scores and life-safety performance objective for retrofitting school buildings was agreed by consensus at a consultative meeting in Islamabad, attended by representatives from the Pakistan Engineering Council, the National Disaster Management Authority, faculty from the National University of Sciences and Technology (NUST) and the University of Engineering and Technology Peshawar, as well as members of the engineering community, government institutions, UN agencies, and civil society.

Table-3: Grading score (G-score)

Condition	Description	Grading scores (G-score)
Good	The assessed element complies with the guidelines intent and shows no visible deficiencies.	0.00
Minor Deficiency	Minor imperfections or localized shortcomings are observed; unlikely to significantly influence seismic behavior.	0.33
Significant Deficiency	Clear structural weaknesses or discontinuities present; likely to adversely influence seismic response.	0.67
Severe Deficiency / Absent	Critical weakness or absence of required features; likely to govern damage mechanism or contribute to collapse.	1

Table-4: Weightage and grading factors for various vulnerabilities

No.	Attributes	Influence	Weightage (W)	Grading (G)
1	Site & foundation conditions	Amplification & settlement	5	G = 0 – Level/ flat ground (0-5 degrees) on competent soil/rock; no visible distress.
				G = 0.33 - Mild/ gentle slope (>5-15 degrees) or fill, but no clear distress.
				G = 0.67 - Moderate/ noticeable slope (>15-25 degrees), minor fills, or nearby drainage issues; some settlement cracks.
				G = 1.0 - Steep slope (>25 degrees), landslide/rockfall potential, or obviously unstable foundations.
2	Number of storeys	Increased seismic force	8	G = 0 - One storey building
				G = 1 - Two-storey building
3	Plan and vertical regularity	Torsion & concentration of damage	5	G = 0 - Nearly rectangular plan, no re-entrant corners; uniform storey heights; no setbacks.
				G = 0.33 - Minor plan irregularities; small projections or recesses.
				G = 0.67 - L- or U-shaped plans; with wing aspect ratio < 0.25; moderate setbacks with lower level.
				G = 1 - Strong plan irregularity with wing aspect ratio > 0.25, large offset between storeys.
4	Length of piers in individual walls (refer to Section 0)	Pier strength & symmetry	5	G = 0 - Exceeds Section 2.6.1 requirements.
				G = 0.33 - Meets Section 2.6.1 requirements.
				G = 0.67 - Does not meet Section 2.6.1 requirements by small margin.
				G = 1.0 - Does not meet Section 2.6.1 requirements by large margin.
5	Wall density ratio (refer to Section 0)	Building strength	5	G = 0 - Exceeds Section 2.6.2 requirements.
				G = 0.33 - Meets Section 2.6.2 requirements.
				G = 0.67 - Does not meet Section 2.6.2 requirements by small margin.
				G = 1.0 - Does not meet Section 2.6.2 requirements by large margin.
6	Mortar quality / workmanship	Strength & ductility	8	G = 0 - Hard, dense mortar; joints filled; no obvious voids or crumbling.
				G = 0.33 - Generally good but with occasional weak or hollow joints.
				G = 0.67 - Mortar soft or friable; can be scraped away easily in many areas, all mud mortar
				G = 1.0 - Very weak or missing mortar; large voids; stones/bricks moving under light tapping.
7	Wall bonding at wall junctions/ through-stones in stone masonry buildings	Controls integrity & delamination	8	G = 0 - Regular bonding; headers/through-stones clearly visible; good interlocking at corners and T-junctions.
				G = 0.33 - Mostly bonded, but some local areas with poor bonding or short stones/bricks.
				G = 0.67 - Bonding irregular; long vertical joints; through-stones rare; some leaves appear separated.
				G = 1.0 - No visible through-stones or interlocking; clear multi-leaf behavior; all stone masonry buildings.

No.	Attributes	Influence	Weightage (W)	Grading (G)
8	Falling hazards (refer to section 0)	Life Safety threats	8	G = 0 - No heavy unrestrained elements; parapets and gables properly anchored.
				G = 0.33 - Limited unanchored elements; likely only minor debris.
				G = 0.67 - Several unbraced parapets (h > 2')/gables.
				G = 1.0 - Large, tall parapets or gables with no bracing; clear risk of falling onto exits or assembly areas.
9	Wall slenderness (H/t), refer Section 0	Out-of-plane stability	8	G = 0 - Slenderness ratios less than set out in Section 2.6.3.
				G = 0.33 - Slenderness ratio meets requirements set out in Section 2.6.3
				G = 0.67 - A few walls exceed Section 2.6.3 requirements
				G = 1.0 – Most walls exceed Section 2.6.3 requirements
10	Roof-to-wall anchorage and diaphragm	Out-of-plane wall stability	8	G =0RC floor and roof slab acting as rigid diaphragm
				G = 1 - Light metal roof on timber or steel structure with sufficient anchorage, and roof/ ceiling bracing.
				G = 0.67 - T-iron roof.
				G = 1.0 - Light metal roof on timber or steel structure with minimal anchorage, no roof/ ceiling bracing.
11	Roof/floor system (mass & diaphragm)	Inertial demand & integrity	8	G = 0 - Light roof,
				G = 0.33 – T-roof- without soil topping.
				G = 0.67 - RC or T-iron with topping floor/ roof.
				G = 1.0 - RC floor/ roof with layers of topping.
12	Seismic bands (lintel/eaves)	Box action and load path	8	G = 0 - Continuous bands at required levels (e.g. lintel/ eaves bands for flexible floor/ roof and lintel bands for rigid floor/ roof), bands well anchored at corners and junctions and vertical reinforcement at wall junctions.
				G = 0.33 - Bands present but with local discontinuities or doubtful anchorage.
				G = 0.67 - Only some bands present (e.g., lintel band only) or with clearly visible local discontinuities or doubtful anchorage.
				G = 1.0 - No effective bands (or only partial lintels).
13	Maintenance / deterioration	Capacity degradation	8	G = 0 - No significant structural cracks; no major dampness or corrosion.
				G = 0.33 - Hairline cracks and local damp patches.
				G = 0.67 - Several structural cracks, spalling, or moisture damage at critical zones, walls leaning < 20 mm/ storey, minor cracks.
				G = 1.0 - Widespread cracking (cement-sand mortar > 0.5 mm and mud mortar > 10 mm); severe erosion/ rotting; portions of wall already failing, walls leaning > 20 mm, foundation breaching.

2.5.7. Hazard Factors (H)

The hazard factor (H-factor) captures seismic hazard of the area where the building is located. Refer Table-5 for H-factors.

Table-5: Seismic hazard factors (H-factor)

Description	H-factor
Low seismic zone	0.33
Moderate seismic zone	0.67
High seismic zone	1.0

Refer to Section 2.4 for definition of low, medium and high seismic zone. Very high zone excluded.

2.5.8. Classroom Density Factor (E-factor)

The classroom density factor (E-factor) presents the exposure and captures the level of life-safety risk associated with the number of students occupying a school building. Higher student density, such as crowded classrooms or multiple sections operating within the same block, significantly increases exposure during an earthquake. For instance, a school with only two classrooms accommodating 150 students presents a far greater concentration of risk than another with the same enrolment spread across four classrooms. E-factor ensures that buildings housing larger numbers of children, or with high occupancy per classroom, are given higher priority for retrofitting. By recognizing that the collapse of even a single heavily occupied classroom can result in disproportionate life-safety consequences, E-factor enables the framework to more accurately reflect true exposure and direct attention to the most at-risk facilities. Classroom density factor is presented in Table-6

Table-6: Classroom density factor (E)

Criteria	E-factor
Low density (≤ 25 students per classroom)	0.85
Moderate density (26–40 students per classroom)	0.90
High density (41–60 students per classroom)	0.95
Very high density (> 60 students per classroom)	1.00

2.5.9. Social prioritization Factor (S-factor)

The societal factor, also referred to as the social prioritization factor (S-factor), reflects the relative social importance of a school within its surrounding community and across different population groups. This factor is used to account for the school's role in providing equitable access to education, supporting vulnerable or underserved communities, and functioning as a key social or community asset. Schools that serve remote areas, marginalized populations, or play a critical role beyond education are assigned higher S-factor values to ensure they receive appropriate priority in planning, assessment, and intervention. The S-factor is defined based on the criteria given in Tabe-7

Table-7: Social prioritization factor (S-facctor)

Criteria	S-factor
Standard school	0.85
Moderate importance (remote communities)	0.90
High importance (girls' school, underserved communities)	0.95
Very high importance (critical community hub)	1.00

Cost-Efficiency

Cost-efficiency shall not reduce priority for highly vulnerable buildings but may be used to determine sequencing within the same priority band.

From DRSI project experience, it was learned that about 30% of total retrofit costs are spent on repairing deteriorated elements (doors, windows, floors, ceilings, trusses, plinth protection, drainage), while around 5% is allocated to upgrades such as floor and wall tiles in toilets, access ramps, and new fixtures.

2.5.10. Discretionary factor (D)

The discretionary factor is compensatory adjustment applied in exceptional circumstances to ensure that deserving buildings are not overlooked in the prioritization process. A limited adjustment between 0.9 and 1.1 may be used to account for special conditions such as recent earthquake damage, urgent local programme needs, or specific donor priorities. Any application of the discretionary factor must be clearly justified and documented to maintain transparency and accountability.

2.5.11. Final priority score (P) and interpretation

The P-score, calculated using Equation 1, represents the combined effect of a building's structural risk and its contextual and social importance. The final P-score is used to rank schools for retrofitting or reconstruction (refer to Table 8). Higher P-score indicates buildings that pose greater life-safety risk or serve communities with higher priority needs and therefore require earlier intervention. Conversely, lower scores reflect buildings with lower vulnerability or limited exposure, which may be scheduled for later phases of the programme. P-score thus provides a transparent and defendable basis for decision-making, ensuring that retrofitting resources are directed first to the most critical and impactful cases.

It enables consistent comparison across different building types and locations, supporting evidence-based prioritization and reducing subjective bias. It also improves resource allocation by aligning technical risk with social urgency. The P-score can be updated over time with new data to reflect changing conditions and improve planning accuracy.

Table 8: Interpretation of P-score

P-Score	Priority Level	Action Taken
≥ 70	Priority 0: Reconstruction	Reconstruction Required
50 - 69	Priority I: Very High	Immediate retrofitting
30 - 49	Priority II: High	Retrofitting planned
10 - 29	Priority III: Moderate	Retrofitting during program cycle
< 10	Priority IV: Low	Repair and maintenance

While deciding between retrofitting and demolition for reconstruction, factors beyond the P-score discussed above should be carefully evaluated. These include the current and projected requirement for classrooms, as well as the overall condition and level of deterioration of the building, etc. For example, if a school has one single-storey with only two classrooms but requires at least four, and there is no available space for horizontal expansion, demolition and reconstruction may be a more appropriate and cost-effective option than retrofitting. Retrofitting in such cases would not address functional inadequacies and could limit the school's ability to meet future needs.

2.6. Minimum Structural Requirements

2.6.1. Locations and lengths of opening

Masonry buildings with doors and windows located near wall corners or with large openings and slender piers *(Refer to Fig-15)* are particularly vulnerable to earthquake damage. Openings close to corners weaken wall intersections, while oversized doors and windows reduce the wall area available to resist seismic forces.

Table-9a: location and lenght of piers

Item Description	Seismicity	
	Moderate & Low	High
Length of middle pier. (P_M)	18” (450 mm)	22” (550 mm)
Length of end pier. (P_E)	14” (350 mm)	20” (500 mm)
Opening Ratio ($B_1+B_2+B_3$)/L, (Single Storey)	< 0.55	< 0.50
Opening Ratio ($B_1+B_2+B_3$)/L, (Double Storey)	< 0.46	< 0.42

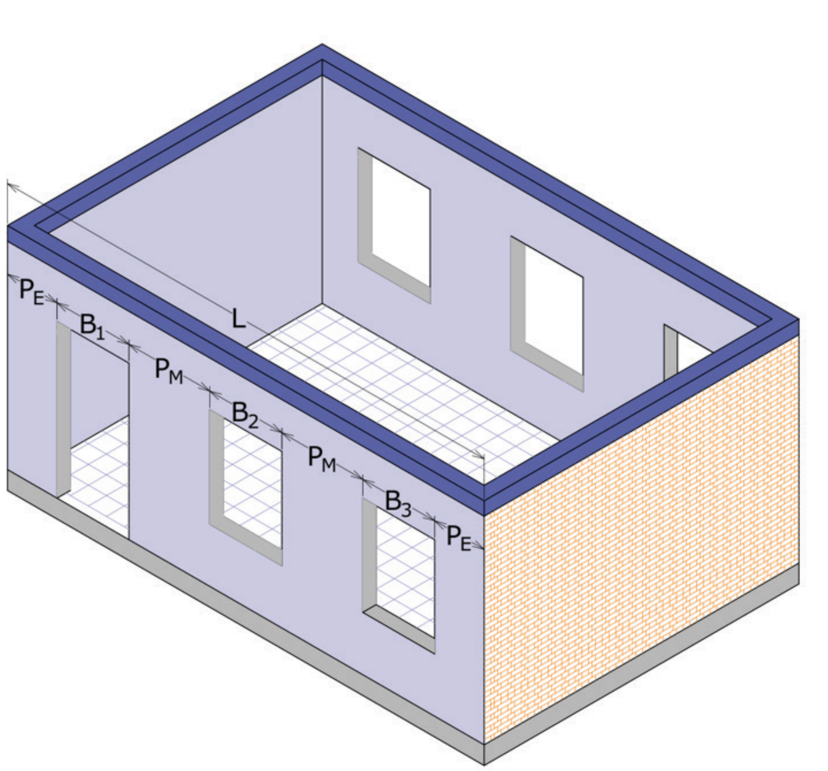


Fig-15: Location and size of openings for buildings in cement-based mortar

2.6.2. Masonry Wall-Density Ratio

Wall density ratio is the ratio of total wall area (excluding openings) in a particular direction to total area of the building. This parameter evaluates whether the building has sufficient lateral resistance based on the amount of masonry wall per plan area. Calculations of the wall-density ratio is given in Fig -16. The minimum permitted wall density ratio is given in table-9b.

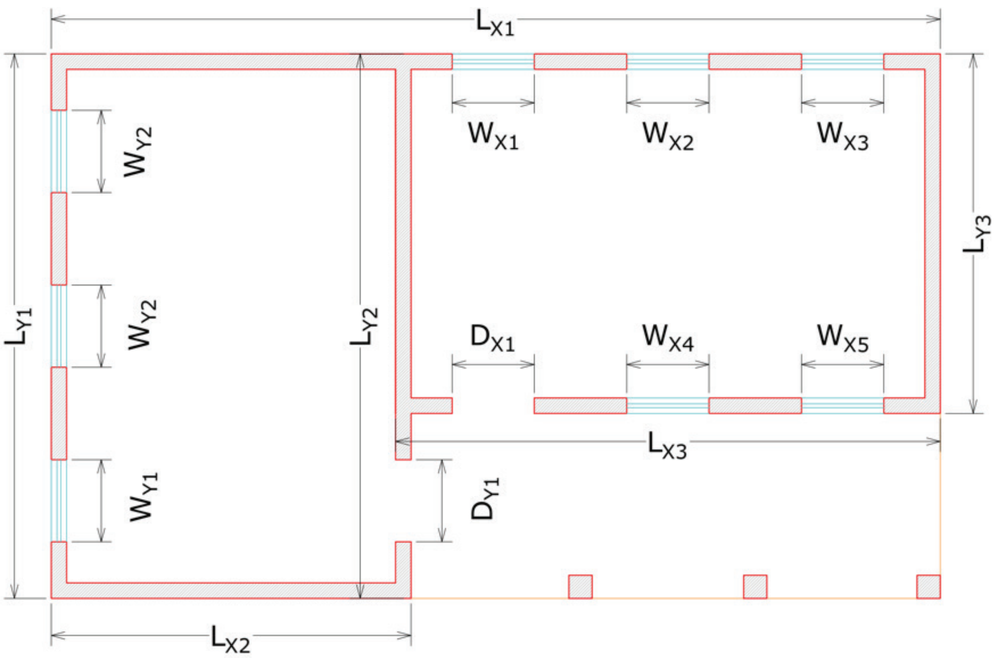


Fig-16: Calculation of wall-density ratio

Plan Area of Building, $A = L_{X1} \times L_{Y1}$

Wall Thickness = t

Effective Wall Area in X-Direction, A_{WX}

$$A_{WX} = [(L_{X1} + L_{X2} + L_{X3}) - (W_{X1} + W_{X2} + W_{X3} + W_{X4} + W_{X5} + D_{X1})] \times (t)$$

Effective Wall Area in Y-Direction, A_{WY}

$$A_{WY} = [(L_{Y1} + L_{Y2} + L_{Y3}) - (W_{Y1} + W_{Y2} + W_{Y3} + D_{Y1})] \times (t)$$

Wall Density Ratio in X-Direction = A_{WX}/A

Wall Density Ratio in Y-Direction = A_{WY}/A

Table-9b: Minimum permitted wall density ratio

Masonry type	Storey	Moderate seismic zone		High seismic zone	
		Ground floor	First floor	Ground floor	First floor
Brick masonry in cement-sand mortar	Single	4.0%	-	6.0%	-
	Double	5.0%	4.0%	7.5%	6.0%
Stone masonry in cement-sand mortar	Single	6.5%	-	10.0%	-
	Double	7.5%	6.5%	11.0%	10.0%

2.6.3. Slenderness ratio of load-bearing walls

The slenderness ratio (H/t) is the ratio of wall height (H) to its effective thickness (t) as shown in Fig-17. Walls with high slenderness ratios are more likely to fail out-of-plane during earthquakes. The effective wall thickness should include any plaster. Refer to Table-10 for limits on slenderness ratio for brick masonry and stone masonry walls. If a wall exceeds these limits, strengthening using splint and bandage techniques or additional vertical splints must be planned. It is suggested to seek specific engineering advice before developing any retrofitting solution.

Table-10 Permitted maximum slenderness ratio of masonry wall

S. No.	Wall type	Max. permissible slenderness ratio	
		Brick*/ ashlar masonry	Rubble stone masonry
1	Wall of one storey building	16	8
2	GF wall of two-storey building	18	9
3	1st floor walls of two-storey building	14	7

** Slenderness ratio of brick masonry presented in this table is adapted from, ASCE41-17*

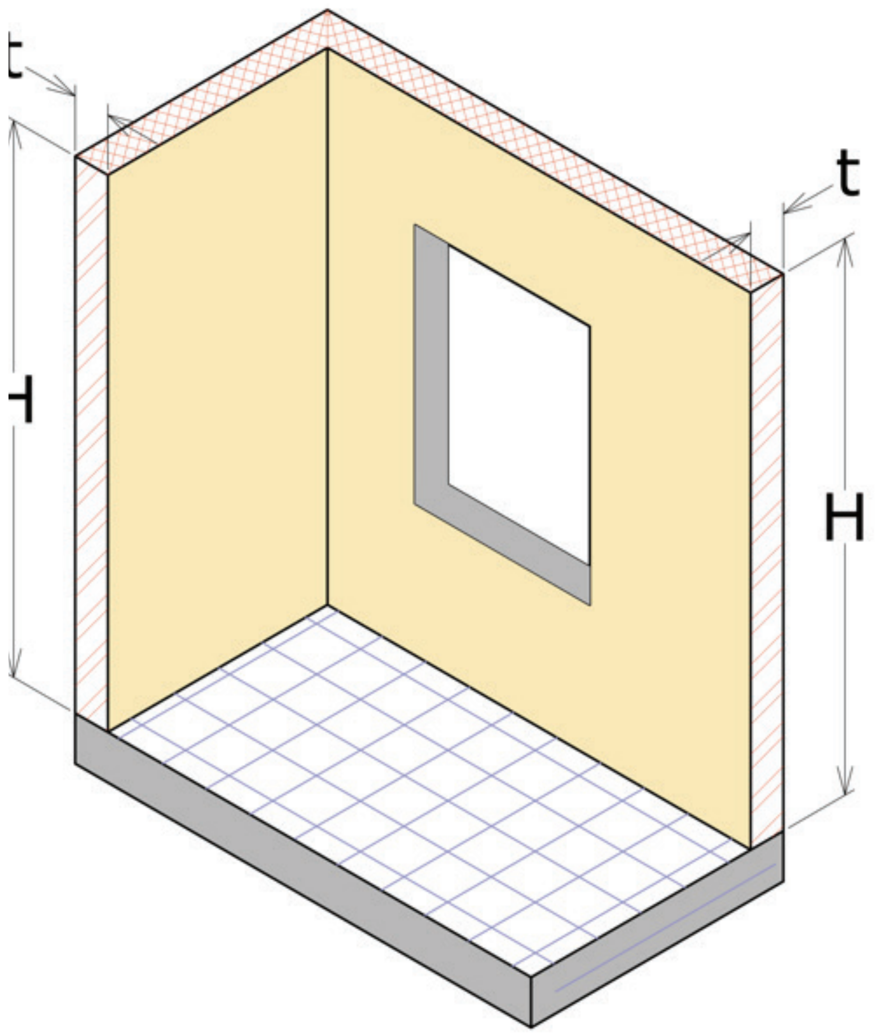


Fig-17: Determination of slenderness ratio of wall.

2.6.4. Non-Structural Components

Non-structural components such as masonry partition walls, gables and parapets often cause injuries, or block exits during earthquakes, even when the main structure remains intact. (see Fig-18) Inspect and document the condition of unanchored internal or external masonry walls, especially parapets and gable walls. Heavy ceiling panels, storage shelves, or hanging fixtures that could fall must be secured or relocated.

The height of any free-standing parapet wall at the first-floor level should be limited to 2’ (600 mm). However, it should be noted that in the case of stone masonry parapet walls, disintegration may still occur due to the lack of through-stones. Therefore, a bond beam is recommended at the top of the stone wall to tie the veneers together and maintain integrity.

Recommendations should be made for removal, strengthening, anchorage, or lightweight replacement of such components as part of retrofitting.

Fig-18: Parapet falling hazard

2.7 Field Application Example

The assessment forms provided in Appendix 6a can be used to record the parameters discussed above. Measurements can be done using simple tools such as a measuring tape, distometer, etc. Modern mobile applications, such as mobile phones, may also assist in capturing approximate measurements, geo-tagged photographs, scanned documents, site notes, and simple sketches. While these apps do not replace standard engineering instruments, they offer a practical supplement for rapid assessments, particularly in remote areas where equipment may be limited.

Locations and size of openings should be presented in building plans and sample calculations for wall slenderness and wall density ratio should be done in the form. As an example, Appendix 6 presents a Rapid Visual Assessment (RVA) of a building in Peshawar, along with the estimation of its prioritisation scores. It also includes sample engineering drawings to guide potential retrofitting of the building.

As an example, the RVS of two buildings located in Peshawar and Chitral have been completed, followed by the estimation of its prioritization scores. Appendix 9a and 9b also provide sample engineering drawings, should the retrofitting of the buildings be undertaken. UN-Habitat, in collaboration with the Elementary & Secondary Education Department (E&SED), implemented a structured, multi-tier assessment process under the DRSI project to identify vulnerable school buildings for repair and retrofitting. Due to the large number of schools, a prioritized screening approach was adopted based on FEMA-310 and FEMA P-154, adapted to local conditions and past disaster impacts. The process included data collection, initial screening using exclusion criteria, and Rapid Visual Screening (RVS) to classify buildings by condition and required intervention. Buildings with complex issues were further assessed by experts. A simplified rehabilitation approach was used to identify strengthening measures without detailed numerical analysis.

Chapter 3

Detailed Investigation and Structural Health Assessment

Following the selection of buildings in the prioritization process, a detailed investigation and health assessment of the building must be carried out before proceeding to retrofitting and intervention design. This assessment is essential to understand the existing structural condition and identify critical weaknesses in the school building. This step ensures that appropriate repair and retrofitting measures are selected and applied effectively. During detailed investigation, the following areas shall be assessed and documented using the standard forms provided in these guidelines and take photographs of key observations. Much of this information could be available from the field visits completed for RVS; however, further field visits may be required. The chapter also provides methods for qualitatively assessing the building capacity based on pre-set criteria, enabling identified deficiencies be appropriately addressed during retrofitting design.

3.1 Investigation

3.1.1. Structural Configuration and Form

Verify and document the overall shape and configuration of the building. Record the form, layout, and major components before proceeding with detailed assessment.

Most standard school buildings in the KP region are rectangular or L-shaped in plan, with two to four classrooms per storey. They are commonly constructed using brick or stone masonry in cement-sand mortar, though some older buildings were built with mud mortar.

Standard classroom size in Pakistan is approximately 16 ft × 25 ft (width × length). In some cases, the school administration has added internal partitions without approvals to create smaller spaces. These partitions are mostly four and half inch (110 mm) thick.

Record the following, particularly the changes made to the building:

- Plan and elevation layouts
- Wall thicknesses and room heights
- Opening sizes, locations, and proportions
- Overall building geometry

These measurements help identify irregularities: for example, uneven wall thicknesses, excessive or poorly placed openings, or irregular plan shapes. They may reduce the earthquake performance of a building.

Also identify and document unrestrained or potentially hazardous components such as parapet walls, gable-end walls, partition walls, or heavy non-structural items like cupboards etc. These can cause damage or injury during an earthquake and should be addressed in retrofitting.

3.1.2. Floor and roof system

Document the type of floor and roof system, whether it is CGI (corrugated galvanized iron) roofing sheets on steel or wooden truss, or cast-in-place or precast reinforced concrete slab or inverted T-iron slab. Check for sagging, corrosion, spalling of concrete cover or decay, especially at the support points where timber or steel beams or trusses rest on masonry walls.

3.1.3. Connections

The continuity and integrity of connections between walls, roofs, and foundations are critical for satisfactory seismic performance. Check critical structural connections and conditions, including wall-to-wall bonding, and wall-to-roof/floor connections, as weak links can lead to failure during earthquakes. Inspect for corrosion in fasteners, moisture or leakage in roof areas, and identify hollow or delaminated plaster and RC slabs through tapping, as these indicate weak bonding or damage.

All such weaknesses must be recorded and addressed during repair and retrofitting to ensure a continuous load path and integrated structural behavior.

3.1.4. Reinforcing bar detailing

Many school buildings in the area have reinforced concrete frames composed of column-beam frames and beams supporting verandah (see Fig-20a). In older construction, it was common practice

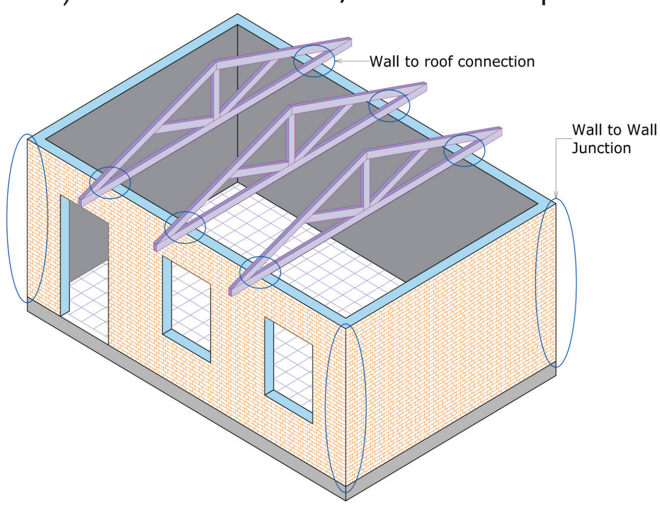


Fig-19: Wall-to-wall and wall-to- roof connection

to lap column reinforcement near the column base with a short splice length of about 300 mm (1 ft), often tied with only a single stirrup. This detailing creates a critical weakness, as during earthquake shaking, the concrete at the column base spalls, making the lap splice ineffective and potentially causing column failure. Such failure can be catastrophic, leading to partial or total structural collapse.

An intrusive investigation can be carried out by stripping the cover to verify the lap length and confinement of column reinforcement. However, considering the need of logistical requirements for intrusive investigation, in most cases it would be cost-effective to remediate the deficiency ignoring presence of any reinforcements.

Lintel Band: Field observations suggest that some brick and stone masonry school buildings were provided with lintel bands or similar horizontal elements. These bands were likely introduced during specific construction programmes as part of seismic improvement efforts; however, complete design records, reinforcement details, and construction specifications are not available, making it difficult to confirm their adequacy. In several cases, 3 to 4" (75 to 100 mm) plain concrete bands appear to have been used mainly as architectural features rather than structural elements.

Fig-20a: RC elements in school buildings

A post-2007 school building with RC frame at the front but lacking reinforcement.

Fig-20b:Veranda with RC column and beam system

If these bands are reinforced, their presence indicates an intent to enhance earthquake resistance, but the reinforcement quality, anchorage, and detailing often vary significantly between buildings. Bars may lack hooks or sufficient embedment, limiting effectiveness in tying walls together. The presence and adequacy of reinforcement should therefore be verified through limited intrusive investigation, by carefully

Although it may be prudent to assume that buildings constructed in Pakistan after 2007 comply with the building codes in force at that time, available information suggests that this assumption may not always be valid. In practice, variations in enforcement, design practices, and construction quality mean that some post-2007 buildings may not fully meet the applicable code requirements and therefore still may warrant assessment.

removing the concrete cover or these bands can be ignored. Where deficiencies are identified, upgrading or replacement in accordance with these guidelines are recommended.

Fig-21: A school building with a lintel band, may be unre-inforced and only architectural.

3.2 Building Health Assessment

Field observations of existing school buildings have identified several recurring problems.

- Wall cracking/bulging due to minor foundation settlement, erosion, temperature variation, or shrinkage.
- Loss of plaster and mortar from aging or prolonged exposure to moisture.
- Corrosion of reinforcement in reinforced concrete (RC) elements such as beams, columns, steel girder and T-iron or RC lintels due to dampness and corrosion of structural steel sections. Corrosion of CGI and PGI sheets
- Efflorescence and moss growth on damp walls and plinths.
- Water leakage through roofs, or joint between wall and roof slab or around foundations due to poor drainage or damaged waterproofing layers.
- Spalling and surface scaling in concrete elements caused by rusting reinforcement and moisture ingress.
- Wood rotting (trusses)

3.2.1. Material condition and deterioration

A visual and tactile examination of masonry and mortar should be carried out to assess material integrity. The following should be recorded:

- Wall materials (brick or stone), mortar type (cement-sand, cement–lime, or mud)
- Surface conditions for cracks, disintegration, out-of-plane bulging, or erosion of walling materials.
- Cracking and disintegration of concrete elements.
- Rotting, insect infection, breaking of timber including broken joints.
- Environmental deterioration such as water ingress, vegetation growth, salt crystallization, and corrosion of embedded steel in reinforced concrete roof slabs, bands and lintels and other elements.
- Damage to non-structural building elements such as floor, etc.

3.2.2. Foundation Settlement

Examine the foundation for signs of wall settlement, tilting, cracking, or erosion caused by water or poor soil conditions. If significant foundation movement or bearing failure is observed, the building may not be suitable for standard retrofitting presented in these guidelines and should be referred for engineering investigation and remediation. Simple checks such as using a plumb line or level can identify wall lean or foundation settlement.

Severe foundation settlement in brick or stone masonry buildings can lead to structural distress and potential instability. The following signs should be carefully observed and documented during assessment:

- Wide diagonal cracks: Cracks wider than ¼" (6 mm) running diagonally from door and window corners toward the foundation or roof level.
- Step cracks in masonry joints: Stepped cracking along mortar joints, particularly near corners or junctions, indicating differential settlement.
- Uneven floors: Noticeable slopes or depressions in floors, especially near walls, suggesting localized or differential settlement.
- Separation at wall junctions: Gaps forming between perpendicular walls or at wall-to-floor/roof interfaces due to uneven movement of foundations.
- Tilting or leaning walls: Out-of-plumb walls, visible leaning, or bulging, especially in tall or slender walls.
- Distress around openings: Cracking or deformation around doors and windows, making them difficult to open or close.
- Crushed or open plinth joints: Crushing of mortar or visible separation between the wall and foundation or plinth level.
- Water Ponding or erosion near foundation: Evidence of soil erosion, poor drainage, or water accumulation around the foundation area contributing to settlement
- In waterlogged or flood-affected areas, it is essential to assess moisture levels in the foundations and implement measures to prevent water ingress.

Part-ii

Chapter 4

Repair, Rehabilitation, Retrofitting Design and Implementation

School buildings, particularly those constructed several decades ago, often show signs of deterioration due to aging materials, minor settlement, corrosion of reinforcement, water ingress, or inadequate maintenance. Although such defects may not pose an immediate structural threat, they can significantly reduce the strength, serviceability, and durability of the building if left unaddressed. Before initiating or implanting any retrofitting measures, it is essential to repair and restore the building's existing strength and integrity. Repair, restoration, and retrofitting may sometimes follow a sequential process, but in many cases, they can be implemented in parallel to optimize resources and ensure comprehensive rehabilitation.

This chapter provides practical guidance on identifying, repairing, and remediating common defects to ensure the continued safety, functionality, and longevity of school buildings.

4.1 Objectives

The primary objectives of repair and rehabilitation are to:

- Restore the original strength and functional performance of the building.
- Arrest deterioration caused by environmental and structural factors.
- Extend the useful life of the building in a cost-effective manner.
- Prepare the building for future seismic retrofitting or strengthening.
- Prevent further water ingress and damage through improved drainage and maintenance.

Repair and rehabilitation are not seismic retrofitting. They restore the building's original strength and durability, while seismic retrofitting enhances its seismic performance. In erathquake prone areas repairs should always precede retrofitting to ensure safety and the effectiveness of the retrofitting measures.

4.2 Repair and Rehabilitation Procedures

All repair works should be executed under the supervision of a qualified engineer or trained technician using approved methods and quality materials. Readers are also encouraged to consult other guidelines for repair and rehabilitation to complement the approaches discussed in this document

4.2.1. Masonry crack repair

For repairing cracks in masonry walls, cement-based grout should be used if the wall is constructed with cement-sand mortar, followed by a 3/4-1” (20–25 mm) thick ferrocement overlay. For mud mortar walls, grouting is not required; the cracks should be directly overlaid with 3/4-1” (20-25 mm) ferrocement of the same thickness. If the wall is planned to be strengthened with a full ferrocement overlay, a separate overlay for crack repair is not necessary. Both grouting and ferrocement overlay methods are described in the following sections.

Before starting any repair, rehabilitation, or retrofitting work, all utility services including main electrical connections must be clearly identified and safely isolated or terminated. Electrical fixtures should be removed or securely covered to prevent damage. Similarly, other building components such as doors, windows, and ventilators must be protected with polythene sheets to avoid staining or damage from mortar and construction debris.

Temporary works may be necessary to stabilize and support vulnerable or unstable components of the building prior to the commencement of repair activities. These measures may include the provision of temporary supports, shoring, or propping for the roof system and structurally unstable walls to ensure safety and prevent further deterioration or collapse during the execution of repair works.

Grout injection

All cracks in masonry walls shall be repaired using cement-based grout injection and should be applied from both sides of the wall. The method presented here is for cement-sand mortar masonry. Refer to Appendix 7 for material specification. The following steps shall be followed to ensure proper consolidation and bonding of cracks within masonry walls:

a. Surface preparation

- Remove existing plaster from both faces of the wall along the cracked area.
- Clean and repoint the cracked joints by removing all loose or deteriorated mortar and refilling with fresh mortar.

b. Nozzle installation

- Drill holes along the cracks at specified spacing:
- 6" (150 mm) for cracks narrower than 1/8" (3 mm).
- 12" (300 mm) for cracks wider than ¼ (6 mm).
- Install injection nozzles securely using a fast-setting mortar.
- The depth of each drilled hole should be at least half the wall thickness.

c. Surface sealing

- Apply a ferrocement overlay or equivalent sealing layer on both wall faces to confine the masonry and prevent grout leakage during injection (Fig-22c).

d. Pre-injection preparation

- After about 14 days (when overlay gains strength), flush clean water through the ports starting from the top to moisten the masonry,
- Verify connectivity between ports, and
- Remove dust and debris.
- Saturate the wall by surface watering 24 hours before injection to reduce suction and improve grout penetration.

e. Grouting operation

- Prepare grout immediately before use and keep it continuously agitated during injection.
- Start injection from the lowest nozzle, proceeding upward. Seal each port as grout emerges from the next one.
- Begin injection at approximately 2 bars pressure, gradually increasing up to 4 bars when the flow stops. Maintain pressure for several minutes to ensure complete consolidation.

Fig-22: Structural restoration of cracked masonry walls

Fig- 22a. Injection Nozzles and Stoppers

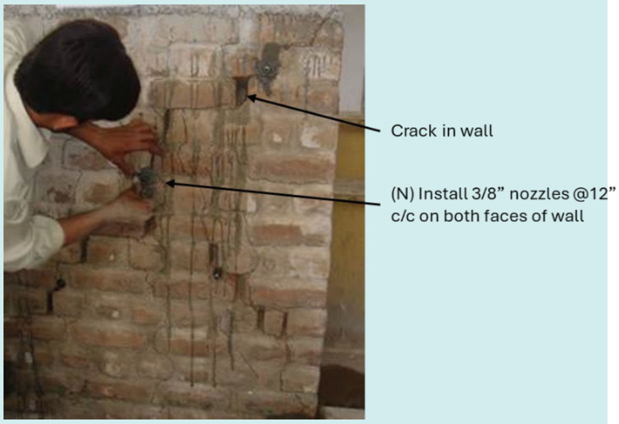


Fig-22b: Inserting and fixing the nozzles

Fig-22c: Injector Assembly

Fig-22d: Watering of the Specimen through Nozzles

Ferrocement Overlay

Ferrocement overlay involves fixing a steel wire mesh to the surface of the wall, followed by plastering with cement–sand mortar. The material specifications for the ferrocement overlay are provided in Appendix 7. The following procedure shall be adopted for the application of ferrocement overlay on cracked masonry walls, whether constructed with mud mortar or cement–sand mortar. Details of the process are illustrated in Fig-23.

a. Surface preparation

- Remove any loose, damaged, or chisel-cut masonry and reinstate using whole or saw-cut bricks or stone as required based on original masonry with fresh 1:4 cement-sand mortar. In case of masonry in mud mortar, use mud mortar.
- Clean the wall surface thoroughly. In case of masonry in mud mortar, rack the mortar to ¾" (20 mm) depth. Remove loose joint mortar and refill the joints with fresh 1:4 cement–sand mortar.
- Remove all paint

b. Fixing of mesh

- Mark and drill holes on the masonry wall at 12–14" (300–350 mm) c/c horizontally (staggered) and 9" (225 mm) c/c vertically for screws.
- At edges and terminations, screws should be placed at 9” (225 mm) centers, both horizontal and vertical.
- Each screw should be fitted with a mild steel washer (ASTM A36) 1/16 ± 1/64 inch (1.6 ± 0.4 mm) thick and 1.0 ±0.2” (25 ± 2.5 mm) in diameter to hold the mesh firmly against the wall.
- Fix the mesh securely to the wall surface using screws, washers, spacers, and plastic expansion plugs as shown in the drawings.
- Additional holes may be drilled where necessary to avoid wrinkles or loose mesh areas.

c. Pre-Plastering preparation

- Wet the masonry wall thoroughly to achieve full saturation by sprinkling water.
- Apply a cement slurry coat to the wall surface immediately before plastering to enhance bond strength.

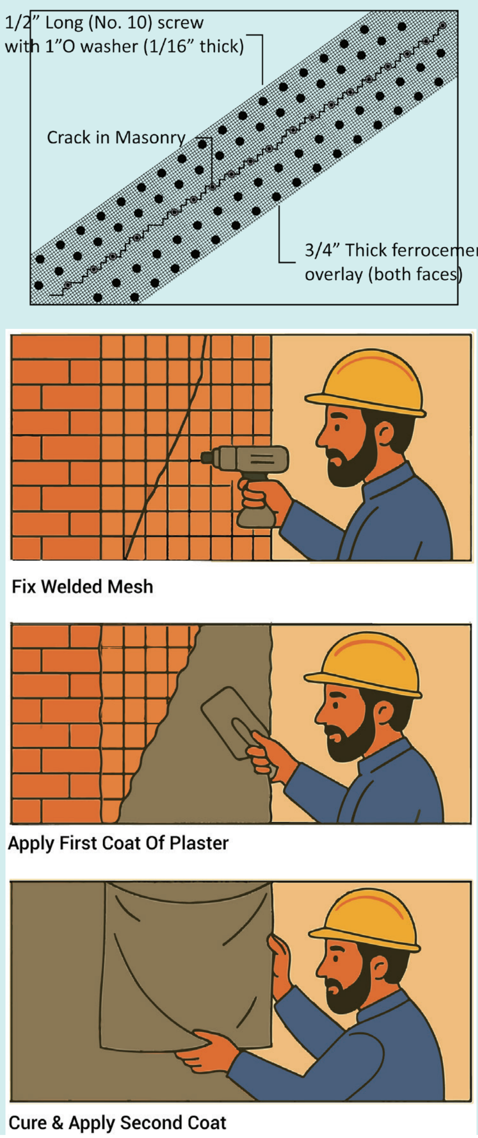
d. Plaster application

- Apply the first coat of plaster, 3/8” to 1/2” (10 to 12 mm) thick, to fill gaps between the mesh and cover the surface evenly.
- After 24 hours, apply the second coat of plaster to achieve a smooth finish, maintaining a total plaster thickness of 3/4” to 1.0” (20 to 25 mm).

e. Curing and Final Works

- Maintain a moist plaster surface for a minimum of 4 days using hessian cloth or polythene sheets.
- Any existing fixtures damaged during retrofitting shall be repaired or replaced at the contractor’s own cost.

Fig-23: Ferrocement Overlay on Cracked Wall (Typical)



Masonry and plaster repair

The following steps shall be followed for the repair of damaged plaster:

- Remove damaged plaster and rake out deteriorated mortar joints to about 3/4” (20 mm) depth.
- Refill joints with fresh 1:3 cement-sand mortar and reapply plaster with 1:4 cement-sand mortar.
- Apply a bonding coat composed of 1:1 cement–sand slurry before new plaster for good adhesion.

4.2.2. Reinforced Concrete Member Repair

RC components in school buildings, such as slabs, lintels, beams, and columns often deteriorate due to corrosion of reinforcing bars caused by water ingress. Proper inspection and timely repair are essential to prevent further reinforcement loss. The following steps can be adopted for rehabilitating damaged reinforced concrete members; however, these apply only where the steel bars have lost less than 20% of their diameter:

- Expose the corroded reinforcement and clean thoroughly with a wire brush or sandblasting. Remove all loose or damaged concrete until sound material is reached (see Fig-24).
- Patch the damaged concrete using rich cement–sand mortar (1:3) or micro-concrete to restore the section. Before patching, apply a 1:1 cement–sand slurry to the cleaned rebars and exposed concrete to ensure proper bonding.
- Keep the repaired area moist for at least seven days to achieve adequate curing and strength development.

If the reinforcement loss exceeds 20% of the bar diameter, or if extensive spalling and cracking are observed, the affected RC member should be reconstructed.

Fig-24: Structural restoration of cracked masonry walls

Repairing spalled concrete

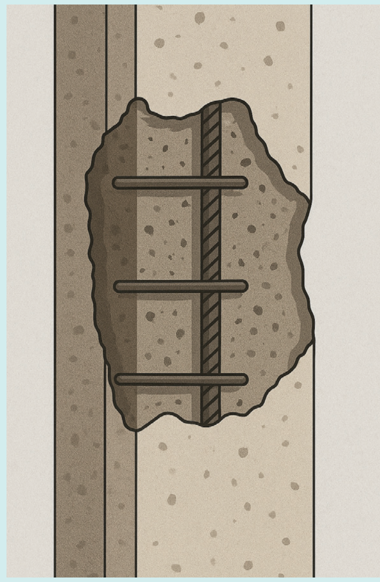


Fig-24a: Applying cement sand slurry to wall

4.2.3. Structural steel member repair

Structural steel components in school buildings, such as roof trusses, steel girders and inverted T-iron often deteriorate due to corrosion resulting from water ingress or inadequate maintenance. Proper inspection and timely rehabilitation are essential to prevent section loss and joint failure. The following steps can be adopted for rehabilitating corroded steel sections; however, these apply only where the thickness of steel section has lost less than 20% of their original thickness:

- Clean all corroded or rusted surfaces by wire brushing, grinding, or sand blasting to remove loose material and scale.
- Repair or strengthen deteriorated sections by welding or bolting additional steel plates,

angles, or channels of equivalent grade.

- Apply anti-corrosive primer or zinc-rich coating on cleaned steel surfaces.
- Replace severely corroded or damaged members if section loss exceeds acceptable limits.
- Finish with two coats of protective paint or epoxy coating to prevent future corrosion.

4.3. Waterproofing and Drainage Improvement

Water is one of the main causes of building deterioration. It weakens foundations, corrodes reinforcement, damages masonry, and significantly reduces the durability of structures. Therefore, rainwater and surface runoff must be drained away from the building as quickly as possible, and no water should be allowed to pond near or beneath the foundation. Ensuring a properly draining roof, along with an apron or paved surface (plinth protection) around the building with adequate slope and functional drainage, is essential to protect the structure from long-term moisture-related damage.

If corrosion of steel sections exceeds 20% of their original thickness, the affected portion or the entire section, if necessary, should be replaced with a new member of equivalent strength.

The replacement steel must be protected and isolated from direct contact with clay brick or soil to prevent future corrosion. This can be achieved by applying two coats of bituminous paint on all surfaces of the steel section before installation. Where steel members are embedded in or adjacent to masonry, provide a 50 mm thick cement mortar or concrete cover around the steel surface.

4.4. Roof Treatment

The roof of the building shall be properly treated to prevent water infiltration through the roofing system. The material specifications for roof treatment are provided in Appendix 7. The following steps shall be followed for the application of waterproofing to the inverted T-iron slab. Cross-sectional details are shown in Fig-26.

- Provide temporary wooden support to T-iron at the mid span to control excessive deflection in T-iron.
- Remove parapet wall and all foreign material (mud, mortar, etc.) on roof brick tiles.
- Apply grout in 1:2 cement-sand mortar on brick tiles (if not applied) with appropriate water cement ratio to get a workable paste.
- After a curing period of 7 days, fabricate steel reinforcement over Jumbolon with a clear cover of 1.25" on both top and bottom.
- Pour concrete and do curing of RC slab concrete for at least 7-days by ponding water on slab.
- Temporary supports shall not be removed before completion of curing period.

Fig-25: Roof treatment .

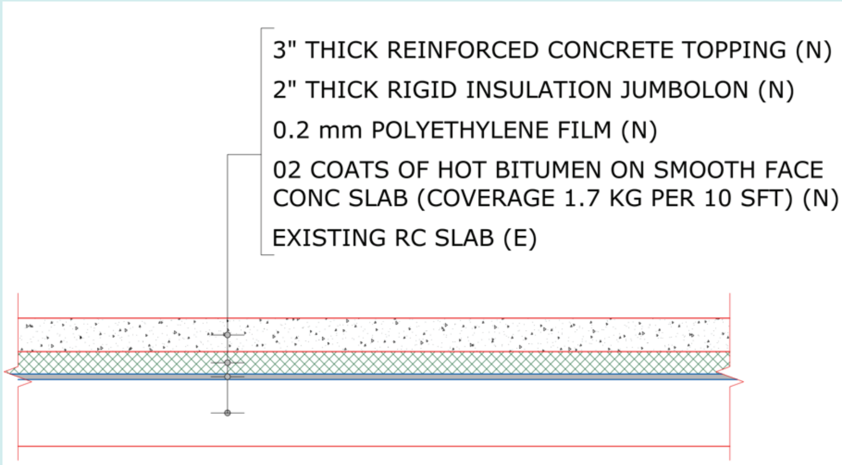


Fig-26: A school building with a lintel band, may be unreinforced and only architectural.

4.5. Drainage Management

To minimize water-related damage, school buildings should be provided with a well-constructed apron, a sloped, impermeable surface (preferably in concrete) extending at least 3’ (900 mm) beyond the plinth line on all sides (see Fig-27). The apron prevents direct contact of rainwater with foundation masonry and reduces erosion near the building base.

Additionally, an effective rainwater drainage system must be incorporated to safely divert surface runoff and roof water away from the structure. This includes properly graded surroundings, gutters, downpipes, and surface drains leading to soak pits or natural discharge points. Maintaining these drainage features through regular cleaning and inspection is critical to prevent water stagnation and infiltration, which can compromise the stability and safety of the building over time.

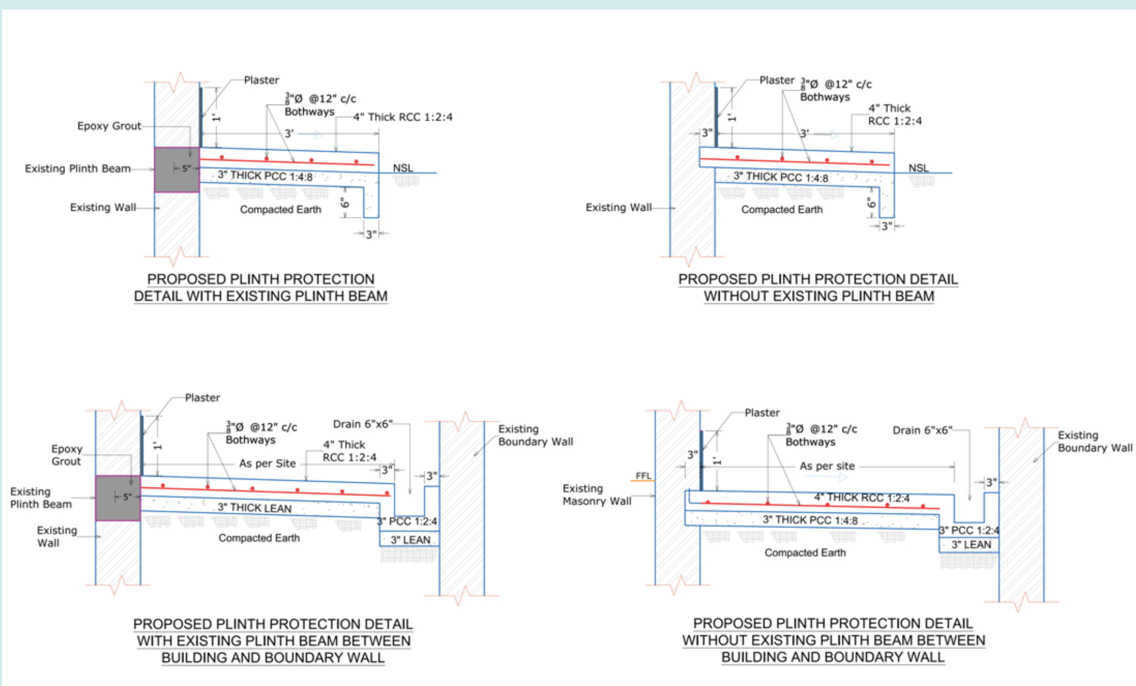


Fig-27: Plinth protection detail

This page is intentionally left blank

Chapter 5

Retrofitting and Implementation

Seismic retrofitting is the process of upgrading existing buildings to improve their resistance to withstand earthquakes. This section focuses on enhancing seismic safety of school buildings at reasonable cost using pre-engineered, practical, standardized solutions. The retrofitting approach primarily employs the 'splint and bandage' to create a 'box effect' and ferrocement overlays to enhance wall shear capacity where necessary.

The provisions in these guidelines apply to both brick and stone masonry buildings constructed in cement-sand or mud mortar, with additional requirements specified for stone masonry and mud-mortar constructions where needed.

The retrofitting provisions developed for moderate seismic zones also apply to low seismic zones.

5.1 Retrofitting Objectives and Performance Levels

The primary objective of seismic retrofitting for school buildings is to achieve the Life Safety performance level. To meet the life-safety performance requirement, retrofitting aims to develop box action (see Fig-28), enabling the building to act as an integrated three-dimensional unit during shaking, thereby preventing collapse and minimizing loss of life during strong earthquakes. When walls, floors, and roofs are properly connected and restrained, the structure behaves as a "box," distributing seismic forces through multiple load paths instead of allowing walls to act independently.

In Unreinforced Masonry (URM) buildings, achieving the box effect is vital to prevent out-of-plane wall failures, corner separations, and partial collapses. This requires continuous and reliable connections among all structural components. Retrofitting measures should therefore:

- Prevent failure of non-structural elements such as parapets and partition walls.
- Prevent collapse of face-loaded walls.
- Improve roof and floor diaphragm action.
- Strengthen wall-to-wall and wall-to-roof connections.
- Enhance strength and ductility of in-plane walls.
- Reduce hazards from other non-structural components from freestanding shelves, etc.

Retrofitting of existing buildings is essential to ensure structural safety and compliance with current standards, especially where earthquake-resistant design was not originally incorporated. Buildings constructed under outdated seismic codes or in areas with revised seismic zoning face increased risk. Additionally, changes in building use, such as conversion to commercial or public occupancy, can impose higher loads and different performance requirements, making structural assessment and strengthening necessary.

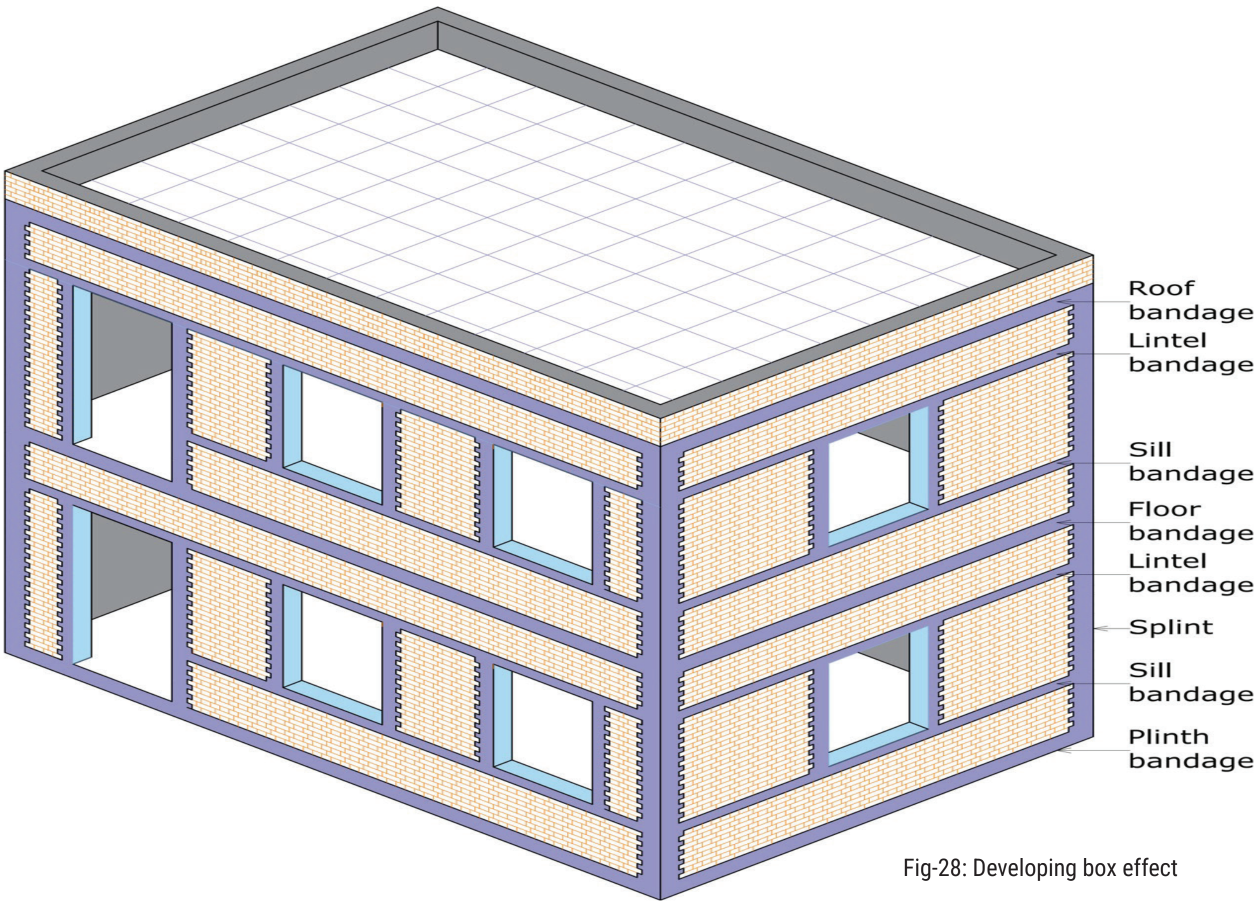


Fig-28: Developing box effect

5.2 Holistic Approach And "Make No Worse" Principle

A holistic approach must be adopted when retrofitting a building to ensure that all vulnerable elements, structural and non-structural or part of the original building or not, are adequately addressed. Unplanned strengthening only selected components can lead to new weaknesses or unintended stress concentrations during an earthquake. The "make no worse" principle should therefore guide all retrofitting interventions, meaning that no measure should compromise the performance of adjacent or interconnected elements. For example, a new room was constructed in a school which was just retrofitted (see Fig-29). Every modification, whether adding a band, anchorage, or diaphragm, should enhance the overall integrity of the building and help it behave as a unified, stable system. This approach ensures balanced performance and helps maintain minimum level of earthquake safety in school campuses.

It is important to ensure that during retrofitting, all existing vulnerabilities are properly addressed and that no new weaknesses are introduced. Interventions such as constructing new masonry parapets, gable walls, or partition walls without adequate stabilization systems, or adding new non−earthquake-resistant structures can inadvertently increase the seismic risk. All interventions should, therefore, reduce the vulnerability of school campus rather than create additional vulnerabilities.

Fig-29: new room constructed without earthquake resistant elements.

5.3 Retrofitting Principles For URM Buildings

While designing a retrofitting scheme, follow these principles:

1. Address the most vulnerable elements first (see Fig-30).
2. Avoid creating new weaknesses or stiffness irregularities.
3. Use incremental and standardized measures.
4. Ensure compatibility between new and old materials.

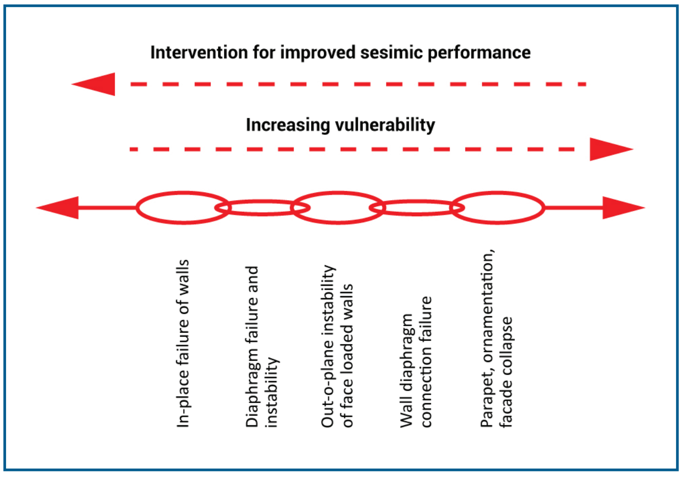


Fig-30: The capacity chain and hierarchy of URM building component vulnerability (MBIE, 2017)

5.4 Cost-Effectiveness Considerations

As a general benchmark, the retrofitting cost should not exceed approximately 40% of the replacement cost of the building. However, this threshold should not be used as the sole criterion for deciding on demolition and reconstruction of a building. Decisions should also consider structural condition, heritage or community value, construction timeline, and feasibility constraints. It should be noted that remediation costs associated with repair of non-seismic defects are not included in the retrofitting cost estimate.

Considering the common use of reinforced concrete, including jacketing and ferrocement, a concrete-based solution has been proposed for retrofitting existing school buildings. However, a steel plate/flat retrofitting scheme is also presented in Section 5.6.1. as an alternative. The proposed retrofitting solutions are based on available guidelines, observed and postulated failure modes and their consequences, and extensive analytical calculations.

irrespective of masonry unit and mortar types. It also presents additional provisions for floor and roof constructed of T-iron and wooden and metal roof structure. Further special provisions have been made for buildings constructed in mud mortar and buildings constructed of stonemasonry in the following sections.

5.5 Retrofitting Solutions By Element

5.5.1. Configuration improvement

Section 2.6.1 shows the minimum recommended pier and the maximum opening lengths. If these requirements cannot be achieved, either the openings must be partially or fully closed or specific engineering retrofitting design by a qualified structural engineer will be necessary.

Reconfiguration of openings to ensure adequate pier width: In existing school buildings, large openings are often provided for lighting and ventilation. However, if not properly reinforced, these reduce pier width and create structural weaknesses. To improve seismic performance, such openings should either be strengthened with appropriate reinforcement or selectively reduced/closed using proper masonry, ensuring effective bonding between new and existing work. Figures 31a and 31b illustrate the closure of openings to enhance wall strength.

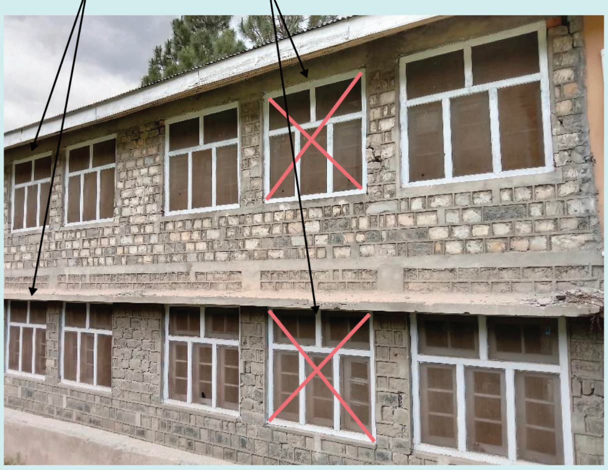


Fig-31a:

Fig-31b:

Retrofitting Solutions for Different Types of Buildings under Various Seismic Zones: Retrofitting requirements vary based on the seismic zone, building type, and number of storeys. In moderate seismic zones, basic measures such as RC bands, crack repair, and wall strengthening are generally sufficient, whereas high seismic zones require more stringent interventions. RC slab roofs provide rigid diaphragms, while truss roofs and inverted T-iron roofs behave as flexible diaphragms. These flexible systems require special attention to improve diaphragm action. Table 11 shows retrofitting solutions for different Types of buildings under various seismic zones

Table-11: General provisions to be implemented for all types of masonry buildings

S. No	Retrofitting items	Normal provisions (RC Slab roof)						*Special provisions (T-iron floor/ roof, timber/ steel roof)					References
		Moderate seismic zone			High seismic zone			One- storey	Two storeys		Light metal roof	Geotechnical Aspects	
		One storey	Two storeys		One storey	Two storeys			Ground	First			
			Ground	First		Ground	First	T-iron	T-iron	T-iron			
1	Replanning of windows if piers are smaller than permitted	✓	✓	✓	✓	✓	✓						Sections 5.5.1
2	Ferrocement splints	✓	✓	✓	✓		✓						Section 5.5.4
3	RC splints					✓							Section 5.5.4
4	RC bandages on both faces of walls at lintel level	✓	✓	✓	✓	✓	✓						Section 5.5.3
5	Confinement of masonry columns with ferrocement overlay	✓		✓	✓		✓						Section 5.5.7
6	RC jacketing of masonry columns		✓			✓							Section 5.5.7
7	Confinement of openings in walls with ferrocement overlay	✓		✓	✓		✓						Section 5.5.2
8	Confinement of piers with ferrocement overlay		✓			✓							Fig-44
9	RC topping with shear connectors on existing T-iron floor/ roof							✓	✓	✓			Section 5.5.5
10	RC bond beam integrated to RC topping to T-iron roof							✓		✓	✓		Section 5.5.5

11	RC bandage on the outer face of walls at eaves level if floor/ roof constructed of T-iron								✓				Section 5.5.5
12	Horizontal roof braces										✓		
13	RC bandage on the outer face of walls at plinth level											✓	Table 5.2

*Applicable to both moderate and high seismic zones.

5.5.2. Opening Confinement belts (around doors and windows)

Masonry walls with door and window openings should be reinforced with ferrocement overlay belts provided around the openings (see Fig-32) to limit cracking and their propagation. The overlay should be applied on both faces of the wall, with a width of about 1 ft (300 mm). If the wall is already being strengthened with a full ferrocement overlay, separate belts around the openings are not required. Likewise, where splints are provided adjacent to the opening jambs, additional belts along the jambs should be avoided. Fig-33 shows retrofiiting elments.

Specifications of the ferrocement overlay are presented in Appendix 7 and application procedure is presented in section 5.6.4

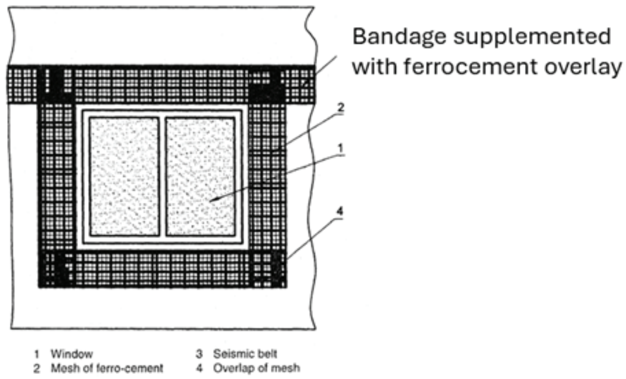


Fig-32: Ferrocement around opening and lintel bandage

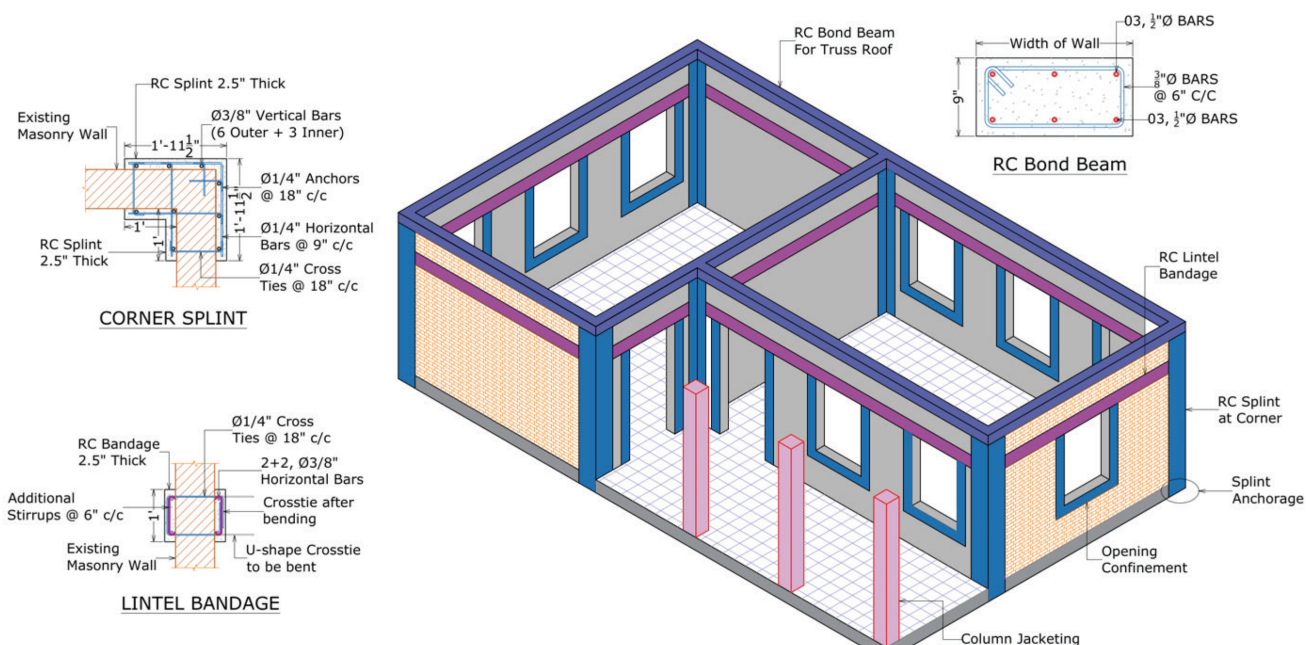


Fig-33: Retrofitting elements

5.5.3 Horizontal Bandages (Seismic Belts)

Seismic bandages are horizontal reinforced belts installed on masonry walls to tie all walls together and create a unified "box" action, thereby improving the building's integrity and earthquake resistance. They enhance load redistribution and help prevent separation and out-of-plane failure. They consist of steel bars tied to the wall using screws, nails, and through-wall connector links. Once fixed, the reinforcement is encased with a layer of micro-concrete plaster, forming a continuous horizontal belt that enhances wall integrity and ensures effective interconnection between adjoining walls. The material specifications are given in Appendix 7.

The following bandages are commonly provided:

• Lintel bandage: RC seismic bandages on all walls is installed, on both faces, just above the lintel level of doors and windows. If the lintels are at different heights, the bandage at the highest lintel level is installed. Any gap between the bandage and lower lintels is filled using a ferrocement overlay to ensure proper continuity and strength.

• Eave's bandage: Bandage on the outer face, at the floor or roof level, would be required if the slab is constructed of T-iron.

• Floor and roof bandages: The floor level bandages shall be omitted if the floor is a RC slab providing a rigid diaphragm. Similarly, if the roof is constructed of RC slab, the roof level bandage shall be omitted.

• Plinth level bandage: A plinth-level bandage should be provided when the plinth height exceeds 3' (900 mm), the building is situated on soft soil, near a retaining wall, or constructed on sloping ground. In such conditions, the plinth band is essential to distribute loads uniformly, reduce differential settlement and hold walls together should the ground spread. The band should be installed continuously around the building, but only from the outside.

• Gable bandage: For buildings with sloping roofs, a bandage near the top of gable walls is provided, just below the roof or a bond beam just above the gable.

The application procedure of the bandage is given below:

1. Marking: Determine the height and width of the belt; however, the typical recommended width of bandages is 12" (300 mm).
2. Plaster removal: Cut and remove existing plaster neatly using a mechanical cutter. Remove all loose mortar layers, brick/ stone pieces.
3. 3. Surface preparation: Rake mortar joints to a depth of about ¾" (20 mm) and clean thoroughly with a water jet.
4. Ideally, the bandage should be cast in a single continuous operation after fixing the formwork at the bandage location, with micro-concrete poured to achieve the required thickness.
5. Alternatively, the bandage may be applied in

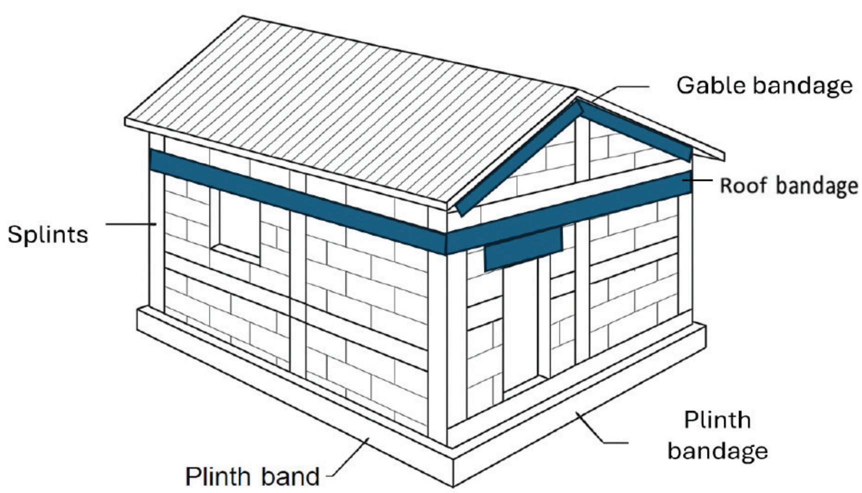


Fig-34: Retrofitting elements

a manner similar to plastering in two layers, following the steps outlined below:

a. First plaster Layer: Apply a 1” (25 mm) 1 cement:1.5 sand:3 pan crush stone micro concrete plaster, filling all raked joints and roughening the surface for better bonding of second plaster.

b. Fix the rebars to wall: Securely tie the reinforcing bars to the appropriately spaced screws or concrete nails with binding wire. Anchor the rebars into the wall through drilled holes filled with mortar grout to ensure proper bonding and load transfer (see Fig-35). Refer to table -12 for reinforcement details.

c. Second plaster layer: Apply another 1.5” (40 mm) thick plaster over the mesh and rebars. To ensure good bonding, brush a neat cement slurry over the first plaster just before applying the second layer.

6. Curing: Cure the finished belt by sprinkling water for at least 10 days to achieve proper strength and durability.

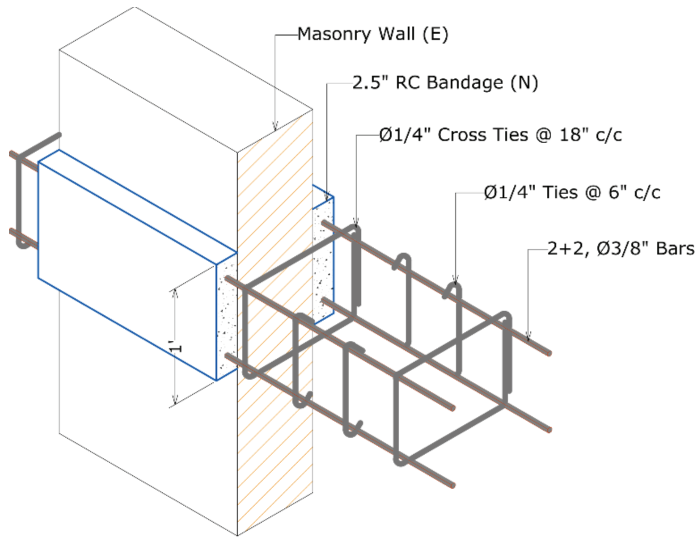


Fig-35: Bandage details at lintel level

Table-12: Reinforcement detail of RC bandages

Bandage level	Clear length of wall between two cross walls	Seismic zone		Remarks
		Medium	High	
Plinth bandage	Any wall length	2 Dia 3/8” (10 mm)	2 Dia 3/8” (10 mm)	Ø1/4’ (6 mm) ties @6” (150 mm) c/c
Lintel bandage	16’ (5.0 m)	2 Dia 3/8” (10 mm)	3 Dia 3/8” (10 mm)	
	25’ (7.6 m)	2 Dia 3/8” (10 mm)	3 Dia 3/8” (10 mm)	
Eave’s bandage	Any wall length	Ferrocement bandage on outer face only with 2 storeys building or one storey building with tall parapet and with T-iron floor		

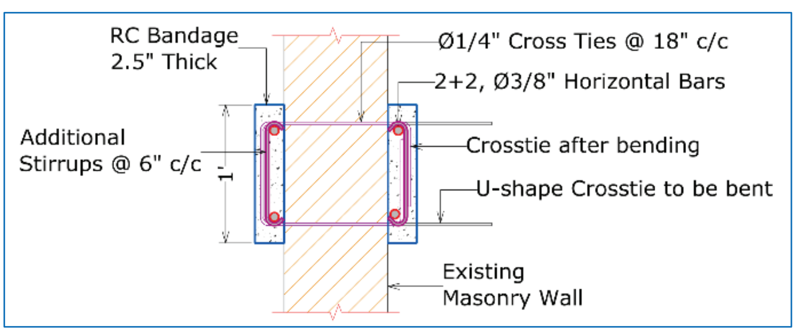


Fig-35a detail of stirrups

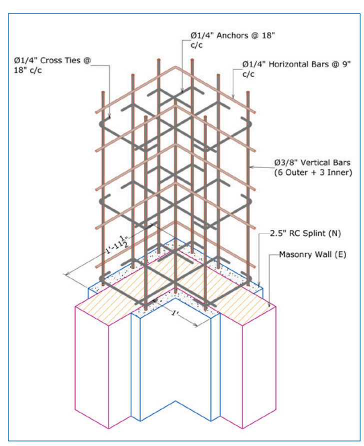


Fig-36: Vertical bar or mesh reinforcement in vertical belt atcorners of rooms

5.5.4 Vertical splints (Vertical belts)

Vertical splints are provided at room corners and wall junctions, on both interior and exterior faces, to enhance the overall integrity and seismic resistance of masonry buildings. Depending on the number of storeys and the seismicity of the area, as shown in Table 13, splints may consist of ferrocement overlays or reinforcing bars embedded in micro-concrete (see Fig 36). These splints should extend at least 18” (450 mm) below ground level and continue upward to connect with the roof slab or eave-level bandage or bond beam, passing through intermediate floors via holes drilled through the slab (see Fig-35). Installation of splints should follow the same procedure used for bandage installation.

Table-13: Details of reinforcement/mesh in according to seismic zone and number of storeys.

Number of storeys	Storey	Seismic zone Medium	High
One	-	Welded mesh only	Welded mesh only
Two	Top	Welded mesh only	Welded mesh only
	Bottom	Welded mesh only	T-junctions = 10 Ø 3/8” and Corners = 9 Ø 3/8”

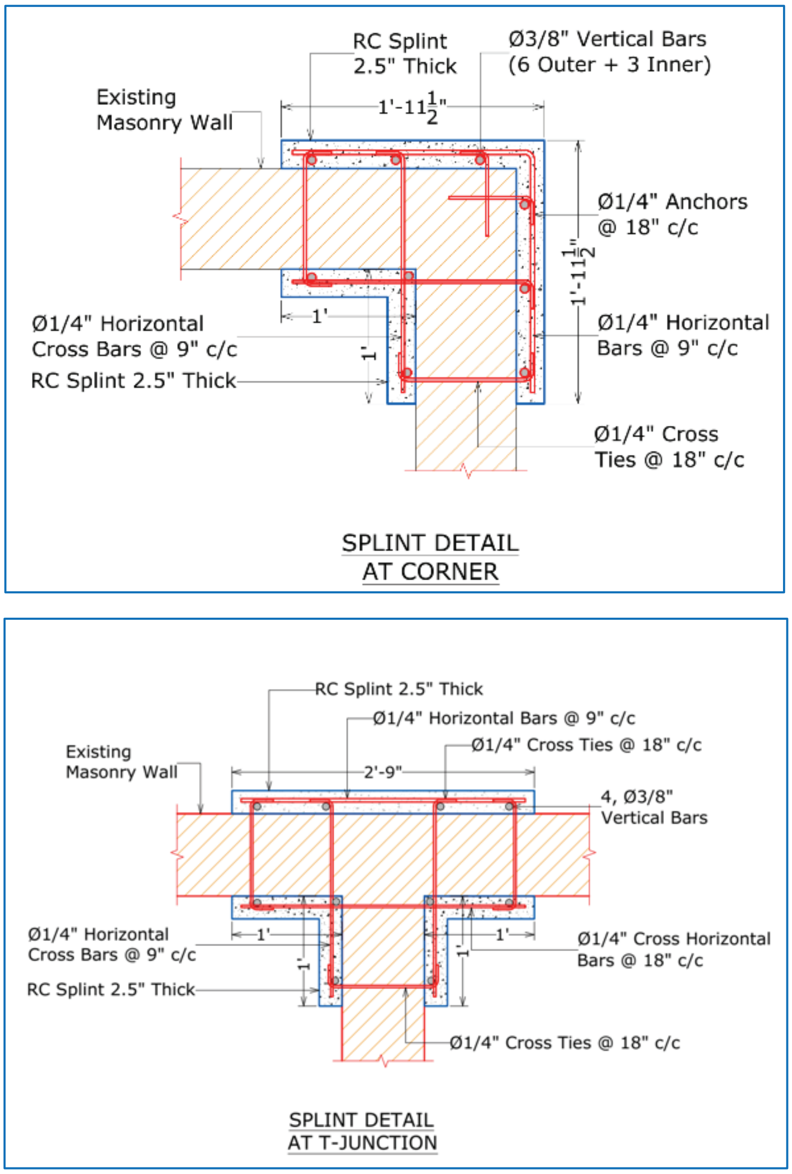


Fig-36a, 36b: RC splint details at wall corner and T-junction

5.5.5. Retrofitting of inverted T-iron floors and roofs

Where the roof or floor consists of prefabricated units such as steel girders with inverted T-sections overlain by brick tiles, or reinforced concrete (RC) T- or channel units supporting brick tiles or concrete slabs, proper integration of all components is essential to ensure effective diaphragm action and uniform seismic performance. The diaphragm effect refers to the ability of the roof or floor system to act as a horizontal structural plate, transferring lateral earthquake forces to the supporting walls.

Providing a 3" (76 mm) thick cast-in-situ concrete topping, reinforced with ¼" (6 mm) diameter bars at 12" (300 mm) c/c in both directions (see Fig-36), creates a unified diaphragm that distributes seismic forces more evenly and improves box effect thereby the overall stability of the building. The topping should be anchored to the supporting steel structure using shear studs and tied to the supporting walls.

For buildings with inverted T-iron roof slab, a reinforced concrete bond beam should be constructed at the top of the walls, cast monolithically with the slab topping. The slab topping reinforcement should be properly anchored into this beam and splint reinforcements should also be anchored to the eaves-level bond beam.

If the building has a parapet and it is decided not to deconstruct and rebuild the parapet, a ferrocement bandage should be provided on the exterior face of the walls at eaves level. In this case, the topping reinforcement should be anchored into the eaves-level bandage (see Fig-37b). Similarly, for a two-storey building or one storey building with tall parapet for an inverted T-iron floor and, an RC bandage should be provided at floor level, and the topping reinforcement should be anchored into it. The material specifications are given in Appendix 7. Below is the step-by-step procedure for strengthening inverted T-iron floor and roof

- Provide temporary supports under T-irons at midspan to control deflection.
- Remove parapet walls and all loose materials

Apply a cement-sand grout (1:2 mix) over brick tiles with appropriate water-cement ratio to achieve workable consistency.

- Cure for at least 7 days.
- Install L-shaped shear connectors, welded to the top of steel girders and inverted T-irons.
- Position Jumbolon (insulation) sheets, press over connectors, and bend the connector tips to secure.
- Lay reinforcement with a minimum clear cover of 1¼ inch (30 mm) at top and bottom. Tie all L-shaped connectors to reinforcements.
- Pour concrete topping, compact properly, and cure for at least 7 days by ponding water on the slab.
- Do not remove temporary supports before the curing period is completed.

Conduct a cost–benefit analysis, taking into account the remaining lifespan of the inverted T-iron slab and long-term usability of the RCC slab. If the existing walls are structurally adequate to support the additional load, consider replacing the T-iron and tile roof with an RCC slab. Fig. 37a shows the replacement of a T-iron roof with an RCC slab based on a cost–benefit analysis considering durability, use as a learning space, and improved structural performance through diaphragm action. Wall load-bearing capacity was first assessed and found adequate for the increased load.slab was appropriate.

Fig-37a: A T-iron roof is being replaced with RCC slab

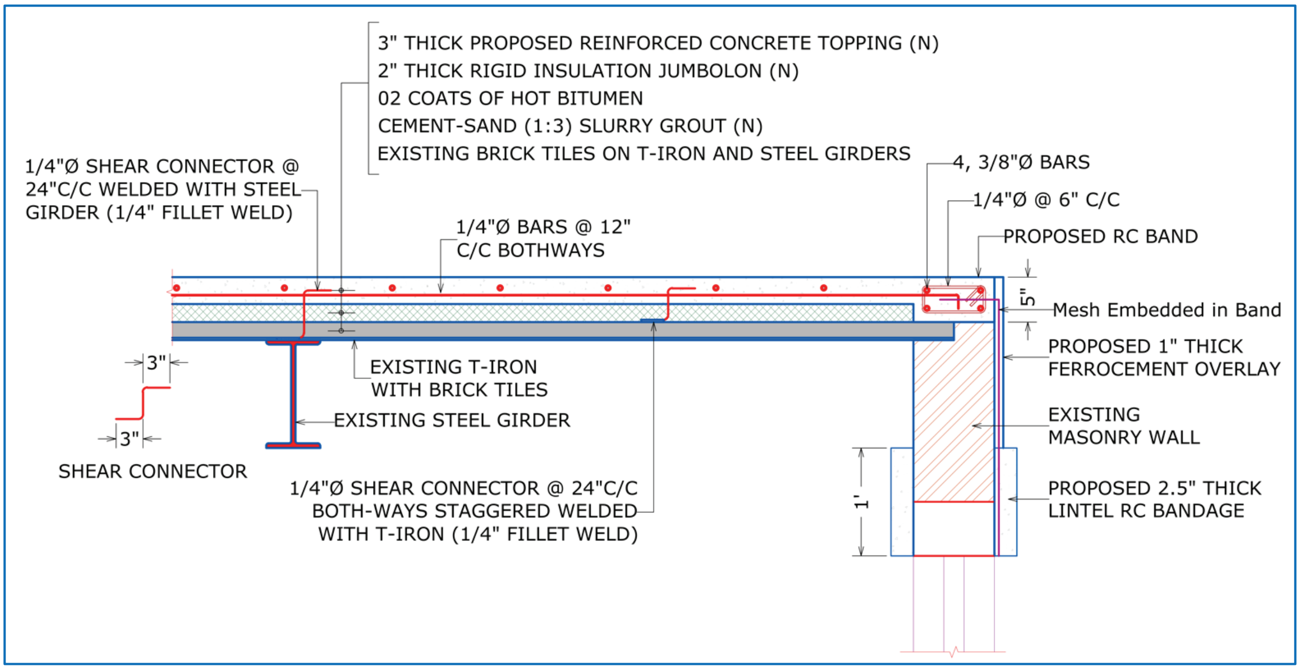


Fig-37b: Strengthening of steel girder and inverted tee floor and roof (one storey)

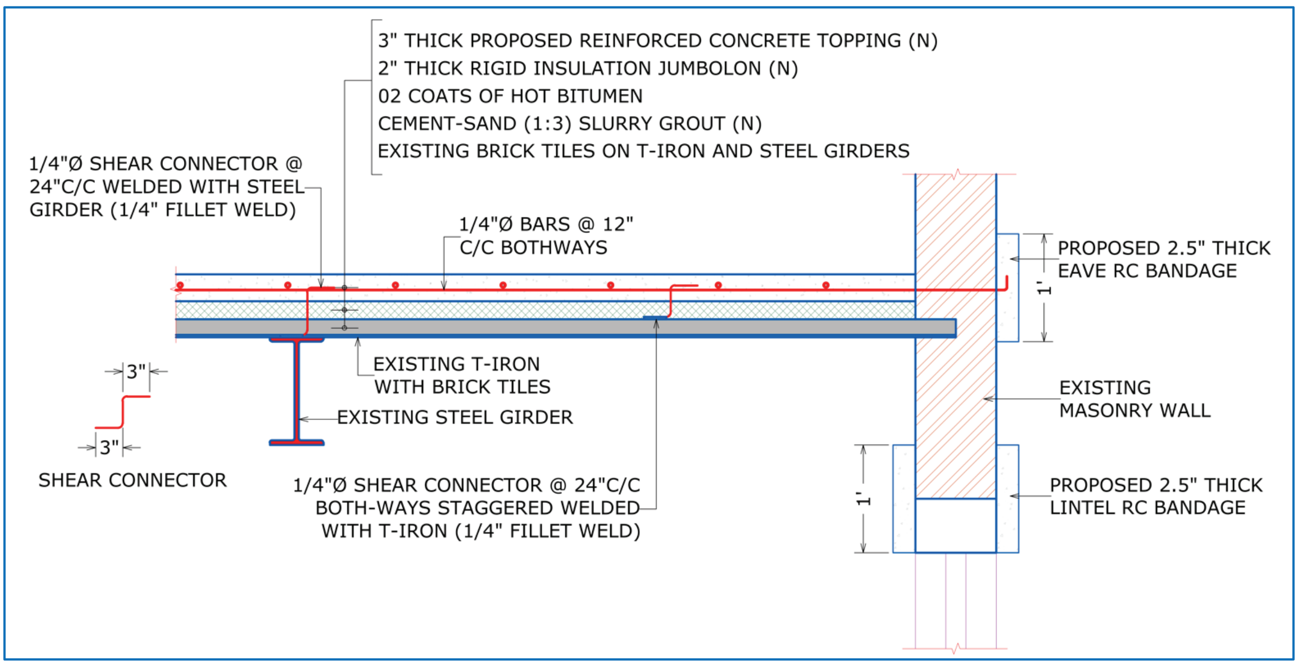


Fig-38: Strengthening of steel girder and inverted tee floor and roof (two-storey or one storey with tall parapet)

5.5.6. Retrofitting of iron sloped roof supported by timber or steel truss

In buildings where the roof consists of metal sheets supported by timber or steel trusses, the roof structure must be properly anchored to the walls to prevent separation during earthquakes. In such cases, a reinforced concrete (RC) bond beam, as shown in Fig-39) should be provided at the eaves level instead of seismic bandages. To install the bond beam, the roof can be temporarily disengaged from the wall and lifted using props. Once the beam formwork is prepared, U-shaped steel straps should be embedded in the concrete before casting to allow secure attachment of the roof trusses or rafters afterward. The reinforcement details of the eave-level bond beam, including reinforcement detailing at wall junctions, are shown in Fig 40. Steel bars from the vertical splints must also be properly anchored into the bond beam to ensure structural continuity and effective load transfer (see Fig-39).

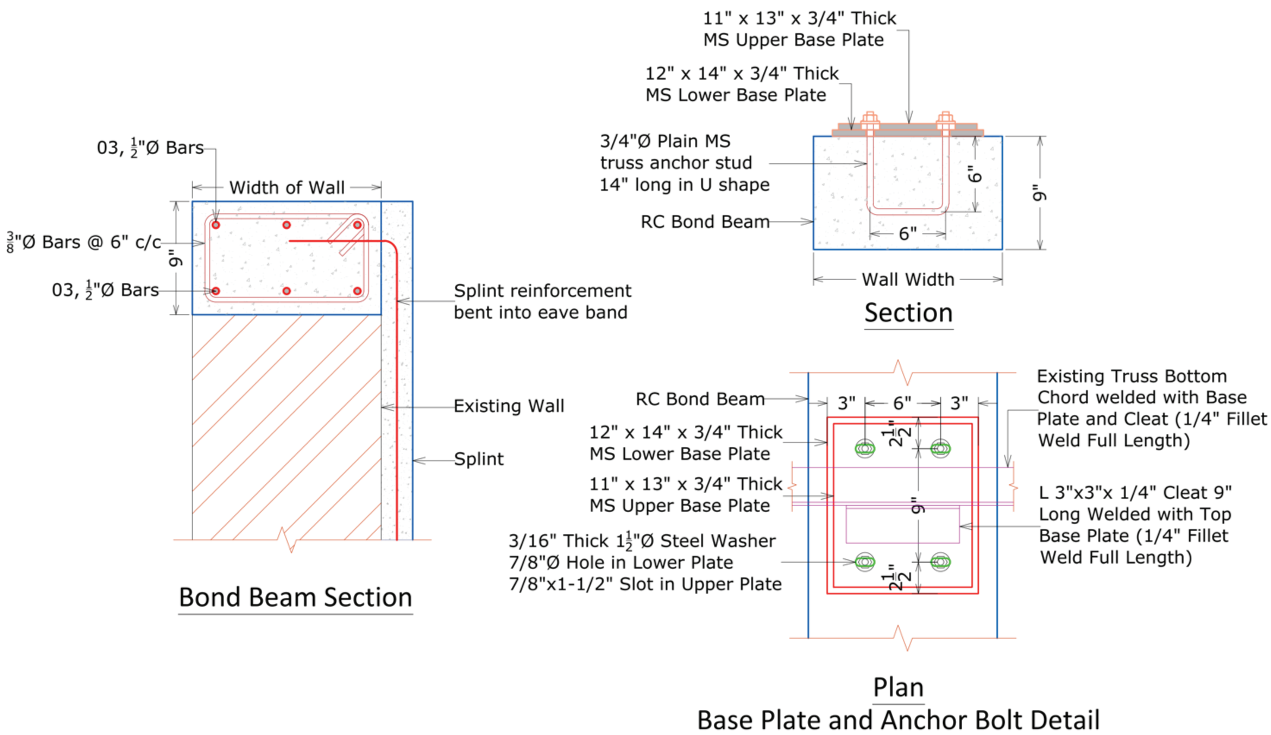


Fig-39: Detail of eave level bond beam and truss anchorage details for buildings with wooden or steel Trusses

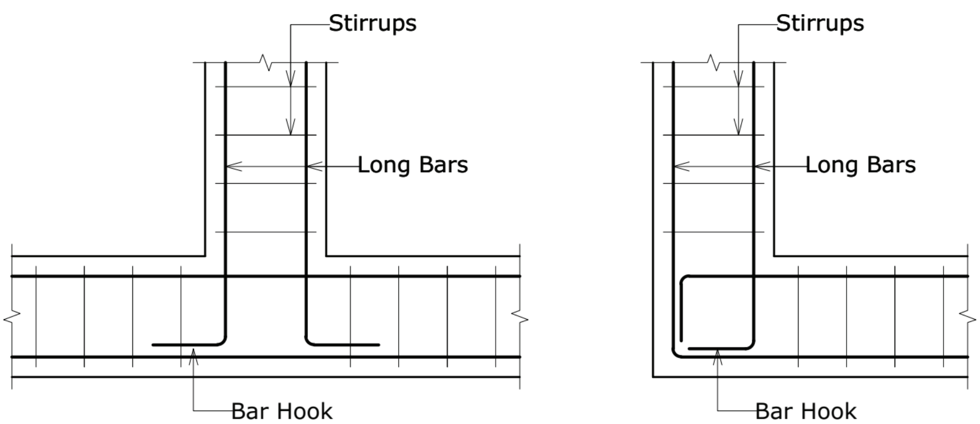


Fig-40: Reinforcement details at wall junctions

5.5.7. Confinement and strengthening of masonry columns (piers)

Masonry columns are highly susceptible to shattering, splitting, or collapse during earthquakes due to their low tensile and shear strength. Their performance can be significantly improved by providing jacketing, either ferrocement or RC, to confine the masonry core and enhance its axial load capacity, shear strength, and deformability. Depending on the number of storeys and the seismicity of the area, brick masonry columns may be strengthened with ferrocement overlays or RC jacketing, whereas stone masonry columns should always be jacketed with RC jacketing (see Fig-41a). The RC jackets are constructed of reinforcing bars embedded into micro concrete. The jacket should extend at least 18 in. (450 mm) below ground level and continue upward to connect with the roof slab or eave bandage or eaves bond beam, passing through intermediate floors via holes drilled through the slab.

The material specifications for column jacketing are given in Appendix 7. The detailed installation process for column jacket is described in the following section.

- Remove existing plaster and clean and roughen the masonry surface to ensure proper bond.
- Drill holes in the adjoining slab or beam for installing main reinforcement, as shown in Fig-42b. Hole diameter should be 1/8" (3.2 mm) greater than the diameter of the reinforcement.
- Fix the reinforcement with approved epoxy; the holes must be dry and dust-free during installation.
- For ferrocement jacket, follow the procedure for ferrocement overlay discussed earlier.
- For RC jacket, insert shear dowels or anchors into the column at a spacing of 18" (450 mm) to ensure composite action between masonry and RC jacket.
- Fabricate steel reinforcement.
- Prepare micro concrete using an approved bonding agent to ensure a good bond between masonry and concrete surfaces.
- Apply 2.5" (65 mm) thick micro concrete in two phases similar to bandages or use firm work. Shotcreting using a machine is encouraged. If manual shotcrete is necessary, apply shotcrete in two layers. Apply 1:1 cement-sand slurry before applying shotcrete.
- Maintain a minimum clear cover of ¾ in (20 mm) for reinforcement.
- The jacket should extend continuously over the full height of the column and, wherever possible, be integrated with adjacent RC bands/ bandages or lintel belts to ensure uniform confinement and continuity.

Shotcrete is generally preferred over micro-concreting due to its higher efficiency, reduced material wastage, and improved structural performance together with durability. However, its use may not always be feasible in remote or resource-limited areas where shotcrete equipment is unavailable. Where practical and equipment can be mobilised, shotcrete should be used in place of micro-concrete to achieve better quality and durability.

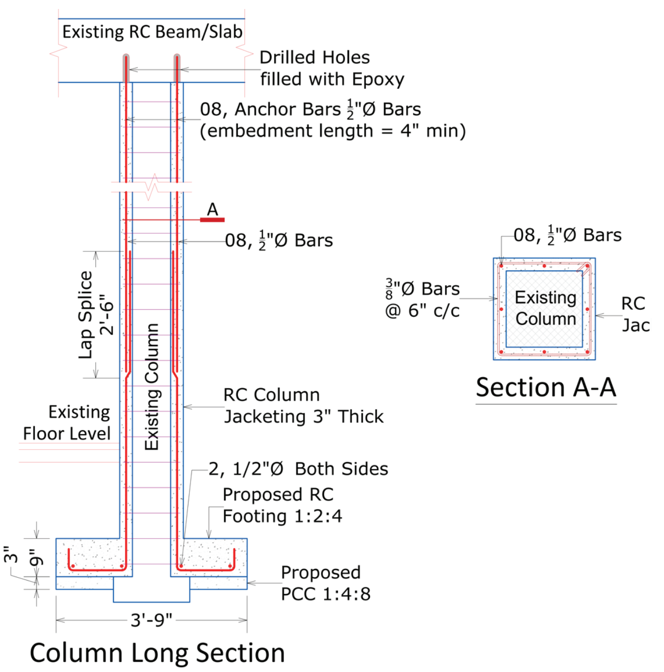


Fig-41: Confinement of masonry column

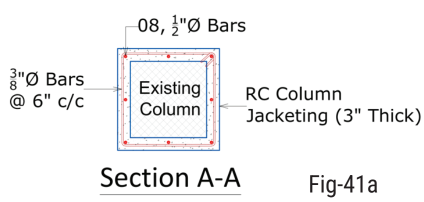


Fig-41a

5.5.8. Reinforced concrete column jacketing

In some cases, particularly where existing RC columns are severely deteriorated due to weathering affects are structurally deficient, repair, rehabilitation, and strengthening are required to restore their load-bearing capacity and seismic performance.

The material specifications for column jacketing are given in Appendix 7. The following procedures outline the recommended construction sequence and material specifications for RC column jacketing using shotcrete or cast-in-place concrete.

- Remove all plaster and deteriorated concrete, corroded reinforcing bars until sound material is exposed.
- Drill holes in the adjoining slab or beam for installing main reinforcement. Also drill holes in the existing column for installing shear connectors. Hole diameter should be 1/8 in (3.2 mm) greater than the diameter of the reinforcement.
- Fix the reinforcement and shear connectors using approved epoxy; the holes must be dry and dust-free during installation.
- Fabricate reinforcement and erect formwork.
- Apply an approved bonding agent or 1:1 cement-sand mixture to the old concrete surface to ensure proper adhesion between old and new concrete.
- Pour concrete in two stages of height not exceeding 4’ (1.2 m) after installing formwork. Concrete shall be compacted with vibrator. Alternatively, a 2.5” (65 mm) thick micro concrete can be applied.
- Maintain adequate moisture for at least 10 days to ensure proper curing and strength development.

Fig-42b:

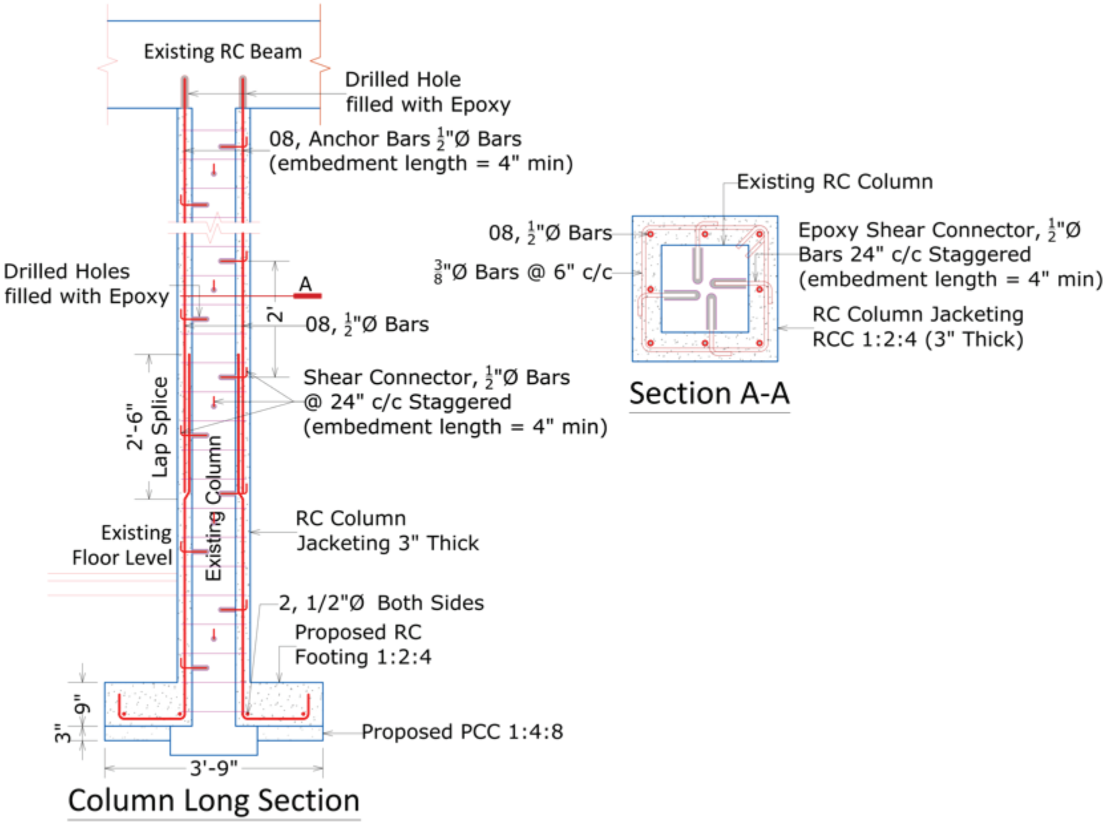


Fig-42: Concrete jacketing of RC column

5.5.9. Reinforced concrete column base connection improvement

It was a common practice in older construction to lap column reinforcement near the base with a splicing length of approximately 300 mm (1 ft), typically confined with only a single stirrup. This detailing creates a critical vulnerability, as during earthquake shaking the concrete at the column base may spall, rendering the lap splice ineffective and potentially leading to column failure. The consequences of such failure can be catastrophic, compromising the stability of the entire structure.

Therefore, intrusive investigation of lap splices is essential during assessment. If the lap length is found inadequate or insufficient confinement, the column base must be strengthened to restore structural integrity and ensure seismic safety (see Fig-42). If investigation is not feasible due to logistical constraints, the column base should still be strengthened as a precautionary measure, even if the RC Columns otherwise sound and undeteriorated.

The construction sequence and material specifications for this work shall follow those outlined for RC column jacketing as discussed above, but only the bottom part of the column can be strengthened.

If the lap length of the longitudinal reinforcement of column is at least 60 times the bar diameter and is accompanied by a minimum of three ties within the lap length, or if continuous rebars have been provided in the columns as longitudinal reinforcements, no strengthening of the reinforced concrete column base is required.

5.5.10. Parapets and gable wall stabilization

If a free-standing masonry parapet is more than 2’ (600 mm) high, the parapet must be properly stabilized to prevent toppling during earthquake shaking. A reinforced concrete band, 4” (100 mm) high and width equal to the wall thickness, should be provided at the top of the parapet. The beam band be reinforced with four Ø3/8” (9.5 mm) longitudinal bars with Ø1/4” (6 mm) ties spaced at 6” (150 mm) c/c (see Fig-43). At wall junctions, the detailing shown in Fig-38 must be followed.

This design is suitable for parapets up to 5’ (1.5 mm) high. For parapets exceeding this height, diagonal bracing or other form of structural strengthening should be provided to stabilize the parapets, and it is strongly recommended to seek professional engineering advice to ensure adequate seismic performance.

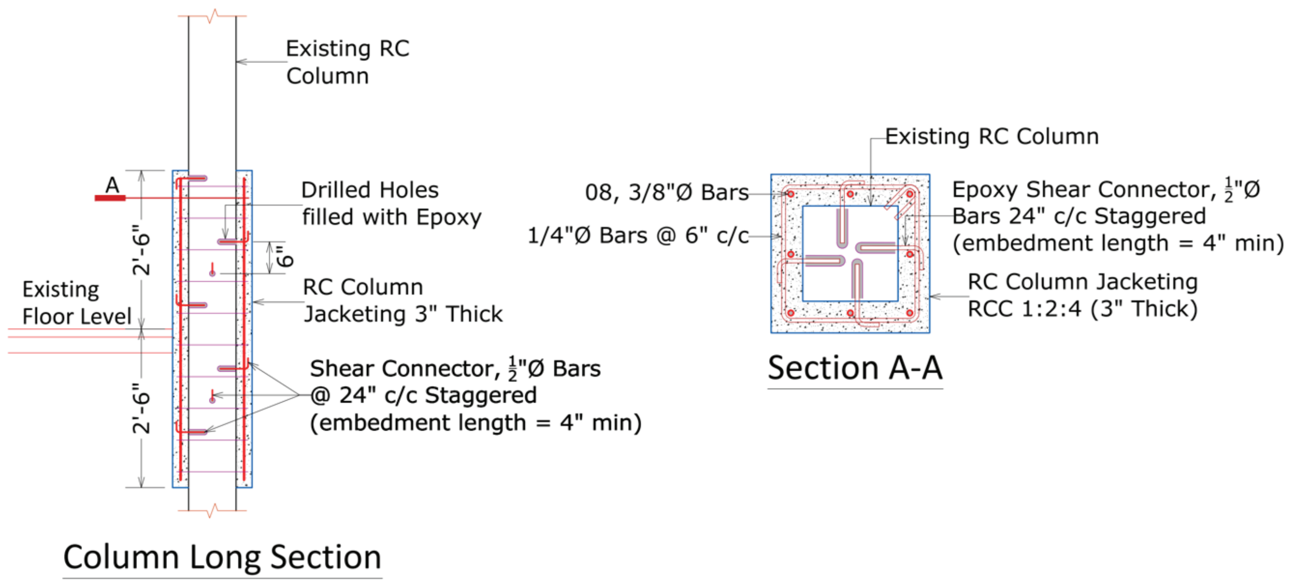


Fig-43: Strengthening of RC column base

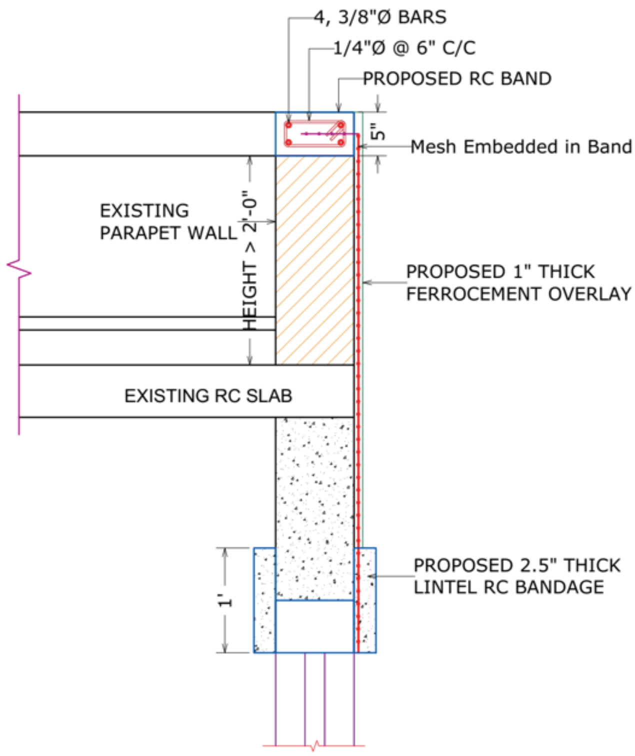


Fig-44: Parapet strengthening

Even if a stone masonry wall is less than permitted height, a thin bond beam should be provided at the top of the wall, unless its height is less than 1', to prevent disintegration caused by the absence of through-stones. The bond beam may be constructed using ferrocement plaster reinforced with welded mesh.

5.6 Retrofitting Solutions By Element & Additional Provisions

5.6.1. Stone masonry in cement or mud mortar

This section outlines additional retrofitting requirements for buildings constructed with stone masonry and mud mortar. While all general and special provisions described earlier apply equally to these building types, additional measures are recommended to address their specific weaknesses.

The primary retrofitting approach proposed for these school buildings is concrete based, incorporating RC belts, bond beams, and ferrocement overlays to enhance overall strength and integrity. Where concrete-based methods are not practical due to site constraints or logistical challenges, the steel plate and ferrocement overlay system may be used as an alternative solution, as discussed below.

Table-14 summarizes the recommended concrete-based retrofitting provisions for buildings constructed of stone masonry in cement-sand or mud mortar. Where walls are constructed of stone masonry in mud or other low-strength mortar, ferrocement strengthening is recommended on both faces of all walls (Fig-44).

Table-14: Additional provisions for stone masonry buildings

Masonry type	General provisions	Ferrocement overlay on all walls	Through stones/ bolts
CR or semi-CR stone masonry in cement–sand mortar (one or two-storeys)	✓		✓
Random Rubble masonry (RRM) in cement–sand mortar (one storey):	✓		✓
Round/river stones in cement–sand or mud mortar or RRM in mud mortar (one storey):	✓	✓	✓
RRM or round river stones in cement–sand or mud mortar (two-storeys)	Not covered		

Through stones

Through-stones (or bond stones) tie the inner and outer wythes of a wall together, preventing delamination, a major cause of stone masonry wall failure during earthquakes. Where these are missing or inadequate, new through-stones should be installed by carefully removing stones on opposite faces to create an aligned opening across the wall thickness. For ease of installation and to minimize disturbance to wall, alternatives such as steel through ties/bolts (see Fig-45) or cast-in-place RC elements may be used in lieu of through stones. Through stones extending over the full wall thickness must be used every 600 mm (2ft) in height and at a 1.2 m (4ft) maximum spacing along the length of the wall and these through stones should be staggered along the wall length. When inserting RC elements, work should proceed cautiously to prevent excessive removal of existing stones, which could weaken the wall.

Installation of Through-Stones (Method 1: Cross-Ties, and Through-Bolts)

The material specifications are given in Appendix 7. The following steps shall be followed during installation of through ties:

- Mark locations for 'through-stones' at bed or head joints of the stone's units.
- Carefully drill holes on the marked locations. If the drill bit hits stone on other side, relocation of the drill hole location may be required. Do not use hammer drill to avoid disturbance to masonry.
- Install through bolt or ties. The bolts and ties are recommended to be galvanized. Galvanization is must if the wall is constructed of mortar mud.
- Place steel washers and bolts and tighten the bolts. If steel ties have been used, weld the tie to the washer.

Installation of through stone (Method 2: RC element)

The material specifications are given in Appendix 7. The following steps shall be followed during installation of through cast-in-place RC elements:

- Mark locations for 'through-stones'.
- Select the stones to be removed. Rack out mortar from all around using extraction rod or crowbar. Loosen the stone gently and remove it carefully.
- Remove any material behind the stone and make 3" (75 m) hole until the stone on other face is reached. Remove the stone from other side carefully.

The hole should be dumbbell shaped, i.e. bigger on wall faces and narrower inside.

- Fill the bottom half of the hole with non-shrink micro concrete, place S-shaped steel bar and fill the hole completely with micro concrete.
- Finish the surface with cement plaster. Cure for 10 days.

Fig-45: Installation of cross tie-Method-1

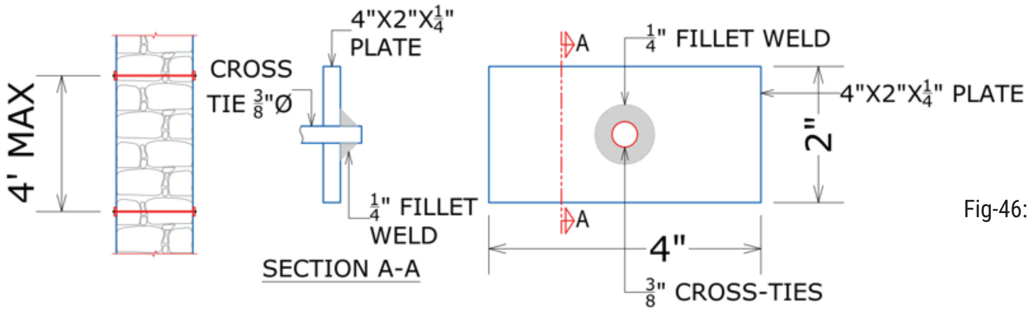


Fig-46: Installation of cross-ties (through bolt)

Fig-47: welding with irone flat with cross ties (method 2)

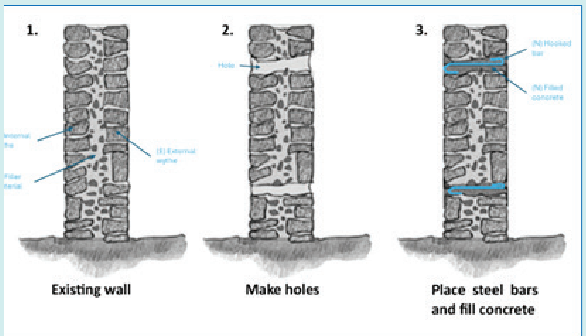


Fig-48: Installation of through RC element

5.6.2. Brick masonry in mud mortar

Where walls are constructed of brick masonry in mud or other low-strength mortar, ferrocement strengthening is recommended on both faces of all walls. Similarly, piers of penetrated walls should be wrapped with ferrocement. The rebars in the splint and bandages are supplemental to ferrocement mesh.

5.6.3. Steel splint and bandage method

As an alternative to the ferrocement or reinforced concrete (RC) splint and bandage method, the use of steel flats with a ferrocement overlay offers a simple and practical solution for strengthening stone masonry school buildings. This method is particularly suitable where conventional RC retrofitting is not feasible due to site conditions, limited skills, or logistical constraints.

In this technique, horizontal and vertical steel flats (typically 1½–2 inches wide and ¼ inch thick) are installed on both interior and exterior faces of the wall, forming a continuous grid that confines and ties the masonry wythes together (See Fig-47and 48). Through-bolts or ties, spaced at regular intervals and passing through the wall, connect both wythes and anchor the flats, ensuring that both wythes act together under seismic loading. The intersections of the flats are bolted and must ne welded at corners to create a continuous, tension-resisting system that enhances the in-plane and out-of-plane strength and deformability of walls.

After installation of the steel elements, a ferrocement overlay of about 1.5” (≈ 40 mm) thick reinforced with welded wire mesh is applied on both faces. This overlay improves ductility, prevents spalling, and increases overall stability.

The method is suitable for single- and two-storey stone masonry buildings built in mud or weak cement mortar. If it is a two-storey building, all vertical steel flats must be continuous from the ground to the top of the building. All general provisions for wall and building configuration, floor improvement, and stabilization of parapets and gables discussed earlier remain applicable.

The material specifications are given in Appendix 7. The following steps shall be followed during installation of steel splints and bandages:

- Disconnect main electrical connections before starting retrofitting work.

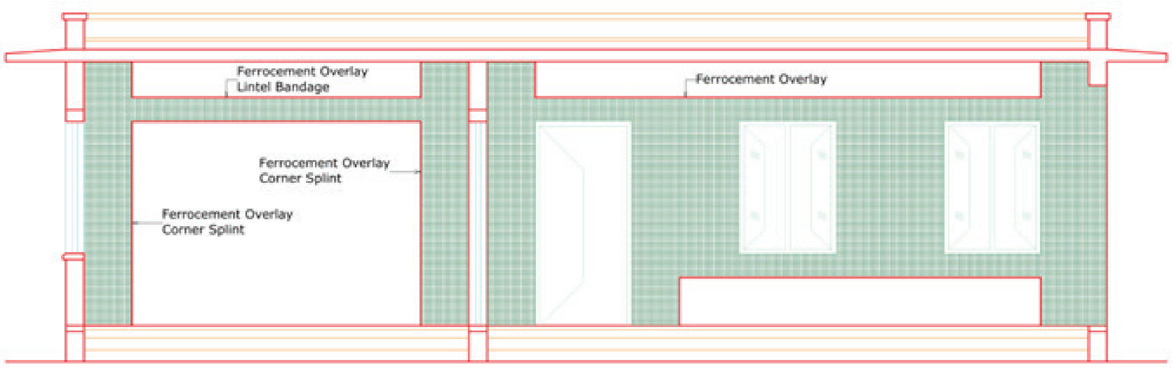
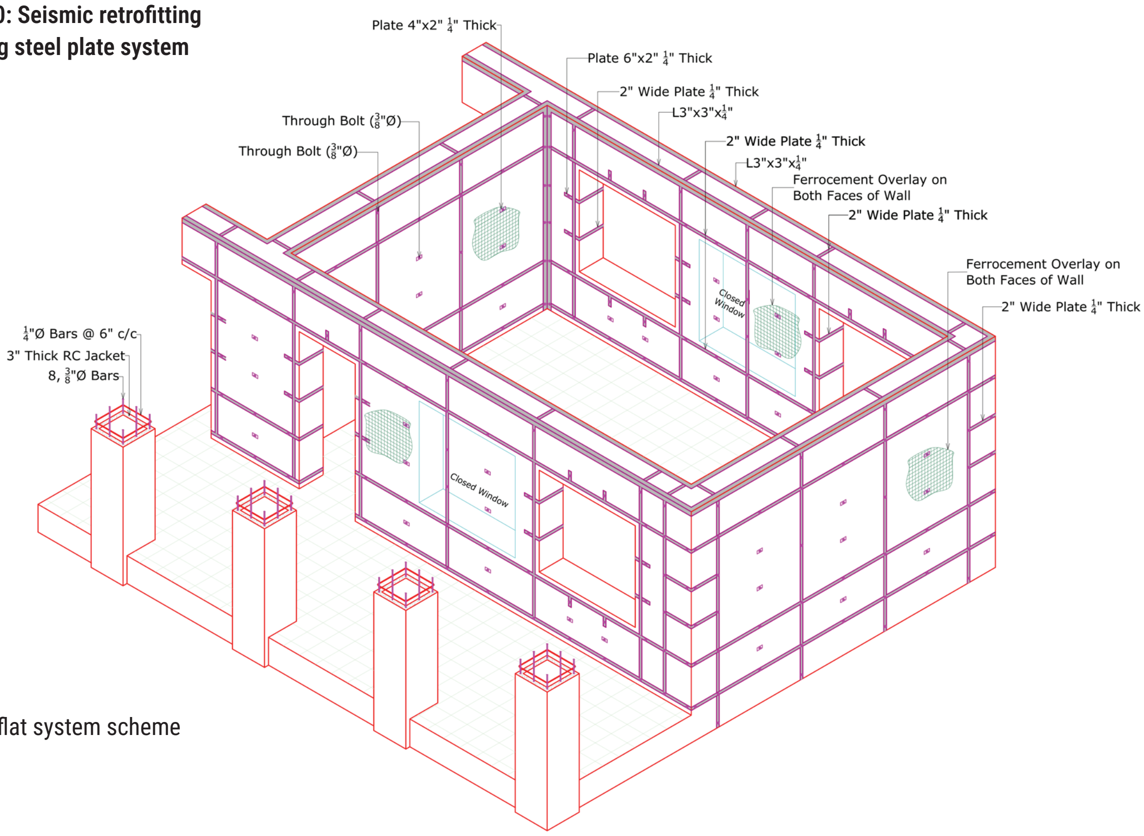


Fig-49: Wrapping of piers and construction of splint and bandage (moderate/high zone, one storey only), two-storey high seismic zone – splints on piers as well.

Fig-50: Seismic retrofitting using steel plate system



Steel flat system scheme

Fig-51: Steel flat retrofitting system under implementation

- Remove electrical fixtures where necessary; cover remaining fixtures, doors, windows, and ventilators with polythene sheets to protect from mortar splashes.
- Carefully remove existing plaster from wall surfaces.
- If any electrical conduit is damaged during chiseling, replace the entire affected length.
- Clean wall surfaces thoroughly. Remove loose mortar from joints and refill with fresh 1:4 cement-sand mortar. Refix any loose stones with the same mortar mix.
- Mark locations for through-bolts or ties on both wall faces. Place cross ties along mortar joints where possible.
- Drill holes at the marked points. Where joints are discontinuous, carefully remove obstructing stones and replace them after drilling.
- Drill corresponding holes in the steel flats as per layout.
- Install the steel flats on both sides of the wall and connect them using through-bolts or welded cross ties to form a continuous grid. Steel flats shall be welded at the corners with high-quality workmanship to ensure a tension-resistant system and secure anchorage of the cross walls. After steel installation, apply the ferrocement overlay on both faces following the procedure described earlier.
- As through-bolts already interconnect the two faces, additional through-stones are not required.

5.6.4. Masonry containment technology

A one-storey stone masonry building in mud mortar with a timber or steel roof can be effectively retrofitted using a containment mesh system (See Fig-52). The system uses 3 mm diameter galvanized steel wire arranged in a 200 mm × 200 mm grid, secured to the walls through crosslinks passing via drilled holes in the walls. These crosslinks form a continuous containment cage that prevents the masonry from bulging or delaminating during seismic shaking, thereby enhancing both deformability and strength. Reinforced concrete lintel bands and eaves-level bond beams complement the containment mesh. The use of traditional through stones is not required, as the crosslinks also prevent delamination.

This retrofitting method is particularly suited for remote and inaccessible regions where transporting conventional construction materials, equipment, and trained personnel is difficult. The wire is commonly available in hill markets of Pakistan, lightweight, and easy to transport by animals or people to construction sites. Its simplicity, minimal material requirements, and few construction steps allow for easy implementation and supervision, making it highly practical for resource-constrained, hard-to-reach areas.

A similar technology uses polypropylene (PP) bands, commonly referred to as PP band technology. In this technique, high-strength polypropylene strips or bands are wrapped around masonry walls or confined elements to provide additional confinement and improve the ductility of the structure. The bands act as a tensioning system, restraining lateral deformation and enhancing the wall's ability to resist seismic forces.

Key features of PP band technology include lightweight and flexible bands that are easy to handle and install without heavy equipment, corrosion resistance due to polypropylene's durability against rust and chemical degradation, cost-effectiveness compared to traditional retrofitting methods like reinforced concrete jackets or steel bands, and improved seismic performance by reducing the likelihood of wall collapse.

5.7 Retrofitting Implementation Sequence

The retrofitting of brick and stone masonry buildings must follow a systematic and carefully monitored sequence to ensure the effectiveness of strengthening interventions and long-term durability of the work. Each step should be performed under the supervision of an experienced engineer or trained supervisor, ensuring compliance with drawings, specifications, and quality standards.

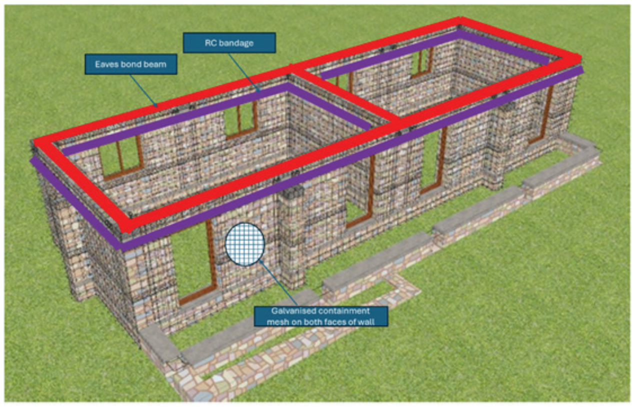


Fig-52: Containment mesh technology

The overall goal is to restore integrity to the existing structure, enhance its seismic resistance, and achieve a box action by connecting all structural elements together. The following sequence of implementation should be adopted:

Step 1: Repair of existing damage

- Isolate all electrical wiring and other services.
- Identify and repair all visible cracks, disintegrated joints, and degraded masonry units before commencing retrofitting.
- Cracks wider than 3 mm should be cleaned and pressure-grouted using cement-sand or epoxy grout, depending on the width and severity. Injection grout shall be prepared by weight as 10 parts of Portland cement, one part of lime and ULTRA expansion grout @ 250 g per 50 kg bag of cement with water cement ratio of 0.9. Any equivalent ready to mix grout may be used. Grout procedure is discussed in Section.
- Replace damaged or weathered bricks or stones with new units of matching size and quality.
- Repoint deteriorated mortar joints with 1:4

cement-sand mortar or compatible lime-based mortar for mud masonry.

- Remove any loose or unstable sections that may compromise the integrity of the retrofitting.
- Remove, remediate or replace any degraded building element such as corroded steel beams or T-iron, or cancerous concrete.
- Avoid removal of unnecessary plaster.
- Avoid use of power tools for stripping of plaster in mud mortar masonry building and take extreme caution to avoid any damage.

Step 2: Removal of existing plaster

Chisel and remove all existing plaster on both internal and external wall face where strengthening elements are proposed. Hand grinders may be used for efficient removal of plaster.

- Clean the exposed masonry surface thoroughly to remove dust, loose mortar, and debris.
- Rake out joints to a minimum depth of 15–20 mm to ensure better bonding with the new mortar.
- Wet the surface lightly prior to applying any cement plaster or micro concrete to avoid premature absorption of water from fresh mortar.

Step 3: Fixing of welded mesh for ferrocement

- Attach hot-dipped galvanized welded wire mesh on both internal and external wall faces using mechanical anchors or screws as per the design drawings.
- Ensure continuous mesh coverage with proper overlap at edges and junctions. The overlap should be minimum of 1’ (300 mm).
- Maintain a uniform gap between the wall and mesh (about 10–15 mm) to allow complete encasement by plaster or micro-concrete.
- Use washers and plastic plugs with screws to prevent mesh slippage.

Step 4: Installation of reinforcement at for bandages and splints (if required)

- Fix vertical reinforcement (rebars or mesh strips) at wall corners and junctions to improve connection between adjoining walls.
- Provide vertical mesh or bar reinforcement at door and window jambs to resist stress concentrations around openings.
- Place horizontal mesh reinforcement at the lintel level for bandage as shown in the drawings to tie the wall panels together.
- All overlaps and terminations should be firmly tied with binding wire to ensure continuity.

Step 5: Application of plaster or micro-concrete overlay

- Apply a two-layer ferrocement plaster or micro-concrete coatings on both wall faces.
- The first layer 3/8” to 1/2” (10 – 12 mm) thick for ferrocement plaster should embed the wire mesh and ensure full contact with the masonry substrate. The second layer 3/8” to 1/2” (10 – 12 mm) thick ferro cement plaster should provide a smooth finish and complete coverage of the mesh.
- The first layer of micro concrete should embed the welded wire mesh or rebars and ensure full contact with the masonry substrate. The second layer should provide a smooth finish and complete coverage of the mesh or rebars.
- Use 1:3 cement-sand mortar or 1:1.5:3 micro-concrete (cement:sand:aggregate) as specified for ferrocement plaster. Alternatively, the second plaster layer may be cement–sand plaster, allowing the surface to be finished without the need for an additional cement–sand finishing coat.
- Ensure continuous curing for at least 10 days by sprinkling or covering with wet hessian cloth.

Step 6: Finishing Works

- After curing, carry out final surface finishing, including plaster trimming, painting, or protective coating.
- Reinstall fixtures, window frames, and fittings removed earlier.
- Clean the site thoroughly and dispose of waste material responsibly.

Fig 53: Retrofitting Implementation Sequence

Fig-53a:Striping wall plaster

Fig-53b.Removing loose materials

Fig-53c: Installing bandage bars

Fig-53d: Constructing splint :

Fig-53e: Micro concreting bandage

Fig-53f: Iron flates and wiremesh on stone masonry

For RC retrofitting works, specified concrete cover shall be maintained for rebars and steel mesh to ensure proper bond and protection against corrosion and fire. Anchorage and lap lengths shall be as specified, with laps staggered to avoid congestion. Reinforcement and RC elements shall be placed within permitted construction tolerances for spacing, alignment, and cover to ensure effective performance of the retrofitting system. Similarly, the RC elements should meet the tolerance requirements. Refer to Appendices 7, 8 and 10 for details.

5.8 Quality Control And Safety Notes

Quality Control and Testing Requirements

General

- All retrofitting work shall be physically inspected by the supervisory staff to verify their dimensions and locations and to ensure compliance with the approved drawings.
- Record progress and photographic evidence for each stage for documentation and quality assurance.
- These quality control and testing requirements shall apply to all structural retrofitting and repair works, including jacketing, overlays, crack repair, anchorage installation, and other retrofitting systems.
- All materials, workmanship, and testing shall comply with the approved drawings, specifications, and manufacturer's recommendations.

- In case of logistical constraints, simple and practical tests may be developed and applied for quality assurance of other retrofitting components, as appropriate for field conditions.
- The Contractor shall submit a Project-Specific QA/QC Plan, including method statements, temporary work, inspection checklists, and testing frequencies, for approval prior to commencement of works.
- Any non-compliance shall be rectified during execution and prior to handover and duly documented as part of project completion.

Quality Control Tests

Concrete Tests

Slump testing in accordance with ASTM C143 shall be performed on fresh concrete used for jacketing, overlays, infill, or replacement works for each batch, and the measured slump shall be verified to comply with the specified slump requirements.

Cement-Sand Mortar

The cement-sand ratio for the mortar shall strictly comply with the drawings and specifications and in accordance with ASTM C109.

Epoxy Grout for Anchors

All anchors shall be installed using epoxy that is approved by the Engineer In-Charge. The bond strength of chemical anchors shall be assessed using pull-out tests in accordance with ASTM E488 / E488M on a minimum of three anchors or 2% of the total anchors, whichever is greater. The measured bond strength shall meet or exceed the values specified in the drawings and project specifications.

Where standard pull-out testing equipment is not available due to site or logistical constraints, a simple field test may be carried out using crowbars or similar tools. The anchor shall be manually pulled with adequate force to check for any movement, loosening, or failure. Anchors that show displacement, rotation, or damage shall be rejected and replaced.

Reinforcement Steel

All reinforcement steel, including rebars used as anchors, shall be tested in the laboratory.

At least three specimens from each rebar size, selected from the steel available at site, shall be tested for yield strength, ultimate tensile strength, percentage elongation, and bend properties in accordance with the requirements of ASTM A615 and ASTM A370.

Ferrocement Mesh

The spacing and diameter of wires in the mesh shall conform to the drawings and specifications.

The mesh shall be galvanized in accordance with the details provided in the drawings and specifications.

Prior to installation on the walls, at least three wire samples extracted from the mesh shall be tested in the laboratory for tensile strength.

Through Ties/Through RC elements

Through ties or through reinforced concrete (RC) elements installed as part of stone masonry retrofitting shall be randomly inspected to verify that they extend fully through the entire thickness of the wall.

A minimum of 10% of the total number of installed through ties or through RC elements shall be extracted from the walls and examined to confirm proper installation and embedment.

For quality control, appropriate provisions shall be included in the specifications. For example, Specifications should specify that at least 1% of the total number of anchors installed at site would be tested by applying a pull force. This helps confirm that the anchors are adequately fixed and capable of resisting tension.

Where standard pull-out testing equipment is not available due to site or logistical constraints, a simple field test may be carried out using crowbars or similar tools. The anchor shall be manually pulled with adequate force to check for any movement, loosening, or failure. Anchors that show displacement, rotation, or damage shall be rejected and replaced.

Similar simple and practical tests may be developed and applied for quality assurance of other retrofitting components, as appropriate for field conditions.

Inspection, Documentation, and Acceptance

- All test results shall be submitted in approved formats, including test locations and reference drawings.
- Failed test results shall be investigated, and corrective measures shall be implemented and retested.
- As-built records, test reports, and compliance certificates shall form part of the final completion of the dossier.
- The final acceptance of retrofitting and seismic strengthening works shall be subject to satisfactory compliance with all quality control and testing requirements.

Safety protocols

Pre-construction safety planning

- Safety planning: Conduct a detailed assessment to identify unstable components (cracked walls, loose parapets, weak roofs, damaged columns). Mark hazardous zones prior to commencement of work.
- Prepare activity-specific method statements (e.g., jacketing, drilling, anchor fixing, through ties).
- If the building is occupied (e.g., schools), segregate construction zones with physical barriers.
- Schedule high-risk activities during non-occupancy hours where possible.
- Disconnect or secure electrical, gas, and water lines in working areas before drilling or demolition.

Temporary works & structural stability

- Provide temporary supports for unstable walls and roof slabs. Temporary works shall be designed or verified by a competent engineer.
- Demolition activities shall be performed carefully by removing first loose masonry. Avoid excessive vibration during chipping or breaking operations
- Do not stockpile materials on weakened slabs or roofs. Limit live loads during retrofitting execution.
- Scaffolding erected for working at height shall be properly braced and anchored and shall have guardrail.
- Use full body harnesses when working at heights greater than 2 m. Provide safe access ladders.
- While working on roof, install edge protection where parapets are inadequate. Avoid work during high winds or rain.

Drilling, anchoring & chemical handling

- During drilling operation, use protective eyewear and face shields. Ensure electrical tools are properly grounded.
- While handling chemical anchors and epoxy, provide gloves and respirators. Ensure adequate ventilation. Follow manufacturer's MSDS guidelines.
- While drilling, use wet drilling or dust extraction systems. Workers shall wear dust masks.

Concrete work

- Formwork shall be properly braced to prevent collapse. Check tightness before pouring concrete.
- Cap exposed rebars to prevent injury. Store steel safely to avoid tripping hazards.
- Ensure no personnel stand under active pouring zones. Maintain safe access routes.

Ferrocement & wire mesh installation

- Workers shall wear cut-resistant gloves. Trim and bend sharp mesh ends.

- Ensure proper support before plastering or micro-concrete application. Prevent falling debris.

Electrical safety

- Keep electrical cables away from water and walkways.
- Inspect power tools daily. Avoid damaged cords and plugs.

Material handling and storage

- Use mechanical lifting for heavy materials. Follow safe manual lifting practices.
- Store cement and chemicals in dry, ventilated areas. Stack materials safely to prevent collapse.

Emergency preparedness

- Provide a first aid kit on site. At least one trained first aider shall be present at the construction site.
- Display emergency contact numbers prominently.
- Provide fire extinguishers near chemical storage and electrical areas. No smoking near flammable materials.

Worker training & PPE

- All mandatory personal protective equipment (PPE) including safety helmets, safety shoes, high-visibility vests, gloves and safety goggles shall be available and used during work.
- Skilled personnel shall carry out specialized tasks such as anchor fixing, welding, and structural modifications.

Site housekeeping

- Keep the walkways clear. Remove debris regularly. Avoid accumulation of rubble near structural edges

5.9 Incremental Retrofitting

Incremental retrofitting is a practical strategy for improving the seismic safety of school buildings when resources, access, time, or funding are limited. Instead of attempting full strengthening in a single phase, the building is upgraded in a sequence that first addresses the most life-threatening vulnerabilities and then progressively improves overall structural performance. The first priority is to secure elements that pose immediate falling hazards during strong shaking, such as parapets, gable walls and other unrestrained components. These elements have historically caused many injuries in earthquakes and can be mitigated quickly and at relatively low cost. Once falling hazards are addressed, the next step is to improve wall-roof and wall-floor connections so that the building begins to act as a unified structural unit rather than as isolated walls. Achieving this “box effect” significantly reduces the likelihood of out-of-plane wall failures, the most common cause of collapse in URM buildings.

After securing high-vulnerability components and improving basic connections, subsequent phases focus on enhancing the stability of face-loaded walls and building’s lateral-force-resisting system. This includes strengthening face-loaded walls, improving diaphragm action where required, and upgrading in-plane wall capacity using techniques such as bandages, vertical reinforcement at wall junctions and openings, or RC jacketing of critical columns as discussed earlier. In the final stages, additional structural components may be added to support global stability, for example, braces, boundary elements, or localized shear reinforcement. The incremental approach allows the most critical life-safety deficiencies to be addressed immediately while enabling gradual, affordable improvement toward the Life Safety performance objective. It also recognizes that retrofitting must be proportional to local seismic hazard, building condition, and available resources, ensuring that each stage provides meaningful risk reduction even if full upgrading is completed over time.

5.10 Common Misconceptions And Facts

During field visits, several misconceptions were observed regarding the scope and execution of retrofitting works as below:

- Splint bars terminating at roof slab level. if parapets exist, these bars should be extended to the top of parapet and anchored to the top beam or these bars must be anchored to roof slab.

- Bandage just below RC floor slab. Roof level bandage is not required if the floor and roof are constructed of RC slab.
- Un-retrofitted infill walls between columns. These walls still pose a life-safety threat either these are part of original design or not as these could topplin.

Table-15: Misconception and facts

Misconception	Fact
Building elements that were not part of the original construction do not require retrofitting.	Retrofitting must adopt a holistic approach. Any element, structural or non-structural, original or later addition that could pose a life-safety risk must be assessed and appropriately strengthened.
Bandages can be provided at any level above door and window openings.	Bandages should be installed as close as possible to the lintel level. An eaves-level bandage is not required if the roof or floor is constructed of a cast-in-place reinforced concrete (RC) slab.
It is acceptable to strengthen only part of a building or start with the upper portion.	Haphazard or top-only interventions can create stiffness imbalance and may cause premature failure. If resources are limited, incremental retrofitting may be adopted. However, retrofitting must follow the correct sequence. Strengthening must start with the most vulnerable, life-safety-critical elements and then progress to less vulnerable components.

Fig-54: A few examples of misconceptions

5.11 Opportunities for Integrated Improvements

The retrofitting of schools offers an opportunity to address infrastructure, safety, inclusion, and maintenance needs alongside structural strengthening. Beyond seismic upgrades, interventions can improve accessibility for persons with disabilities, integrate solar energy, enhance water resilience through Rainwater Harvesting, and strengthen safety through lightning protection and flood mitigation measures.

Upgrading WASH facilities is essential, particularly to ensure gender-responsive and disability-friendly toilets, while addressing menstrual hygiene needs to improve girls' attendance. Environmental sustainability can be promoted through tree plantation, energy-efficient appliances, and improved learning environments with modern teaching tools.

Many schools also suffer from deteriorated finishes due to aging and heavy use. upgrading floors and plaster, including replacing PCC floors with more durable materials and adding skirting, can improve durability, hygiene, and functionality.

The process further enables integration of disaster risk reduction, climate awareness, hygiene promotion, and first aid training, along with provision of emergency kits to strengthen preparedness and community resilience.

Part-iii

Chapter 6

Logistical Challenges and Management

This chapter outlines key logistical challenges and provides practical planning and implementation strategies drawn from field experience and stakeholder consultations. The guidance is intended for project planners, engineers, contractors, and other stakeholders to support timely, safe, and cost-effective delivery of retrofitting works.

6.1 Introduction

Even when seismic assessments and retrofitting designs are technically sound, projects can face severe delays or even failure without effective logistical planning and coordination. In Pakistan's diverse and often remote terrain, ensuring efficient transport, supply chain management, workforce mobilization, and safety oversight is critical to project success.

6.2 Challenges

Implementing seismic retrofitting in the rural and mountainous areas of Khyber Pakhtunkhwa (KP) presents major logistical challenges. Many schools are located in hard-to-reach terrain with limited road access, making the transport of materials, equipment, and skilled labour difficult and time-consuming. Seasonal conditions, such as snow, heavy rain, landslides, and road closures, further disrupt supply chains and construction schedules. In urban areas, due to narrow streets and limited access, transportation of materials often cannot be done by full-sized trucks and instead requires smaller vehicles such as jeeps or rickshaws or donkey carts. In rural areas, alternative access routes are frequently disrupted during the cropping season, further affecting the delivery of materials. Limited local availability of quality materials (cement, steel, wire mesh), unreliable electricity, and scarce water supplies add further complexity. In girls' schools, privacy demands careful planning of work schedules and site management. Inadequate on-site storage, security, and limited technical supervision can also compromise quality. A few of these challenges are discussed in the following sections.

Contractual and Cost-Related Challenges: Retrofitting projects frequently encounter contractual and financial constraints that affect timely implementation. Delays in payment processing can disrupt contractor cash flow and slow progress on site. Transportation costs are often high, particularly in remote areas where materials must be carried manually or by donkeys. Multiple handling of materials during loading and unloading further increases costs. Delays in site handover and completion certification may also affect project timelines. In some cases, school staff or local communities request expansion of scope during implementation, leading to cost variations and contractual complications.

Construction Material and Equipment Haulage and Storage: Transportation and logistics pose significant challenges, especially in remote or mountainous regions. Materials often need to be hauled over long distances from urban centers or warehouses. Many project sites are not connected by motorable roads and require human or animal transport. Access routes are frequently limited to a single narrow or unpaved road, creating congestion and bottlenecks, particularly where mixed traffic is present. Seasonal disruptions due to rain, snow, floods, landslides, or extreme weather conditions further complicate material supply. In addition, government or local regulations may restrict commercial vehicle movement during daytime. Limited on-site storage facilities also constrain material management and increase the risk of damage or delays.

Societal Challenges: Societal factors can significantly influence project implementation. Political or community interference may occur during construction, affecting decision-making and progress. Security concerns in remote or conflict-prone areas may require additional precautions and coordination. In girls' schools, privacy considerations necessitate tailored site arrangements and careful scheduling of works. Cultural differences and language barriers between project teams and local communities may also affect communication and community engagement, requiring proactive and sensitive coordination.

Engineering and Design Challenges: Retrofitting projects often face challenges due to incomplete or non-standard drawings, making it difficult to assess existing structural systems accurately. Foundation conditions may be complex or unknown, sometimes requiring additional investigation and design adjustments during construction. Limited contingency allowances for unforeseen works further complicate implementation, especially when hidden deficiencies are discovered. Additionally, excessive and uncoordinated monitoring visits can disrupt progress and create dissatisfaction among school administrations.

Construction and Material Challenges: Limited availability of water and electricity affects construction operations, particularly in remote areas. Centralized procurement of prefabricated doors and windows is recommended to ensure quality and timely delivery. Floor finishes such as PCC and plaster are often used before adequate curing, leading to reduced strength and surface damage. More durable finishes, such as ceramic tiles or marble, are preferable where early use is expected.

Environmental Challenges: Construction works may generate community concerns related to noise, dust, and heavy traffic near school sites. Increased vehicular movement also raises safety risks for students and surrounding communities, requiring appropriate mitigation measures.

Utilities and Infrastructure Challenges: Frequent power outages, weak mobile network coverage, and limited water availability disrupt construction activities and coordination, particularly in remote locations.

Human Resource Challenges: Remote project areas often face shortages of trained engineers, supervisors, and skilled tradespeople. Limited practical training, high staff turnover, and reluctance of skilled labour to relocate can affect quality and delay implementation.

Limited Resources for Non-Classroom Infrastructure: The school administration also sought to use this opportunity to repair or retrofit non-classroom spaces, such as the headmaster's office, staff rooms, and to extend support to DEO offices; however, due to funding constraints, classrooms were typically prioritized. Competing Community Demands: A challenge arose when surrounding communities repeatedly requested retrofitting for schools that had not been identified through the assessment process

6.3 Planning And Sequencing

Proper sequencing and planning of construction activities are essential for cost control, efficiency, and quality assurance. Planning must take into account site accessibility, community engagement, and environmental conditions to minimize disruption to school operations.

- Clustering of Schools: Group schools into geographic clusters to reduce travel distances, optimize manpower and equipment use, and facilitate supervision
- Route and Logistics Surveys: Conduct pre-mobilization route surveys to identify accessibility constraints, labour availability, and potential seasonal blockages
- Scheduling: Avoid monsoon seasons and school examination periods. For girls' schools, schedule works during holidays or after hours to respect privacy and social norms
- Contingency Planning: Incorporate buffer time to accommodate weather disruptions, material shortages, or transport delays
- Community coordination: Engage local communities and authorities early to ensure safe access, cooperation, smooth project execution and efficient management of local politics

6.4 Procurement And Supply Chain Management

Efficient procurement and supply management are essential to avoid delays and cost overruns. Table-16 summarizes common challenges, associated risks, and recommended mitigation measures, and Fig-55 presents supply chain planning for construction materials.

6.5 Cluster Approach For Implementation

The schools are grouped into clusters based on geographic proximity and accessibility. Construction activities, including material supply, labor deployment, and work sequencing, are implemented cluster by cluster rather than simultaneously across all sites. This approach optimizes the use of skilled labor and ensures efficient material preparation at the central depot. Site teams consolidate the requirements for each cluster and communicate them to the project manager, who coordinates fabrication and supply through the central workshop.

Table-16: Procurement and supply chain risks and mitigation

Challenge	Risk	Mitigation Measure
High transport costs	Budget overruns	Bulk haulage, local sourcing, shared transport
Remote access	Delays	Donkey or shoulder carriage for last-mile delivery
Material shortages	Work stoppages	Maintain buffer stock, engage multiple suppliers
Poor storage	Damage or loss of material, machines and tools	Weatherproof sheds, secure fencing, elevated storage
Fuel shortage	Power/fuel interruptions	Maintain reserve supply, use hybrid power (solar + generator)
Long lead times	Schedule delays	Advance procurement planning, framework agreements with suppliers

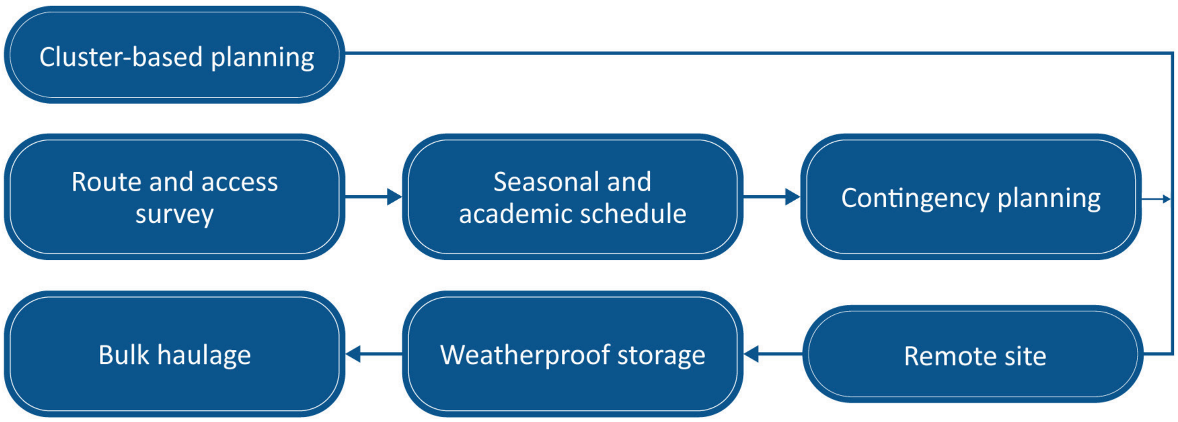


Fig-55: Supply chain planning for construction materials

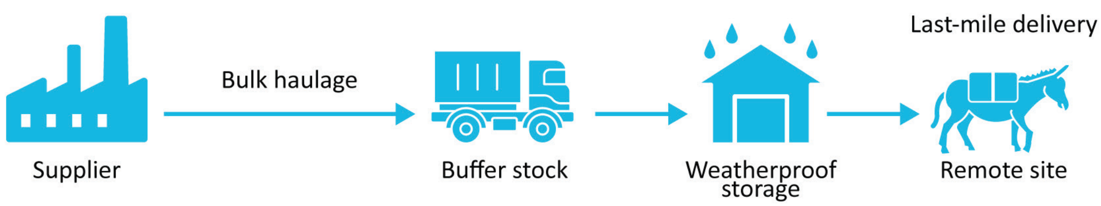


Fig-56: Example of cluster-based school grouping concept.

Materials are procured in bulk and stored at a centrally located warehouse that can efficiently serve all project clusters. Within this facility, a fabrication team prepares doors, windows, steel grills, steel bars, stirrups etc and other components, including painting and finishing works. These prefabricated items are then transported to the schools for installation. Centralized fabrication minimizes material wastage and improves quality control compared to on-site production.

The school cluster approach allows optimization of logistics, resources, and supervision. Clustering schools within a defined geographic radius (e.g., 10–20 km) enables shared use of equipment, skilled labour, and transport (see Fig-53). This approach improves efficiency and reduces costs by minimizing repeated mobilization and transport. Key benefits include:

- Reduced transport time and fuel consumption
- Easier coordination and monitoring by supervision engineers
- Shared storage and batching areas
- Enhanced efficiency through sequential mobilization within a cluster
- Improved site security and resource utilization

6.6 Coordination And Communication

Effective coordination among stakeholders ensures smooth implementation and reduces duplication of effort. Regular communication improves transparency, accountability, and timely decision-making. Suggested actions include:

- Regular meetings between contractors, education departments, implementing agencies, and supervision consultants (see Fig-54)
- An area-level logistics focal person to coordinate material supply, transport permissions, and communication between clusters
- Use of digital monitoring tools (GPS-tagged photos, WhatsApp updates, mobile apps) for remote supervision
- Clear documentation and reporting protocols to ensure transparency and accountability

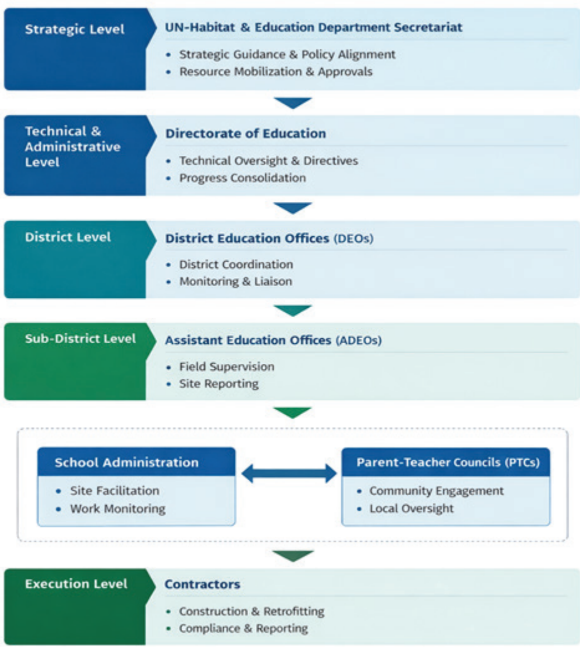


Fig-57: Coordination and communication flow diagram

It is important that, during the project kick-off meeting, the frequency of visits and a tentative visit plan are discussed and agreed upon with the school administration. This should clearly outline who will visit, the purpose of the visits, how the visits will be conducted, and the expected timing (time of day) of most visits. This will ensure that the school administration is informed in advance and that any privacy and security concerns are addressed, including arrangements for a watchman if visits are scheduled after school hours.

6.7 Site Environmental Health And Safety (EHS)

Ensuring the safety of workers, students, and staff is paramount during retrofitting works. Health and safety measures must be integrated into every stage of implementation, from planning to completion.

- Mandatory use of personal protective equipment (PPE) for all site workers
- Safety fencing and signage to isolate construction areas from operational school zones
- Toolbox talks and safety induction for all personnel before work begins
- Provision of first-aid kits and emergency evacuation plans
- Regular site inspections to ensure compliance with safety protocols
- Including EHS responsibilities in contractor contracts and progress reporting

6.8 Summary

Proper logistical planning transforms potential obstacles into manageable tasks. By clustering schools, planning transport routes, using local resources, and coordinating stakeholders, retrofitting programmes can achieve efficiency and quality within allocated budgets. Visual planning tools, simple reporting formats, and continuous communication ensure that logistical hurdles do not compromise the safety and durability of retrofitted schools.

This page is intentionally left blank

Chapter 7

Workforce and Training

Effective assessment and retrofitting of existing school buildings require a skilled and safety-conscious workforce. Engineers, technicians, and tradespeople must undergo both technical and safety training before the programme begins. The training must emphasize practical learning and demonstration rather than theoretical lectures in full classroom type training. Safety training, including the correct use of personal protective equipment (PPE), should be mandatory for all participants

The DRSI project adopted an on-the-job training approach to build the capacity of local masons in seismic retrofitting. Masons within each cluster first worked collectively on one pilot school under close supervision of UN-Habitat engineers to ensure quality and compliance with technical standards. After successfully completing the pilot school and demonstrating competency, the trained masons were deployed to other schools within the cluster.

7.1 Training Of Engineers, Technicians And Contractors

Training for engineers and technicians should focus on developing practical field competencies. Each session must combine short theoretical briefings with hands-on exercises in real or simulated field environments. Trainees should practice assessment techniques, such as identifying seismic deficiencies, filling out the forms and preparing retrofit plans using pre-engineered solutions.

Training to engineers, technicians and construction contractors should also include live demonstrations of retrofitting methods, including mesh fixing, band casting, anchorage detailing, and quality control inspections. Emphasis should be placed on the coordination of site activities, sequencing of retrofit works, logistical management and supervision of construction to ensure quality and safety compliance.

7.2 Training Of Local Craftsmen

Craftsmen play a critical role in the success of retrofit implementation. Their training must therefore be entirely practical and skill-based. Craftsmen should receive hands-on instruction under direct supervision of trainers, learning through active participation in constructing and retrofitting mock-ups of building elment. This includes surface preparation, wire mesh fixing, installation of crossties, band casting, anchoring of roofs, and plastering with proper curing techniques.

The objective is to ensure that each Craftsmen is capable of executing retrofit works with accuracy, consistency, and confidence in maintaining quality of work and communication. Demonstrations should be delivered in local language and focus on practical problem-solving, proper tool handling, and adherence to safety standards. It is expected that each craftsman should successfully complete part of the retrofitting work before working on an actual school building.

Fig-58: On the job training & site monitoring

Under the DRSI project, the programme started by retrofitting one school building as a pilot. During this process, tradespeople were trained on-site in the required retrofitting techniques. After successful completion and learning from the pilot building, the same approach was scaled up and applied to the remaining schools.

7.3 Training On Health And Safety

Health and safety training is essential for all workforce categories. It should cover safe work practices, proper use of PPE, Use of safe scaffolding, ladder and operation of tools (such as grinders, cutters, and drills), handling of epoxy and other materials, paint, and dust removal, identify any asbestos or hazardous material early on, including handling and mixing of construction materials, and emergency procedures. Workers shall wear suitable respiratory protection to prevent dust inhalation Toolbox safety meetings should be held daily to reinforce awareness and encourage reporting of unsafe conditions. Training shall be conducted at regular intervals to reinforce correct construction practices, inform site personnel of any changes in methods or specifications, and address common construction errors.

Chapter 8

Monitoring, Evaluation, and Maintenance

Monitoring, evaluation, and maintenance are essential to ensure that retrofitted school buildings perform as intended throughout their service life. Monitoring ensures compliance with design and quality standards, while periodic evaluations help verify continued safety and functionality. Maintenance protocols are critical to sustain the effectiveness and longevity of retrofitting interventions.

8.1 Site Management

Proper site management ensures safety, efficiency, and minimal disruption to school operations during retrofitting. Temporary classrooms should be arranged to maintain academic continuity, especially in girls' schools where privacy is a concern. Construction zones should be securely fenced to prevent unauthorized access and ensure student safety (see Fig-59).

Worker camps, if provided, must include adequate water supply, sanitation, rest areas, and first aid facilities. Site layouts must include safe access, waste disposal, and storage areas for materials to maintain order and hygiene.

8.2 Post-Retrofitting Inspection Protocols

After retrofitting, inspections should verify that all interventions conform to design drawings and specifications. Qualified engineers should perform these inspections using checklists and photographic records. Critical items include continuity of seismic bands, mesh fixing, roof anchorage, plaster quality, and curing practices. Any non-compliance must be rectified as work progresses and before handover and documented as part of project completion.

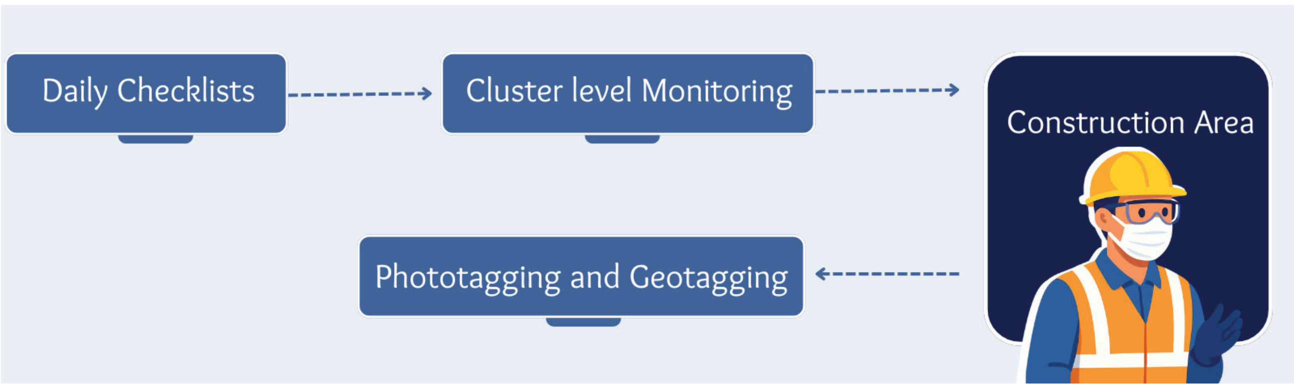


Fig-59: Example of safe retrofitting site layout within a functioning school compound.

8.3 Maintenance And Monitoring

Retrofitting is a complex process, and its success depends on accurate assessment, sound design, and quality implementation. Any deficiencies in design, workmanship, or construction quality can adversely affect the structural performance of the building. The post-retrofitting phase therefore requires regular monitoring to maintain structural integrity; for example, continuous exposure to water can lead to deterioration of both structural and non-structural elements, weakening overall strength. Although schools are typically allocated annual maintenance funds, these are often insufficient to meet repair needs. Monitoring, evaluation, and maintenance are essential to ensure that retrofitted school buildings perform as intended throughout their service life. Monitoring ensures compliance with design and quality standards, while periodic evaluations confirm continued safety and functionality. Regular maintenance is essential to preserve the structural and functional integrity of retrofitted buildings. A preventive maintenance plan should include routine inspections and timely minor repairs to address cracks, water leakage, steel' corrosion, and plaster deterioration. Moisture control and proper drainage around the foundation must remain a priority. Recommended practices are:

- Inspect the building annually, particularly before and after the monsoon season
- Keep roofs, gutters, and drains clean and functional. Avoid any water stagnation on the roof and near building site, and continuous wetting of walls.
- Seal new cracks or leaks immediately to prevent progression.
- Maintain a logbook of all repair and maintenance activities for each building.

Reference

Arya, A. S., Boen, T., & Ishiyama, Y. (2013). Guidelines for Earthquake Resistant Non-Engineered Construction. Paris: United Nations Educational, Scientific and Cultural Organization. Doi:ISBN 978-92-3-000032-5

Bothara, J. K., Ahmad, N., Ingham, J., & Dizhur, D. (2024). Innovative Earthquake Resistant School Building Typologies for Earthquake-Hit Areas of Nepal. Engineering Structures. (NOTHING IN PIPELINE)

Bothara, J. K., Naveed, A., Ingham, J. M., & Dizhur, D. (2023). Mechanical properties of stone masonry set in mud mortar and contained by steel wire mesh. Construction and Building Materials, 405, 20. Doi: https://doi.org/10.1016/j.conbuildmat.2023.133348

Bothara, J., & Brzev, S. (2011). A Tutorial: Improving the Seismic Performance of Stone Masonry Buildings. Oakland: Earthquake Engineering Research Institute. Doi: ISBN: 978-1-932884-48-7

FEMA. (1997a). FEMA 273 – NEHRP Guidelines for the Seismic Rehabilitation of Buildings. Washington DC: Federal Emergency Management Agency. Retrieved from https://www.scinc.co.jp/nanken/pdf/fema273.pdf

FEMA. (1997b). FEMA 274 – NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings. Washington, D.C.: Federal Emergency Management Agency. Retrieved from https://www.conservationtech.com/FEMA-publications/FEMA274-1997.pdf

FEMA. (2006). FEAM 547 – Techniques for the Seismic Rehabilitation of Existing Buildings. Federal Emergency Management Agency. Retrieved from https://www.fema.gov/node/techniques-seismic-rehabilitation-existing-buildings

PEC. (2021). Building Code of Pakistan. Islamabad, Pakistan: Pakistan Engineering Council. Retrieved from https://www.pec.org.pk/wp-content/uploads/2024/09/BCP2021-Final-Draft-dated-26.10.2021.pdf

UNDP. (2009). Seismic Retrofitting and Repair Manual for Buildings (Earthquake Vulnerability Reduction Project). National Disaster Management Authority Pakistan and United Nations Development Programme Pakistan. Retrieved from https://www.ndma.gov.pk/storage/publications/July2024/Y6yxuW9k8hbXwrWw10fc.pdf

UNESCO. (2019a). UNESCO Guidelines for Assessing Learning Facilities in the Context of Disaster Risk Reduction and Climate Change Adaptation, VOLUME 1 – Introduction to learning facilities assessment and to the VISUS methodology. 7, place de Fontenoy, 75352 Paris 07 SP, France: United Nations Educational, Scientific and Cultural Organization (UNESCO). Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000371185

UNESCO. (2019b). UNESCO Guidelines for Assessing Learning Facilities in the Context of Disaster Risk Reduction and Climate Change Adaptation, VOLUME 2 – VISUS Methodolog. 7, place de Fontenoy, 75352 Paris 07 SP, France: United Nations Educational, Scientific and Cultural Organization (UNESCO). Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000371186

UNESCO. (2019c). UNESCO Guidelines for Assessing Learning Facilities in the Context of Disaster Risk Reduction and Climate Change Adaptation, VOLUME 3 – VISUS Implementation. 7, place de Fontenoy, 75352 Paris 07 SP, France: United Nations Educational, Scientific and Cultural Organization (UNESCO). Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000371188

UN-Habitat. (2019.). Retrofitting Guideline for Developing Hazard Resilient Schools. Education Department, Government of Khyber Pakhtunkhwa. Retrieved from https://unhabitat.org.pk/retrofitting-guideline

UN-Habitat (2022) 'Structural Vulnerability Assessment of school's buildings in 8 districts of Khyber Pakhtunkhwa- Pakistan.

UN-Habitat (2008) 'Compliance Catalogue Guidelines for the Construction of Compliant Rural Houses, Retrieved from https://unhabitatmyanmar.org/wp-content/uploads/2025/08/COMPLIANCE-CATALOGUE-GUIDELINES-FOR-THE-CONSTRUCTION-OF-COMPLIANT-RURAL-HOUSES.pdf.

Appendix 1: Definitions And Acronyms

Building code: A set of ordinances or regulations and associated standards intended to control aspects of the design, constructions, materials, alteration and occupancy of structures that are necessary to ensure human safety and welfare, including resistance to collapse and damage.

Building damage classification: Evaluation and recording of damage to structures, facilities or infrastructure according to three or more categories:

Building code: A set of ordinances or regulations and associated standards intended to control aspects of the design, constructions, materials, alteration and occupancy of structures that are necessary to ensure human safety and welfare, including resistance to collapse and damage.

Building damage classification: Evaluation and recording of damage to structures, facilities or infrastructure according to three or more categories:

Disaster: A situation or event that overwhelms local capacity, an unforeseen and often sudden event that causes great damage, destruction, and human suffering (LISC, 2019)

Damage classification:

Light damage, such as broken windows, minor damage to roofing and siding, interior partitions blown down, or cracked walls, where the damage is not severe enough to preclude use for its intended purpose.

Moderate damage, which precludes further use of the structure, facility, or object for its intended purpose, unless major repairs are made short of complete reconstruction,

Severe damage, which precludes further use of the structure, facility, or object for its intended purpose.

Delamination: Bulging of exterior wythes in stone masonry walls due to earthquake shaking. Delamination usually leads to either partial or total wall collapse. Delamination is a common failure mechanism in stone masonry walls without through-stones. However, delamination has also been seen in brick masonry walls where stretcher bricks have not been provided.

Design Basis Earthquake (DBE): The level of earthquake shaking that a building is designed to resist. It represents a realistic but strong earthquake that could occur during the life of the building. The structure should be able to withstand this level of shaking without collapse, protecting the safety of occupants, even if some damage occurs.

Detailed Investigation and Structural Health Assessment: Detailed investigation involves a thorough examination of the building's existing condition through review of drawings, visual inspection, and necessary testing. Structural health assessment uses this information to evaluate the building's structural integrity, safety, and seismic performance, and to determine the need for repair or retrofitting.

Ductile: The ability of a structure to deform by a large amount without breaking or collapsing, even when it suffers overload and bends, sways, and deforms.

Ferrocement overlay: A thin layer of rich cement-sand mortar plaster reinforced with one or more layers of fine steel wire mesh, applied to the surface of a masonry wall to improve its strength, ductility, and crack resistance.

Local materials: Material which could be locally extracted, processed and procured which are close enough to building site such as stones, soil, timber in the hills and mountains. The local materials could be area specific.

Locally available materials: The materials which could be locally procured and transported to the site easily are locally available materials. These include local materials as well as imported from outside such as cement, steel, sand, etc.

Load path: A path through which vertical or seismic forces travel from the point of their origin to the foundation and, ultimately, to the supporting soil.

Low-strength masonry: Masonry laid in weak mortar; such as mud, weak cement/sand or lime/ sand mortar.

Maximum Considered Earthquake (MCE): MCE represents a severe but plausible level of earthquake shaking that could reasonably occur at a site, based on regional seismic hazard. It reflects a rare, high-intensity event used to assess the upper-bound seismic demand on a structure and to evaluate its capacity to prevent collapse under extreme conditions.

Detailed Investigation and Structural Health Assessment: Detailed investigation involves a thorough examination of the building's existing condition through review of drawings, visual inspection, and necessary testing. Structural health assessment uses this information to evaluate the building's structural integrity, safety, and seismic performance, and to determine the need for repair or retrofitting.

Ductile: The ability of a structure to deform by a large amount without breaking or collapsing, even when it suffers overload and bends, sways, and deforms.

Ferrocement overlay: A thin layer of rich cement-sand mortar plaster reinforced with one or more layers of fine steel wire mesh, applied to the surface of a masonry wall to improve its strength, ductility, and crack resistance.

Local materials: Material which could be locally extracted, processed and procured which are close enough to building site such as stones, soil, timber in the hills and mountains. The local materials could be area specific.

Locally available materials: The materials which could be locally procured and transported to the site easily are locally available materials. These include local materials as well as imported from outside such as cement, steel, sand, etc.

Load path: A path through which vertical or seismic forces travel from the point of their origin to the foundation and, ultimately, to the supporting soil.

Low-strength masonry: Masonry laid in weak mortar; such as mud, weak cement/sand or lime/ sand mortar.

Maximum Considered Earthquake (MCE): MCE represents a severe but plausible level of earthquake shaking that could reasonably occur at a site, based on regional seismic hazard. It reflects a rare, high-intensity event used to assess the upper-bound seismic demand on a structure and to evaluate its capacity to prevent collapse under extreme conditions.

Resilience: The ability of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of its essential basic structures and functions (IPPC, 2012).

Rigid diaphragm: A suspended floor, roof or ceiling structure that is able to transfer lateral loads to the walls with negligible horizontal deformation of the diaphragm. Floors or roofs made from reinforced concrete, such as reinforced concrete slabs, fall into this category.

Risk: The combination of the probability of an event and its negative consequences. Risk depends on hazard, vulnerability and coping mechanisms.

Return Period: The average time interval, expressed in years, between earthquakes (or other hazard events) of a given intensity or greater. For example, a 475-year return period earthquake means that, on average, an event of that size is expected once every 475 years, although it may occur sooner or later.

Seismic assessment: A process used to determine the seismic capacity of a building structure to survive an earthquake. The assessment requires resources of highly skilled and experienced engineers.

Seismic Hazard: The potential for damage caused by earthquakes. The level of hazard depends on the magnitude of probable earthquakes, the type of fault, the distance from faults associated with those earthquakes, and the type of soil at the site.

Stiffness: Resistance to deformation. A stiff (rigid) wall does not deform much, even when subjected to significant lateral loads. Stone masonry walls are usually very stiff, as opposed to timber walls, which are flexible (the opposite of stiff).

Through-stone: A long stone that connects two wythes together in a stone masonry wall. It is also known as bond stone. Contrary to its name, a through-stone can also be a concrete block, a wood element, or steel bars with hooked ends embedded in concrete that perform the same function.

Vulnerability: The characteristic of building that influences their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard.

Wythe: A vertical leaf or layer of stone in a masonry wall. Stone masonry walls usually have two exterior wythes constructed using large stone boulders.

Appendix 2: Notations, Symbols And Abbreviations

BCP	Building Code of Pakistan
B-score	Building typology score
CR	Coursed rubble stone masonry
DBE	Design Basis Earthquake
D-factor	Discretionary factor
€	Existing
E-factor	Classroom density factor (exposure)
H-factor	Seismic hazard factor
G-score	Grade score of deficiency
MCE	Maximum Considered Earthquake
(N)	New
P-score	Prioritization score
RC	Reinforced concrete
S-factor	Social prioritization factor
UNDP	United Nations Development Programme
UN-Habitat	United Nations Human Settlements Programme
URM	Unreinforced masonry
W-score	Weightage score for building deficiency

Appendix 3: Engineering Basis Of Retrofitting Design

The engineering basis underpinning the Guidelines document is outlined in the following sections. These foundational principles define the technical approach, design assumptions, and performance objectives that inform the development of the proposed retrofitting measures.

Coverage: The Guidelines document is intended to cover the entirety of Pakistan; however, the proposed retrofitting measures will be based on the masonry building typologies observed in Khyber Pakhtunkhwa (KP) and adjacent areas of Kashmir and possibly in other parts of Pakistan. For the purposes of this document, the country will be broadly divided into four seismic zones, as illustrated in the below. It should be noted that the boundaries shown are indicative and may be subject to change depending upon findings of further analysis.

Seismic zonation of Pakistan defined for this guideline

Seismic design parameters: For defining the seismic design parameters, Chapter 16 of the Building Code of Pakistan, 2021

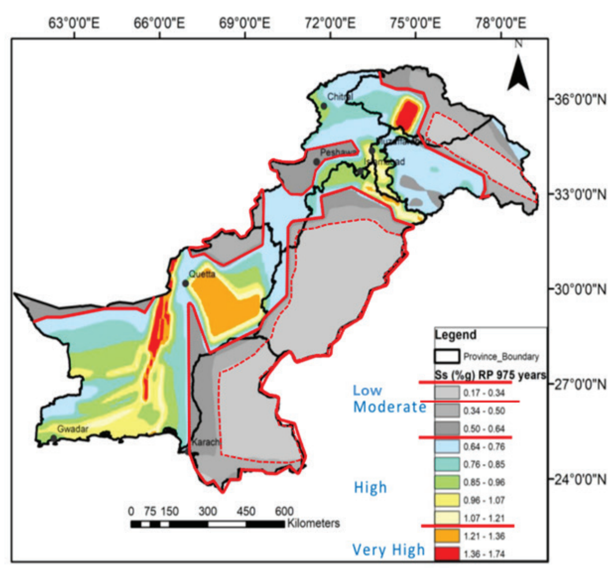


FIGURE C-5

0.2- SECONDS SPECTRAL ACCELERATION for 5% probability of exceedance in 50 years (975 years return period) retrofitting system for the school buildings has been designed to achieve the Life Safety performance objective, which ensures that buildings can withstand strong earthquake shaking without collapsing, thereby allowing safe evacua tion of occupants, even if significant structural damage occurs.

The design is based on the following key seismic parameters:

Design Based Earthquake (DBE): The Design Basis Earthquake (DBE) ensures that the building achieves the Life Safety performance level. As per ASCE 41, in the assessment and retrofit of existing buildings, the DBE is represented by an earthquake with a return period of 225 years (corresponding to an 80% probability of non-exceedance in 50 years), which is defined as two-thirds of the Maximum Considered Earthquake (MCE) (Equation 16-22 of BCP – 2021):

$$S_{DS} = \frac{2}{3} S_{MS}$$

Maximum Considered Earthquake (MCE): 975 years Return Period (95% probability of non-exceedance in 50 years)

Risk category = III (to reflect the critical function of school buildings and the higher occupancy risk)

Site Class = Class D

As the schools under consideration are single- and two-storey structures with fundamental periods less than the short-period threshold of 0.2 seconds, the seismic demand will be governed by the short-period spectral acceleration, SMS and SDS.

Importance Factor = 1.25 (BCP 2021 that refers ASCE 7. By applying an importance factor of 1.25, the building's performance will be enhanced, positioning it between the Life Safety and Immediate Occupancy performance levels.

Engineering design parameters

All engineering design parameters for the retrofitting works, such as dead and live loads, and material properties, were determined in accordance with the relevant Pakistani loading and material standards (e.g., those referenced in the Building Code of Pakistan-2021). Where specific parameters are not defined within the national standards, they were adopted from internationally recognized standards or derived from credible research papers and technical reports, ensuring their suitability or local conditions.

Appendix 4: Seismic zones of Pakistan

Seismic hazard data for various districts and tehsils of Pakistan for 5% Probability of exceedance in 50 years (Return Period = 975 Year) is given in the following table.

Note: This list includes districts in Moderate, higher and very high seismic zones only. All other districts fall in Low seismic zone.

S.No	Province	District	Tehsil	S_s	Zone
1	Federal Capital Territory	Islamabad	Islamabad	0.93	High
2	Azad Kashmir	Neelum	Athumqam	0.74	High
3	Azad Kashmir	Bagh	Bagh	1.03	High
4	Azad Kashmir	Bagh	Dheerkot	1.12	High
5	Azad Kashmir	Hattian	Hattian Bala	0.92	High
6	Azad Kashmir	Haveli	Haveli	0.91	High
7	Azad Kashmir	Muzaffarabad	Muzaffarabad	0.99	High
8	Azad Kashmir	Poonch	Abbaspur	1.06	High
9	Azad Kashmir	Poonch	Hajeera	1.1	High
10	Azad Kashmir	Poonch	Rawalakot	1.12	High
11	Azad Kashmir	Sudhnoti	Pallandari	1.12	High
12	Azad Kashmir	Bhimber	Barnala	1.13	High
13	Azad Kashmir	Bhimber	Bhimber	1.1	High
14	Azad Kashmir	Bhimber	Samahni	1	High
15	Azad Kashmir	Kotli	Kotli	1.02	High
16	Azad Kashmir	Kotli	Nakial	0.94	High
17	Azad Kashmir	Kotli	Sehnsa	1.08	High
18	Azad Kashmir	Mirpur	Dudyal	0.99	High
19	Azad Kashmir	Mirpur	Mirpur	1.16	High
20	Disputed Territory	Disputed Territory		0.76	High
21	Gilgit Baltistan	Ghizer	Ishkomen	0.6	Moderate
22	Gilgit Baltistan	Ghizer	Yasin	0.72	High
23	Gilgit Baltistan	Hunza Nagar	Aliabad	0.55	Moderate
24	Gilgit Baltistan	Hunza Nagar	Gojal	0.47	Moderate
25	Gilgit Baltistan	Hunza Nagar	Nagar-I	0.59	Moderate
26	Gilgit Baltistan	Hunza Nagar	Nagar-Ii	0.59	Moderate
27	Gilgit Baltistan	Diamir	Chilas	1.14	High
28	Gilgit Baltistan	Diamir	Darel Tangir	0.81	High
29	Gilgit Baltistan	Ghanche	Mashabrum	0.48	Moderate
30	Gilgit Baltistan	Ghizer	Gupis	0.78	High
31	Gilgit Baltistan	Ghizer	Punial	0.81	High
32	Gilgit Baltistan	Gilgit	Gilgit	0.92	High
33	Gilgit Baltistan	Skardu	Rondu	1.29	Very High
34	Gilgit Baltistan	Skardu	Shigar	0.38	Moderate
35	Gilgit Baltistan	Astore	Astore	1.19	High
40	Khyber Pakhtunkhwa	Chitral	Mastuj	0.73	High
41	Khyber Pakhtunkhwa	Chitral	Chitral	0.87	High
42	Khyber Pakhtunkhwa	Kohistan	Kandia	0.81	High
43	Khyber Pakhtunkhwa	Swat	Bahrain	0.81	High
44	Khyber Pakhtunkhwa	Upper Dir	Sharingal	0.82	High
45	Khyber Pakhtunkhwa	Batagram	Alai	0.75	High
46	Khyber Pakhtunkhwa	Batagram	Batagram	0.82	High
47	Khyber Pakhtunkhwa	Buner	Daggar	0.62	Moderate
48	Khyber Pakhtunkhwa	Buner	Gagra	0.6	Moderate
49	Khyber Pakhtunkhwa	Kohistan	Dassu	0.74	High
50	Khyber Pakhtunkhwa	Kohistan	Palas	0.72	High
51	Khyber Pakhtunkhwa	Kohistan	Pattan	0.76	High
52	Khyber Pakhtunkhwa	Lower Dir	Adenzai	0.73	High

53	Khyber Pakhtunkhwa	Lower Dir	Lalqilla	0.76	High
54ww	Khyber Pakhtunkhwa	Lower Dir	Munda	0.75	High
55	Khyber Pakhtunkhwa	Lower Dir	Samarbagh(Barwa)	0.78	High
56	Khyber Pakhtunkhwa	Lower Dir	Temergara	0.73	High
57	Khyber Pakhtunkhwa	Malakand	Sam Ranizai	0.65	High
58	Khyber Pakhtunkhwa	Malakand	Swat Ranizai	0.68	High
59	Khyber Pakhtunkhwa	Mansehra	Balakot	0.71	High
60	Khyber Pakhtunkhwa	Mansehra	Mansehra	1	High
61	Khyber Pakhtunkhwa	Shangla	Alpuri	0.73	High
62	Khyber Pakhtunkhwa	Shangla	Bisham	0.73	High
63	Khyber Pakhtunkhwa	Shangla	Chiksar	0.72	High
64	Khyber Pakhtunkhwa	Shangla	Martung	0.65	High
65	Khyber Pakhtunkhwa	Shangla	Puran	0.68	High
66	Khyber Pakhtunkhwa	Swat	Babuzai	0.72	High
67	Khyber Pakhtunkhwa	Swat	Barikot	0.7	High
68	Khyber Pakhtunkhwa	Swat	Charbagh	0.72	High
69	Khyber Pakhtunkhwa	Swat	Kabal	0.73	High
70	Khyber Pakhtunkhwa	Swat	Khawaza Khela	0.73	High
71	Khyber Pakhtunkhwa	Swat	Matta	0.75	High
72	Khyber Pakhtunkhwa	Torgher	Torgher	0.64	High
73	Khyber Pakhtunkhwa	Upper Dir	Dir	0.81	High
74	Khyber Pakhtunkhwa	Upper Dir	Wari	0.76	High
75	Khyber Pakhtunkhwa	Abbottabad	Abbottabad	1.04	High
76	Khyber Pakhtunkhwa	Abbottabad	Havelian	1	High
77	Khyber Pakhtunkhwa	Buner	Khado Khel	0.59	Moderate
78	Khyber Pakhtunkhwa	Charsadda	Charsadda	0.59	Moderate
79	Khyber Pakhtunkhwa	Charsadda	Shabqadar	0.56	Moderate
80	Khyber Pakhtunkhwa	Charsadda	Tangi	0.58	Moderate
81	Khyber Pakhtunkhwa	Haripur	Ghazi	0.79	High
82	Khyber Pakhtunkhwa	Haripur	Haripur	0.9	High
83	Khyber Pakhtunkhwa	Mansehra	Oghi	0.71	High
84	Khyber Pakhtunkhwa	Mardan	Katlang	0.61	Moderate
85	Khyber Pakhtunkhwa	Mardan	Mardan	0.6	Moderate
86	Khyber Pakhtunkhwa	Mardan	Takht Bhai	0.59	Moderate
87	Khyber Pakhtunkhwa	Nowshehra	Nowshera	0.89	High
88	Khyber Pakhtunkhwa	Nowshehra	Pabbi	0.75	High
89	Khyber Pakhtunkhwa	Peshawar	Peshawar	0.62	Moderate
90	Khyber Pakhtunkhwa	Swabi	Lahor	0.84	High
91	Khyber Pakhtunkhwa	Swabi	Razar	0.64	Moderate
92	Khyber Pakhtunkhwa	Swabi	Swabi	0.77	High
93	Khyber Pakhtunkhwa	Swabi	Topi	0.72	High
94	Khyber Pakhtunkhwa	Bannu	Bannu	0.74	High
95	Khyber Pakhtunkhwa	Bannu	Domel	0.67	High
96	Khyber Pakhtunkhwa	Hangu	Hangu	0.54	Moderate
97	Khyber Pakhtunkhwa	Hangu	Tall	0.52	Moderate
98	Khyber Pakhtunkhwa	Karak	Banda Daud Shah	0.53	Moderate
99	Khyber Pakhtunkhwa	Karak	Karak	0.64	Moderate
100	Khyber Pakhtunkhwa	Karak	Takht E Nasrati	0.71	High
101	Khyber Pakhtunkhwa	Kohat	Kohat	0.87	High

102	Khyber Pakhtunkhwa	Kohat	Lachi	0.8	High
103	Khyber Pakhtunkhwa	Dera Ismail Khan	Kulachi	0.73	High
104	Khyber Pakhtunkhwa	Dera Ismail Khan	Paharpur	0.69	High
105	Khyber Pakhtunkhwa	Lakki Marwat	Lakki Marwat	0.73	High
106	Khyber Pakhtunkhwa	Lakki Marwat	Naurang	0.74	High
107	Khyber Pakhtunkhwa	Tank	Tank	0.75	High
108	Khyber Pakhtunkhwa	Dera Ismail Khan	D.I.Khan	0.38	Moderate
109	Khyber Pakhtunkhwa	Dera Ismail Khan	Daraban	0.74	High
110	Khyber Pakhtunkhwa	Dera Ismail Khan	Paroa	0.42	Moderate
111	Merged Area Of KP	Bajaur Agency	Bar Chamarkand	0.84	High
112	Merged Area Of KP	Bajaur Agency	Barang	0.72	High
113	Merged Area Of KP	Bajaur Agency	Khar	0.75	High
114	Merged Area Of KP	Bajaur Agency	Mamund	0.82	High
115	Merged Area Of KP	Bajaur Agency	Nawagai	0.8	High
116	Merged Area Of KP	Bajaur Agency	Salarzai	0.77	High
117	Merged Area Of KP	Bajaur Agency	Utman Khel	0.73	High
118	Merged Area Of KP	Mohmand Agency	Ambar Utman Khel	0.72	High
119	Merged Area Of KP	Mohmand Agency	Safi	0.79	High
120	Merged Area Of KP	Mohmand Agency	Upper Momand	0.79	High
121	Merged Area Of KP	Fr Kohat	Fr Kohat	0.84	High
122	Merged Area Of KP	Fr Peshawar	Fr Peshawar	0.87	High
123	Merged Area Of KP	Khyber Agency	Bara	0.55	Moderate
124	Merged Area Of KP	Khyber Agency	Jamrud	0.55	Moderate
125	Merged Area Of KP	Khyber Agency	Landi Kotal	0.57	Moderate
126	Merged Area Of KP	Kurram Agency	Central Kurram	0.55	Moderate
127	Merged Area Of KP	Kurram Agency	Upper Kurram	0.59	Moderate
128	Merged Area Of KP	Mohmand Agency	Halimzai	0.66	High
129	Merged Area Of KP	Mohmand Agency	Pindiali	0.68	High
130	Merged Area Of KP	Mohmand Agency	Prang Ghar	0.64	High
131	Merged Area Of KP	Mohmand Agency	Yaka Ghund	0.58	Moderate
132	Merged Area Of KP	Orakzai Agency	Central Orakzai	0.55	Moderate
133	Merged Area Of KP	Orakzai Agency	Lower Orakzai	0.55	Moderate
134	Merged Area Of KP	Orakzai Agency	Upper Orakzai	0.55	Moderate
135	Merged Area Of KP	Fr Bannu	Fr Bannu	0.6	Moderate
136	Merged Area Of KP	Kurram Agency	Lower Kurram	0.56	Moderate
137	Merged Area Of KP	North Waziristan Agency	Data Khel	0.62	Moderate
138	Merged Area Of KP	North Waziristan	Dossali	0.76	High
139	Merged Area Of KP	North Waziristan	Ghulam Khan	0.76	High
140	Merged Area Of KP	North Waziristan	Mir Ali	0.76	High
141	Merged Area Of KP	North Waziristan A	Miran Shah	0.76	High
142	Merged Area Of KP	North Waziristan	Shewa	0.59	Moderate
143	Merged Area Of KP	North Waziristan	Spinwam	0.74	High
144	Merged Area Of KP	Orakzai Agency	Ismailzai	0.54	Moderate
145	Merged Area Of KP	Fr Lakki Marwat	Fr Lakki	0.76	High
146	Merged Area Of KP	Fr Tank	Fr Tank	0.76	High
147	Merged Area Of KP	North Waziristan A	Garyum	0.76	High
148	Merged Area Of KP	North Waziristan	Razmak	0.76	High
149	Merged Area Of KP	South Waziristan	Birmal	0.41	Moderate

150	Merged Area Of KP	South Waziristan	Ladha	0.76	High
151	Merged Area Of KP	South Waziristan	Makin	0.76	High
152	Merged Area Of KP	South Waziristan	Saraogha	0.76	High
153	Merged Area Of KP	South Waziristan	Serwekai	0.76	High
154	Merged Area Of KP	South Waziristan A	Tiarza	0.7	High
155	Merged Area Of KP	South Waziristan	Toi Khulla	0.45	Moderate
156	Merged Area Of KP	South Waziristan	Wana	0.75	High
157	Merged Area Of KP	FR D.I.KHAN	Fr D.I.Khan	0.76	High
158	Punjab	Attock	Attock	0.93	High
159	Punjab	Attock	Hassanabdal	0.93	High
160	Punjab	Attock	Hazro	0.9	High
161	Punjab	Rawalpindi	Kotli Sattian	1.1	High
162	Punjab	Rawalpindi	Murree	1.08	High
163	Punjab	Rawalpindi	Taxila	0.93	High
164	Punjab	Attock	Fateh Jang	0.92	High
165	Punjab	Attock	Jand	0.91	High
166	Punjab	Attock	Pindi Gheb	0.85	High
167	Punjab	Chakwal	Chakwal	0.61	Moderate
168	Punjab	Chakwal	Kallar Kahar	0.53	Moderate
169	Punjab	Chakwal	Tala Gang	0.56	Moderate
170	Punjab	Gujrat	Sarai Alamgir	1.25	Very High
171	Punjab	Jhelum	Dina	1.18	High
172	Punjab	Jhelum	Jhelum	0.77	High
173	Punjab	Jhelum	Sohawa	1.02	High
174	Punjab	Mianwali	Isakhel	0.84	High
175	Punjab	Rawalpindi	Gujar Khan	1.18	High
176	Punjab	Rawalpindi	Kahuta	1.02	High
177	Punjab	Rawalpindi	Kallar Sayyedan	0.94	High
178	Punjab	Rawalpindi	Rawalpindi	0.88	High
179	Punjab	Bhakkar	Kalur Kot	0.42	Moderate
180	Punjab	Chakwal	Choa Saidan Shah	0.55	Moderate
181	Punjab	Gujranwala	Gujranwala	0.52	Moderate
182	Punjab	Gujranwala	Gujranwala City	0.52	Moderate
183	Punjab	Gujranwala	Kamoke	0.45	Moderate
184	Punjab	Gujranwala	Nowshera Virkhan	0.37	Moderate
185	Punjab	Gujranwala	Wazirabad	0.42	Moderate
186	Punjab	Gujrat	Gujrat	0.94	High
187	Punjab	Gujrat	Kharian	1.01	High
188	Punjab	Hafizabad	Hafizabad	0.34	Moderate
190	Punjab	Jhelum	Pind Dadan Khan	0.52	Moderate
191	Punjab	Khushab	Khushab	0.48	Moderate
192	Punjab	Khushab	Qaidabad	0.48	Moderate
193	Punjab	Mandi Bahauddin	Malakwal	0.42	Moderate
194	Punjab	Mandi Bahauddin	Mandi Bahauddin	0.52	Moderate
195	Punjab	Mandi Bahauddin	Phalia	0.39	Moderate
196	Punjab	Mianwali	Mianwali	0.69	High
197	Punjab	Mianwali	Piplan	0.75	High
198	Punjab	Narowal	Narowal	0.81	High
199	Punjab	Narowal	Shakargarh	1.26	Very High

200	Punjab	Narowal	Zafarwal	1.1	High
201	Punjab	Sargodha	Bhalwal	0.4	Moderate
204	Punjab	Sargodha	Shahpur	0.36	Moderate
205	Punjab	Sialkot	Daska	1.13	High
206	Punjab	Sialkot	Pasrur	1.21	High
207	Punjab	Sialkot	Sambrial	1.09	High
208	Punjab	Sialkot	Sialkot	0.92	High
235	Punjab	Sheikhupura	Ferozewala	0.35	Moderate
236	Punjab	Sheikhupura	Muridke	0.39	Moderate
240	Punjab	Dera Ghazi Khan	De-Exclude area	0.76	High
241	Punjab	Dera Ghazi Khan	Taunsa	0.47	Moderate
268	Punjab	Dera Ghazi Khan	Dera Ghazi Khan	0.53	Moderate
279	Punjab	Rajanpur	Jampur	0.44	Moderate
289	Punjab	Rajanpur	De-Excluded Area	0.74	High
291	Punjab	Rajanpur	Rojhan	0.36	Moderate
295	Balochistan	Killa Abdullah	Dobandi Sub	0.69	High
296	Balochistan	Killa Saifullah	Badini	0.43	Moderate
297	Balochistan	Killa Saifullah	Loi Band	0.52	Moderate
298	Balochistan	Sheerani	Sheerani	0.73	High
299	Balochistan	Zhob	Ashwat Sub-	0.43	Moderate
300	Balochistan	Zhob	Kashatoo Sub-	0.41	Moderate
301	Balochistan	Zhob	Qamar Din Karez	0.4	Moderate
302	Balochistan	Zhob	Sambaza Sub	0.4	Moderate
303	Balochistan	Zhob	Zhob	0.58	Moderate
304	Baluchistan	Harnai	Harnai	1.3	Very High
305	Balochistan	Killa Abdullah	Chaman	1.36	Very High
306	Balochistan	Killa Abdullah	Gulistan	0.91	High
307	Balochistan	Killa Abdullah	Killa Abdullah	0.78	High
308	Balochistan	Killa Saifullah	Kan Mehtarzai	1.07	High
309	Balochistan	Killa Saifullah	Killa Saifullah	0.64	High
310	Balochistan	Killa Saifullah	Muslim Bagh	0.71	High
311	Balochistan	Killa Saifullah	Shinkai	0.61	Moderate
312	Balochistan	Loralai	Loralai	0.88	High
313	Balochistan	Loralai	Mekhtar	0.9	High
314	Balochistan	Musa Khel	Drug Sub	0.76	High
315	Balochistan	Musa Khel	Kingri	0.76	High
316	Balochistan	Musa Khel	Musa Khel	0.77	High
317	Balochistan	Pishin	Barshore	0.67	High
318	Balochistan	Pishin	Huramzai	0.68	High
319	Balochistan	Pishin	Karezat	0.83	High
320	Balochistan	Pishin	Pishin	0.67	High
321	Balochistan	Pishin	Saranan	0.68	High
322	Balochistan	Quetta	Quetta Saddar	0.85	High
323	Balochistan	Ziarat	Sinjawi Sub	1.12	High
324	Balochistan	Ziarat	Ziarat Sub Division	1.29	Very High
325	Balochistan	Barkhan	Barkhan	1.05	High
326	Balochistan	Dera Bugti	Bekerh	1.25	Very High
327	Balochistan	Dera Bugti	Phelawagh	1.24	Very High
328	Balochistan	Harnai	Khost	1.34	Very High

329	Balochistan	Harnai	Shahrig	1.33	Very High
330	Balochistan	Kachhi (Bolan)	Dhadar	1.33	Very High
331	Balochistan	Kachhi (Bolan)	Mach Sub	1.21	Very High
332	Balochistan	Kalat	Mango Char	0.81	High
333	Balochistan	Kohlu	Girsani Sub	1.13	High
334	Balochistan	Kohlu	Kahan	1.29	Very High
335	Balochistan	Kohlu	Kohlu	1.12	High
336	Balochistan	Kohlu	Mawand	1.23	Very High
337	Balochistan	Loralai	Duki	0.95	High
338	Balochistan	Mastung	Dasht	0.83	High
339	Balochistan	Mastung	Khad Kocha Sub	0.74	High
340	Balochistan	Mastung	Kirdgap Sub	1.01	High
341	Balochistan	Mastung	Mastung	0.69	High
342	Balochistan	Nushki	Dak_	0.58	Moderate
343	Balochistan	Nushki	Nushki_	1.31	Very High
344	Balochistan	Quetta	Panj Pai Sub	1.11	High
345	Balochistan	Quetta	Quetta City	0.92	High
346	Balochistan	Sibi	Kut Mandai	1.36	Very High
347	Balochistan	Sibi	Sangan	1.35	Very High
348	Balochistan	Sibi	Sibi	1.37	Very High
349	Balochistan	Chagai	Chagai Sub	0.68	High
350	Balochistan	Chagai	Dalbadin	0.78	High
351	Balochistan	Chagai	Naukandi	0.75	High
352	Balochistan	Chagai	Taftan	0.63	Moderate
353	Balochistan	Dera Bugti	Dera Bugti	1.18	High
354	Balochistan	Dera Bugti	Loti Sub	0.94	High
355	Balochistan	Dera Bugti	Malum	1.15	High
356	Balochistan	Dera Bugti	Pir Koh	1.28	Very High
357	Balochistan	Dera Bugti	Sangsilla	1.3	Very High
358	Balochistan	Dera Bugti	Sui	0.99	High
359	Balochistan	Jaffarabad	Sohbat Pur	0.87	High
360	Balochistan	Jhal Magsi	Gandawa	0.66	High
361	Balochistan	Jhal Magsi	Mirpur Sub	1.1	High
362	Balochistan	Kachhi (Bolan)	Bagh	1.28	Very High
363	Balochistan	Kachhi (Bolan)	Balanari Sub	1.34	Very High
364	Balochistan	Kachhi (Bolan)	Khattan Sub	1.25	Very High
365	Balochistan	Kachhi (Bolan)	Sanni Sub	0.77	High
366	Balochistan	Kalat	Gazg	0.62	Moderate
367	Balochistan	Kalat	Johan	0.64	Moderate
368	Balochistan	Kalat	Kalat	1.01	High
369	Balochistan	Kharan	Kharan	0.77	High
370	Balochistan	Khuzdar	Zehri	0.73	High
371	Balochistan	Nasirabad	Chattar	1.28	Very High
372	Balochistan	Nasirabad	Dera_Murad_Jamali	1.22	Very High
373	Balochistan	Sibi	Lehri	1.31	Very High
374	Balochistan	Jaffarabad	Ghandakha	0.72	High
375	Balochistan	Jaffarabad	Jhat Pat	0.9	High
376	Balochistan	Jaffarabad	Usta Muhammad	0.73	High
377	Balochistan	Jhal Magsi	Jhal Magsi	0.63	Moderate

378	Balochistan	Kalat	Surab	1.33	Very High
379	Balochistan	Khuzdar	Karkah Sub	0.61	Moderate
380	Balochistan	Khuzdar	Khuzdar	0.85	High
381	Balochistan	Khuzdar	Moola Sub	0.7	High
382	Balochistan	Nasirabad	Baba_Kot	1.15	High
383	Balochistan	Nasirabad	Tamboo	1.21	Very High
384	Balochistan	Washuk	Mashkhel	0.91	High
385	Balochistan	Washuk	Nag	0.85	High
386	Balochistan	Washuk	Shahdo Garhi Sub	1.17	High
387	Balochistan	Washuk	Washuk	0.92	High
388	Balochistan	Awaran	Mashkai	1.42	Very High
389	Balochistan	Khuzdar	Aranji Sub	0.82	High
390	Balochistan	Khuzdar	Nal Sub	1.05	High
391	Balochistan	Khuzdar	Ornach Sub	0.96	High
392	Balochistan	Khuzdar	Wadh Sub	0.87	High
393	Balochistan	Panjgur	Panjgur	0.8	High
394	Balochistan	Washuk	Besima	0.98	High
395	Balochistan	Awaran	Awaran	1.1	High
396	Balochistan	Awaran	Jhal Jhao	1	High
397	Balochistan	Awaran	Jhal Jhao Sub	0.92	High
398	Balochistan	Kech	Buleda	0.88	High
399	Balochistan	Kech	Hoshab	1.08	High
400	Balochistan	Kech	Mand	0.71	High
401	Balochistan	Kech	Tump	0.69	High
402	Balochistan	Kech	Zamuran	0.71	High
403	Balochistan	Khuzdar	Saroona Sub	0.73	High
404	Balochistan	Lasbela	Bela	0.9	High
405	Balochistan	Lasbela	Kanraj	0.84	High
406	Balochistan	Panjgur	Gichk	0.93	High
407	Balochistan	Panjgur	Gowargo	0.98	High
408	Balochistan	Panjgur	Parome	0.75	High
409	Balochistan	Awaran	Gishkore Sub	1	High
410	Balochistan	Gwadar	Gwadar	0.94	High
411	Balochistan	Gwadar	Jiwani	0.92	High
412	Balochistan	Gwadar	Ormara	1.06	High
413	Balochistan	Gwadar	Pasni	1.06	High
414	Balochistan	Gwadar	Sunstar Sub	0.98	High
415	Balochistan	Kech	Balngor	0.91	High
416	Balochistan	Kech	Dasht	1	High
417	Balochistan	Kech	Kech	0.96	High
418	Balochistan	Lasbela	Durji	0.61	Moderate
419	Balochistan	Lasbela	Hub	0.68	High
420	Balochistan	Lasbela	Lakhra	0.92	High
421	Balochistan	Lasbela	Liari	1.17	High
422	Balochistan	Lasbela	Sonmiani	0.83	High
423	Balochistan	Lasbela	Uthal	0.85	High
424	Balochistan	Lasbela	Gaddani	0.8	High
426	Sindh	Ghotki	Ghotki	0.37	Moderate

429	Sindh	Jacobabad	Garhi Khairo	0.58	Moderate
430	Sindh	Jacobabad	Jacobabad	0.66	High
431	Sindh	Jacobabad	Thul	0.56	Moderate
432	Sindh	Kashmore	Kandhkot	0.45	Moderate
433	Sindh	Kashmore	Kashmore	0.42	Moderate
434	Sindh	Kashmore	Tangwani	0.49	Moderate
435	Sindh	Larkana	Ratodero	0.41	Moderate
436	Sindh	Shahdad Kot	Miro Khan	0.49	Moderate
437	Sindh	Shahdad Kot	Qubo Saeed Khan	0.63	Moderate
438	Sindh	Shahdad Kot	Shahdad Kot	0.52	Moderate
439	Sindh	Shahdad Kot	Sijawal Junejo	0.47	Moderate
440	Sindh	Shikarpur	Garhi Yasin	0.42	Moderate
441	Sindh	Shikarpur	Khanpur	0.45	Moderate
442	Sindh	Shikarpur	Lakhi	0.4	Moderate
443	Sindh	Shikarpur	Shikarpur	0.5	Moderate
444	Sindh	Sukkur	New Sukkur	0.36	Moderate
445	Sindh	Sukkur	Pano Aqil	0.35	Moderate
446	Sindh	Sukkur	Sukkur	0.36	Moderate
447	Sindh	Dadu	Dadu	0.55	Moderate
448	Sindh	Dadu	Khairpur Nathan Shah	0.6	Moderate
449	Sindh	Dadu	Mehar	0.57	Moderate
453	Sindh	Khairpur	Kingri	0.35	Moderate
457	Sindh	Larkana	Bakrani Taluks	0.35	Moderate
458	Sindh	Larkana	Dokri	0.35	Moderate
459	Sindh	Larkana	Larkana	0.38	Moderate
463	Sindh	Shahdad Kot	Kambar Ali Khan	0.6	Moderate
464	Sindh	Shahdad Kot	Nasirabad	0.44	Moderate
465	Sindh	Shahdad Kot	Warah	0.57	Moderate
468	Sindh	Dadu	Johi	0.6	Moderate
469	Sindh	Jamshoro	Sehwan	0.59	Moderate
473	Sindh	Naushahro Feroze	Moro	0.41	Moderate
479	Sindh	Shaheed Benazirabad	Kazi Ahmed	0.36	Moderate
486	Sindh	Jamshoro	Kotri	0.34	Moderate
487	Sindh	Jamshoro	Manjand	0.38	Moderate
488	Sindh	Jamshoro	Thano Bula Khan	0.59	Moderate
489	Sindh	Karachi City	Gadap Town	0.6	Moderate
508	Sindh	Badin	Badin	0.44	Moderate
509	Sindh	Badin	ShaheedFazal Rahu	0.4	Moderate
512	Sindh	Karachi City	Bin Qasim Town	0.54	Moderate
513	Sindh	Karachi City	Kimari Town	0.73	High
514	Sindh	Karachi City	Urban	0.6	Moderate
518	Sindh	Thar Parkar	Diplo	0.43	Moderate
519	Sindh	Thar Parkar	Mithi	0.34	Moderate
521	Sindh	Thatta	Ghorabari	0.5	Moderate
522	Sindh	Thatta	Jati	0.49	Moderate
524	Sindh	Thatta	Mirpur Sakro	0.48	Moderate
525	Sindh	Thatta	Sujawal	0.44	Moderate
526	Sindh	Thatta	Thatta	0.53	Moderate
530	Sindh	Thatta	Shah Bunder	0.45	Moderate

Appendix 5: Geotechnical Hazard

Purpose: This guide provides simple field rules to help technicians identify potential geotechnical hazards at a site and decide when further investigation by a geotechnical engineer is required.

These checks are screening only and do not replace engineering analysis.

Liquefaction potential (Earthquake-related hazard): Liquefaction may occur in loose, saturated sandy soils during earthquakes.

Step 1. Check soil type: Liquefaction is more likely if soil is:

- Sand or silty sand
- Loose and easily disturbed
- Loses strength when wet
- Cannot hold shape when squeezed by hand

Liquefaction is less likely if soil is:

- Stiff clay
- Dense gravel
- Cemented or very hard material

If sandy or silty sand soil is observed, then flag the site.

Step 2: Check groundwater conditions: Liquefaction requires shallow groundwater. Indicators include:

- Standing water or waterlogged ground
- Water appearing in shallow pits or exca vations
- Proximity to rivers, canals, lakes, flood plains, or coast
- History of seasonal flooding

If groundwater is shallow (within a few meters), then flag the site

Step 3: Check site location and history: Higher liquefaction risk if the site is:

- In a floodplain or river delta
- Near rivers, canals, or old river channels
- On reclaimed land or filled ground

In an area where sand boils, settlement, or ground cracking occurred during past earthquakes

If any of the above apply, then flag the site

Slope instability (landslide risk): Slope instability may be present if:

- Slopes are steep (natural or cut slopes)
- Cracks are visible near slope edges
- Trees, poles, or walls lean downhill
- Water seepage is observed on slope faces

If steep slopes and water are present, then flag for slope stability review

Other problematic ground conditions:

Filled or Reclaimed Ground: Potential risk if:

- The site was previously filled
- Construction debris is visible in soil
- No compaction records are available

Treat filled ground as potentially weak

Soft or expansive Soils: Indicators include:

- Wide soil cracks during dry seasons
- Heaving or uneven floors
- Very soft ground that deforms under foot

Severe cracking to the building walls is an indication of the soft or expensive soil.

Appendix 6a: Case Study Building

1: Brick masonry building

School Building Data Collection Form

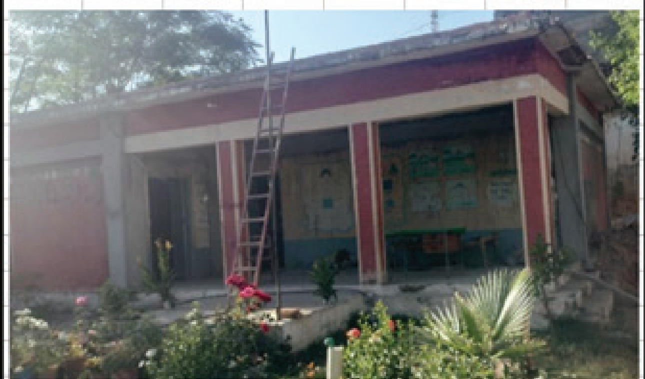
Surveyor's Name: Engr. Muhammad Sohail
School Name: GPS No.2 Peshawar
District: Peshawar
Latitude: 34.0083° N Longitude: 71.5189° E

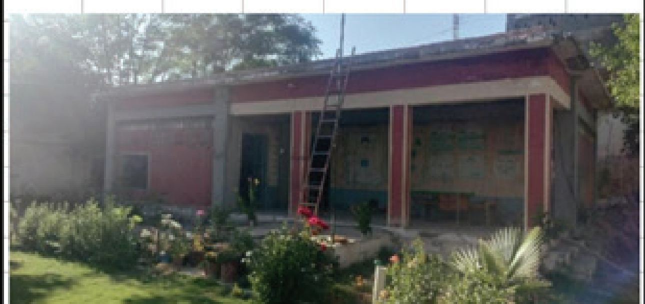
Seismic Zone: ☐ Very High ☐ High ☑ Moderate ☐ Low
Building Type: ☐ RRM in Mud ☐ RRM in CSM ☐ Semi-Dressed Stone in Mud ☐ Semi-Dressed Stone in CSM ☐ Block Masonry in CSM ☐ Dressed Stone in Mud ☐ Dressed Stone in CSM ☑ Brick Masonry in CSM
No. of Stories: ☑ Single Storey ☐ Double Storey
Roof Type: ☑ RC Slab ☐ Inverted T ☐ Truss Roof
Regularity: ☑ Regular ☐ Minor Irregularity ☐ Moderate Irregularity ☐ Major Irregularity

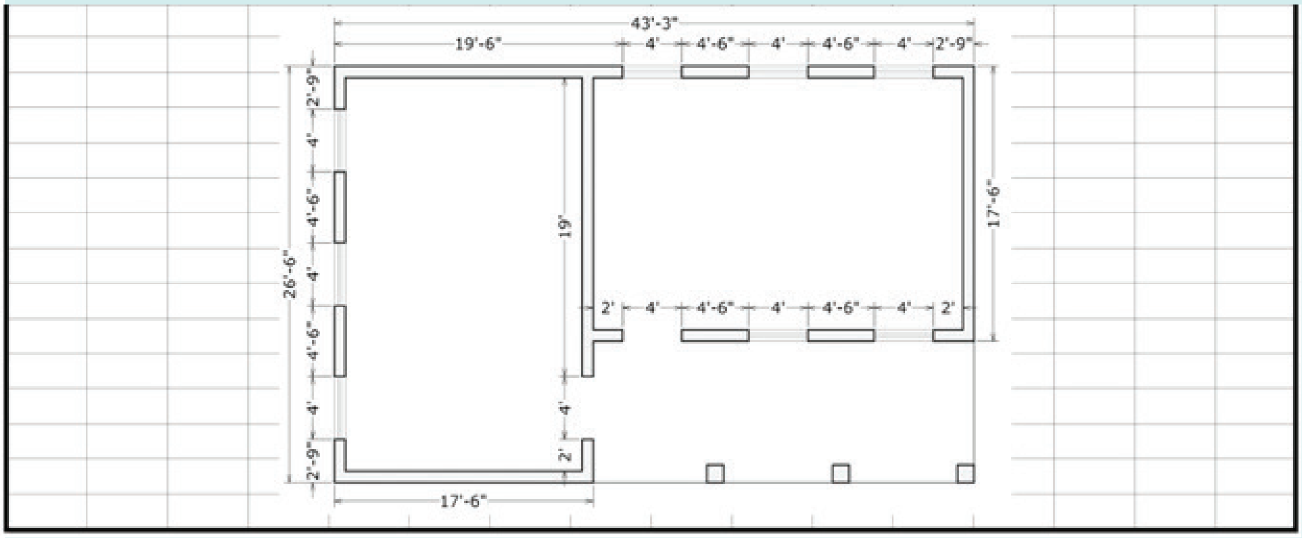
Length of Building, ft: 43.25 Width of Building, ft: 26.5
Area (SFT): 1146 Storey Height, ft: 11.0
Wall Thickness (inch): 9.0 Pier Length (min), ft: 2.75
Parapet Height, ft: 3.0
Window Size (max): L, ft: 4.0 H, ft: 5.5
Door Size (max): L, ft: 4.0 H, ft: 8.5
Total Wall Length, Long, ft: 87.25 Transverse, ft: 70.5
Total Open. Length, Long, ft: 24.0 Transverse, ft: 16.0

Soil Type: ☐ Soft and Poor Soil ☑ Stiff and Hard Soil
Ground Slope: ☑ Level ☐ Mild ☐ Moderate ☑ Steep
Quality: ☐ Good ☑ Acceptable ☐ Weak ☐ Worse
Wall to Wall Connections: ☐ Good ☑ Acceptable ☐ Weak ☐ Worse
Seismic Bands: ☐ Continuous and Connected ☐ Present but doubtful anchorage ☐ Partial Bands ☑ No Bands
Damage Condition: ☐ No Damage ☑ Hairline Cracks ☐ Several Structural Cracks ☐ Widespread Craking

No. of Students per Classroom:
Social Factor: ☐ Standard School ☐ Moderate Importance ☐ High Importance ☐ Very High Importance





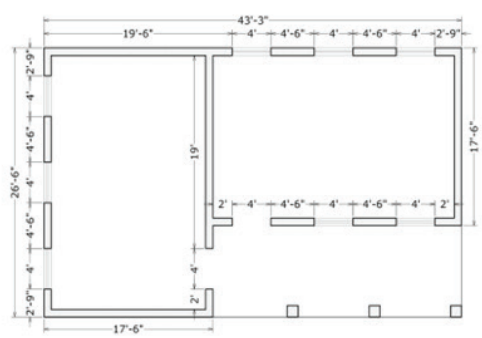


Exclusion Criteria		
No	Critera	Yes/No
1	The building is designed and constructed after BCP 2007	No
2	Very old buildings (age > 50 years)	No
3	Building already rehabilitated by other agency	No
4	Building handed over to other agency	No
5	Buildings located in extra high seismic zone	No
6	Expose to high geotechnical hazard	No
7	Reinforced concrete frame structure	No
8	More than 2-storey high buildings	No
9	More than 1-storey with mud mortar	No
10	Two storey building with GF wall thickness less than 13.5"	No
11	Highly Irregular Building (wing ratio > than 2.2)	No
12	Building with complex geometry (no defined load path)	No
13	Significantly damaged buildings	No
	The building is covered by the guideline	

School Building Data		
No.	Description	School Data
1	School Name	GPS No.2 Peshawar
2	School Location:	Peshawar
3	Seismic Zone:	**Moderate seismic zone**
4	No. of Storey:	**Single Storey**
5	Masonry Type:	**Brick masonry in cement-sand mortar**
6	Roof Type	**RC Slab**
7	Length of Building, ft	43.25
8	Width of Building, ft	26.5
9	Area of School Building, SFT	1146.1
10	Storey Height (ft):	11
11	Wall Thickness (inch):	9
12	Slenderness (Height/Thickness)	**14.67**
13	Minimum Pier Width (inch):	**33**
14	Height of Parapet Wall, ft	**3**
15	Total Length of Walls (Long), ft	87.25
16	Total Length of Walls (Transverse), ft	70.5
17	Total Length of Opening (Long), ft	24
18	Total Length of Walls (Transverse), ft	16
19	Wall-density Ratio (Long):	**4.14%**
20	Wall-density Ratio (Transverse):	**3.57%**
21	Openings to Wall Lengths Ratio (Long)	**0.28**
22	Openings to Wall Lengths Ratio (Transverse)	**0.23**
23	Damage Condition:	Minor Cracks
24	No. of students per classroom	High density (41–60 students per classroom)
23	Societal Factor	Standard school

Prioritisation Score (P-Score)		
No.	Factor	Score
1	Building specific vulnerability Factor (D = Σ (W x G))	19.00
2	Masonry Type (B-Factor)	5.00
3	Seismic Hazard (H-Factor)	0.67
4	Class Density, Exposure (E-Factor)	0.95
5	Social prioritisation factor (S-factor)	0.85
6	Discretionary factor (D-Factor)	1.00
	Prioritisation Score (P-Score)	**13**
	Priority III: Moderate	
	Retrofit during programme cycle	

P-Score	Priority Level	Action Taken
≥ 70	Priority 0: Reconstruction	Reconstruction Required
50 - 69	Priority I: Very High	Immediate retrofitting
30 - 49	Priority II: High	Retrofit planned
10 - 29	Priority III: Moderate	Retrofit during programme cycle
< 10	Priority IV: Low	Repair and maintenance



Deficiency-Based Vulnerability Score (D-score)

S. No.	ATTRIBUTES	SEISMIC EFFECT	Weightage	Grading		D = WxG
				Condition	G-Value	
1	Site and Foundation Condition	Seismic Amplification and Settlement	4	G = 0 - Level ground on competent soil/rock; no visible distress.	0.00	0.00
2	Number of Stories	Increase Seismic Demand	5	G = 0 - One storey building	0.00	0.00
3	Plan and Vertical Irregularities	Torsion effect resulting in concentration of damages	4	G = 0 - Nearly rectangular plan, no re-entrant corners; uniform storey heights; no setbacks.	0.00	0.00
4	Minimum Length of Pier between Openings	Low seismic resistance	3	G = 0 - Exceeds Section 2.5.5 requirements.	0.00	0.00
5	Minimum Wall Density Ratio	Low seismic resistance	3	G = 0.67 - Does not meet Section 2.5.6 requirements by small margin.	0.67	2.00
6	Mortar Quality and Workmanship	Low material strength	5	G = 0.33 - Generally good but with occasional weak or hollow joints.	0.33	1.67
7	Wall Bonding and Wall Junction/Through Stone in Stone Masonry	Controls integrity & delamination resulting in Box Action	5	G = 0 - Regular bonding; headers/through-stones clearly visible; good interlocking at corners and T-junctions.	0.00	0.00
8	Falling Hazard (Parapet Walls/Gable Walls)	Life Safety Threat	5	G = 0.67 - Several unbraced parapets (h . 2')/gables.	0.67	3.33
9	Wall Slenderness (Height to Thickness Ratio)	Out-of-plane failure	5	G = 0 - Slenderness ratios less than set out in Section 2.5.7.	0.00	0.00
10	Roof to Wall Anchorage (Diaphragm Type)	Out-of-plane resistance	5	G = 0 - RC floor and roof slab.	0.00	0.00
11	Inertial Mass (RC Slab, T-iron Roof and Truss Roof)	More Lateral Load demand on Walls	5	G = 1.0 - RC floor/ roof with layers of topping.	1.00	5.00
12	Seismic Bands (Lintel Band for RC Slab and Lintel and Eave Band for Truss Roof)	Box Action and Load Path	5	G = 1.0 - No effective bands (or only partial lintels).	1.00	5.00
13	Material Deterioration, Maintenance	Capacity Degradation	6	G = 0.33 - Hairline cracks and local damp patches.	0.33	2.00
	Total D-Weightage		60	D-Score = Σ (W x G)		19.00

Appendix 6b: Case Study Building
2: stone masonry building

School Building Data Collection Form

Surveyor's Name: Engr. Muhammad Sohail
School Name: GGPS Garam Chashma
District: Chitral Lower
Latitude: 35°59'9.80"N Longitude: 71°33'25.06"E

Seismic Zone: ☐ Very High ☑ High ☐ Moderate ☐ Low
Building Type: ☐ RRM in Mud ☐ RRM in CSM
☑ Semi-Dressed Stone in Mud ☑ Semi-Dressed Stone in CSM
☑ Block Masonry in CSM ☐ Dressed Stone in Mud
☐ Dressed Stone in CSM ☐ Brick Masonry in CSM
No. of Stories: ☑ Single Storey ☐ Double Storey
Roof Type: ☐ RC Slab ☐ Inverted T ☑ Truss Roof
Regularity: ☑ Regular ☐ Minor Irregularity
☐ Moderate Irregularity ☐ Major Irregularity

Length of Building, ft: 45.5 Width of Building, ft: 28
Area (SFT): 1274 Storey Height, ft: 11.0
Wall Thickness (inch): 18.0 Pier Length (min), ft: 2.0
Parapet Height, ft: -
Window Size (max): L, ft: 4.0 H, ft: 4.0
Door Size (max): L, ft: 4.0 H, ft: 7.0
Total Wall Length, Long, ft: 92.5 Transverse, ft: 75
Total Open. Length, Long, ft: 32.0 Transverse, ft: 20.0

Soil Type: ☐ Soft and Poor Soil ☑ Stiff and Hard Soil
Ground Slope: ☐ Level ☑ Mild ☐ Moderate ☑ Steep
Quality: ☐ Good ☑ Acceptable ☐ Weak ☐ Worse
Wall to Wall Connections: ☐ Good ☐ Acceptable ☑ Weak ☐ Worse
Seismic Bands: ☐ Continuous and Connected ☐ Present but doubtful anchorage ☐ Partial Bands ☑ No Bands
Damage Condition: ☐ No Damage ☐ Hairline Cracks ☑ Several Structural Cracks ☐ Widespread Craking

No. of Students per Classroom: 50
Social Factor: ☐ Standard School ☐ Moderate Importance ☑ High Importance ☐ Very High Importance

Appendix 7: Construction Material Specifications

Grout for crack repair

- The grout mix shall be prepared by weight using 10 parts Portland cement, 1 part lime, and 250 g of ULTRA expansion grout per 50 kg of cement, with a water–cement ratio of 0.9. Equivalent pre-packaged grout mixes may also be used.
- Injection nozzles shall have a diameter of 3/8 (10 mm) and length of 4" (100 mm), with threads at the outer end for fixing stoppers.

Ferrocement

- Mesh size: ¾" (19 mm) square hot-dipped galvanized welded wire mesh with wire diameter 0.065 ± 0.005" (1.65 ± 0.15 mm), minimum yield strength 30 ksi (205 Mpa) and 65 g/m² zinc coating, conforming to ASTM A641 Class 1.
- Screws: No. 10 screws, 1.5" (38 mm) or 2" (50 mm) long, spaced 12–14" (300–350 mm) c/c horizontally (staggered) and 9" (225 mm) vertically. Along edges and terminations, screws shall be placed at 9" (225 mm) c/c.
- Washers: 1⁄16" ± 1⁄64" (1.6 ± 0.4 mm) thick, 1.0" ± 0.2" (25 ± 2.5 mm) in diameter, fabricated from mild steel conforming to ASTM A36.
- Plastic Expansion Plugs: Compatible with 1.5" (38 mm) or 2" (50 mm) long No. 10 (3⁄16", 4.8 mm) screws.
- Plaster mix: 1 part cement and 3 parts coarse sand or 1 part cement, 1.5 parts coarse aggregate and 3 parts 1/4" (6 mm) pan crushed stone
- Plaster thickness: ¾"-1" (19–25 mm) thick

Concrete

All concrete should be prepared using a mechanical mixture. If a mechanical mixer is not available, hand mixing may be permitted under strict supervision, ensuring proper proportioning and thorough dry blending of materials before adding water.

Lean concrete: Lean concrete (base layer): Minimum 28-day strength 1500 psi (10 Mpa) with concrete mix: 1:3:6 (cement:sand:3/4" down aggregate) with adequate compaction.

Normal reinforced concrete

For plinth protection slab: Minimum 28-day cylinder compressive strength 2000 psi (≈150 Mpa) with concrete mix: 1:2:4 (cement: sand:3/4" down aggregate) with adequate compaction and curing for 10 days.

All other reinforcement works: The 28 days cylinder compressive strength of concrete shall be 3000 psi (20 Mpa) prepared using 3/4" down aggregate. The size of the aggregate for T-iron roof shall be limited to 1/2". Slump shall be 4"-6" (100-150 mm). Adequate compaction and curing for at least 10 days.

Micro concrete : 28 days cylinder compressive 3.

strength of micro concrete in lintel bandages, column jacketing shall be 3000 psi (20 Mpa) prepared using 1/4” (6 mm) pan crushed stone. Slump shall be 4”-6” (100-150 mm). Adequate compaction and curing for at least 10 days.

Reinforcements: All longitudinal and transverse bars, shear connectors and cross ties shall be deformed bars conforming to ASTM A615 Grade-60 with minimum yield strength equal to 60 ksi (410 Mpa).

All deformed bars for ties shall be conforming to ASTM A615 (Grade 40) with minimum yield strength of 40 ksi (275 Mpa).

Epoxy: The pull-out bond strength of epoxy used for shear connectors shall be at least 125 % of steel yield strength.

Steel for splint and bandage

- All steel plates and angle sections shall conform to ASTM A36 with minimum yield strength of 36,000 psi
- Cross ties shall be made with deformed bars conforming to ASTM A615 Grade-60, with minimum yield strength of 60 ksi (410 Mpa).
- All welding electrodes (E60XX) for Shielded Metal Arc Welding (SMAW) shall conform to the specification of AWS A5.1/5.1M:2015
- All welds shall be 1/4” (6 mm) fillet weld applied over full length of the connection.
- Maximum spacing between splints (vertical steel plates) shall be 5’ (1.5 m)
- Splints shall be provided at the sides of all openings
- Horizontal steel plates (bandages) shall be provided at plinth, sill and lintel. At floor/roof level, angle section shall be provided
- Additional bandages shall be provided at the corners with maximum spacing of 2’ (600 mm)
- Maximum vertical and horizontal spacing between cross ties shall be 3’ (900 mm).

Appendix 8: Detailing Requirements

1.Clear Cover for Concrete: According to section 20.5.1.3 of ACI 318-19, the following minimum concrete cover shall be provided to reinforcing steel unless otherwise noted.

- Footing in contact with soil: 3.0” (75 mm)
- Column jacketing: 1.0” (25 mm)
- Floor/roof slabs: 0.75” (20 mm)
- Splints and bandages: 0.75” (20 mm)
- Plinth protection: 1.0” (25 mm)

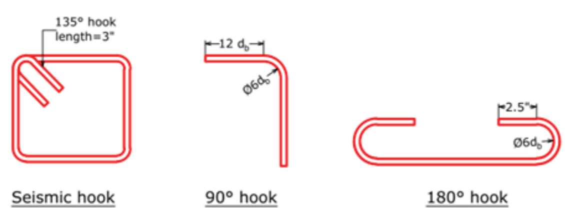
2.Embedment length of epoxy anchor: The minimum length of embedment for 3/8” and 1/2” (10 mm and 12 mm) dia. Epoxy anchors in concrete shall be 4.0 inch.

3.Lap length for rebars: According to Section 25.5.2 of ACI 318-19, Minimum lap length for 3/8” (10 mm) and 1/2” (12 mm) dia. Bars shall be 18” and 24” (450 mm and 600 mm) respectively.

4.Lap length in wire mesh: The minimum lap length in wire mesh shall be 12” (300 mm) on all sides.

1.Standard hook: All main bars shall be provided with 90o hook according to section 25.3.1 of ACI 318-19 as shown in Figure A1. The minimum diameter of inside bend shall be 6db and the length of straight extension of 90o hook shall be 12db.

- For 1/2” (12 mm) bar bend diameter and straight extension shall be 3” (75 mm) and 6” (150 mm) respectively.
- For 3/8” (10 mm) bar bend diameter and straight extension shall be 2.25” (56 mm) and 4.5” (113 mm) respectively.



2. Seismic hook: All stirrups and ties shall be provided with 135o hook according to section 25.3.4 of ACI 318-19. For both 1/4” (6 mm) and 3/8” (10 mm) dia. bars, length of the hook shall be 3.0” (75 mm) as shown in Figure A1.

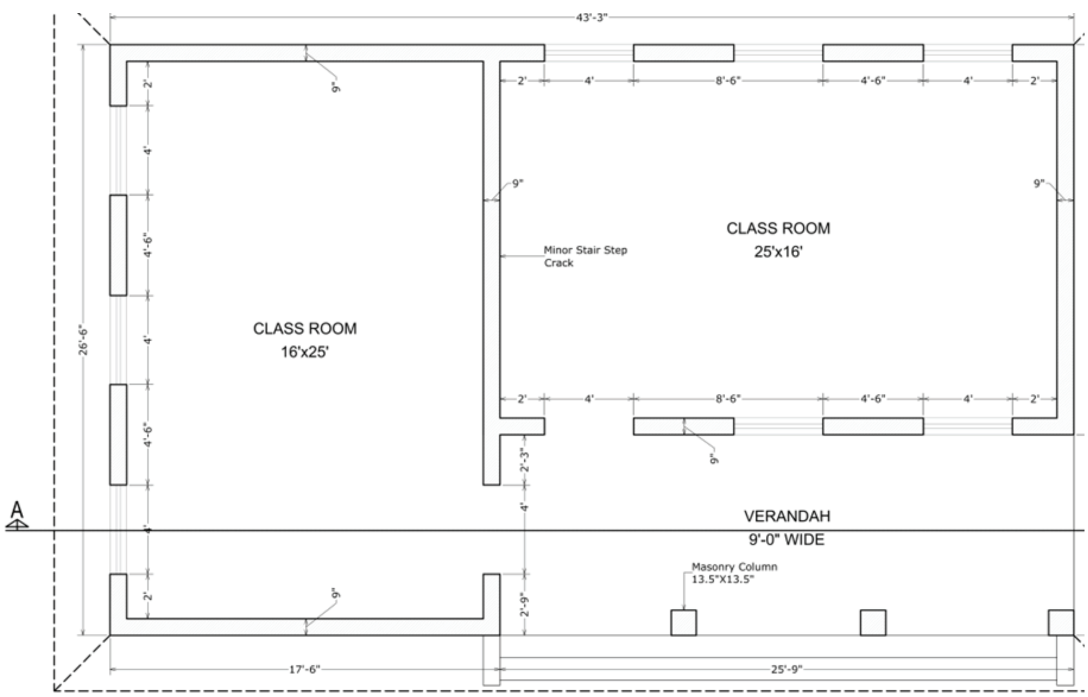
Tolerances: the tolerance in concrete elements shall be according to ACI 117-10.

- For concrete column jacketing, RC splints, bandages and slabs where the thickness is less than 4” (100 mm), the tolerance shall be 1/4” (6 mm)
- For 9” (225 mm) thick bond beam at eave location, the tolerance shall be 3/8” (10 mm)
- Reduction in the concrete cover shall not exceed one third of the specified cover.
- Tolerance in the spacing of ties and stirrups shall 1/2” (12 mm).
- Tolerance in the nominal diameter, calculated based on the weight and length of bar shall be 3.0%. For 1/4” (6 mm), 3/8” (10 mm) and 1/2” (12 mm) bars, the tolerances are 0.008” (0.2 mm), 0.011” (0.4 mm) and 0.015” (0.5 mm) respectively.

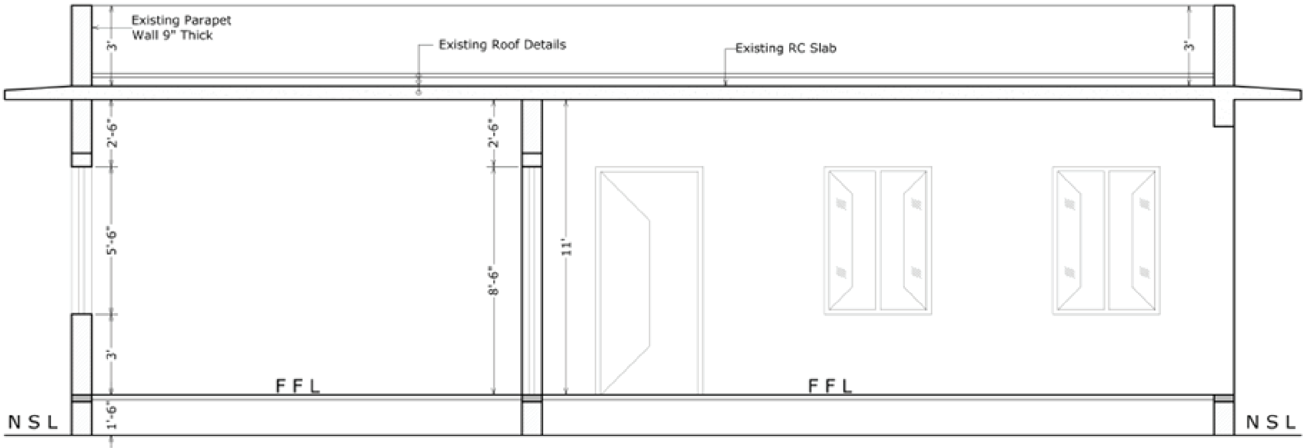
Appendix 9a: Case Study Retrofitting Drawings: Brick Masonry Building

CASE STUDY BUILDING RETROFITTING OF GPS PESHAWAR CITY

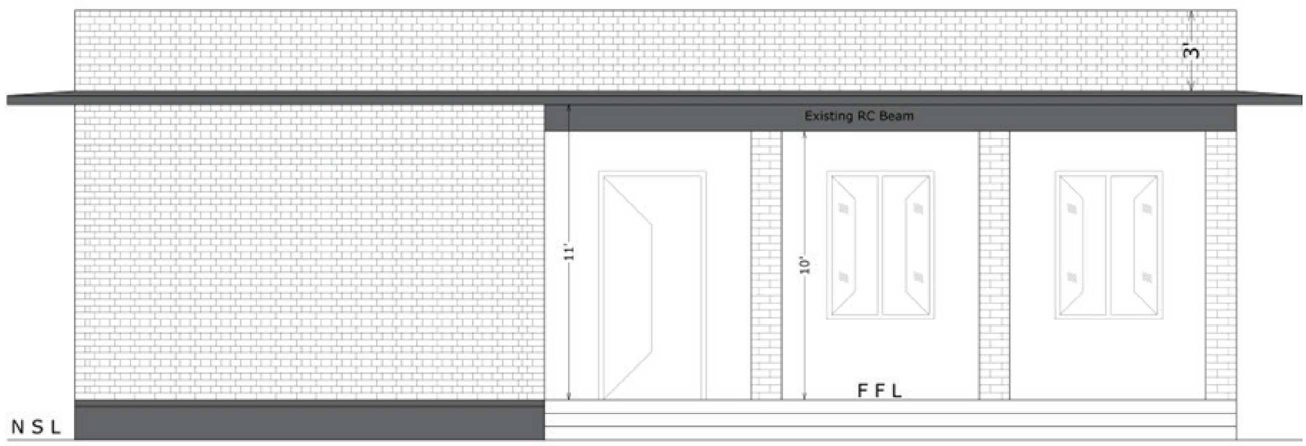
EXISTING DRAWINGS



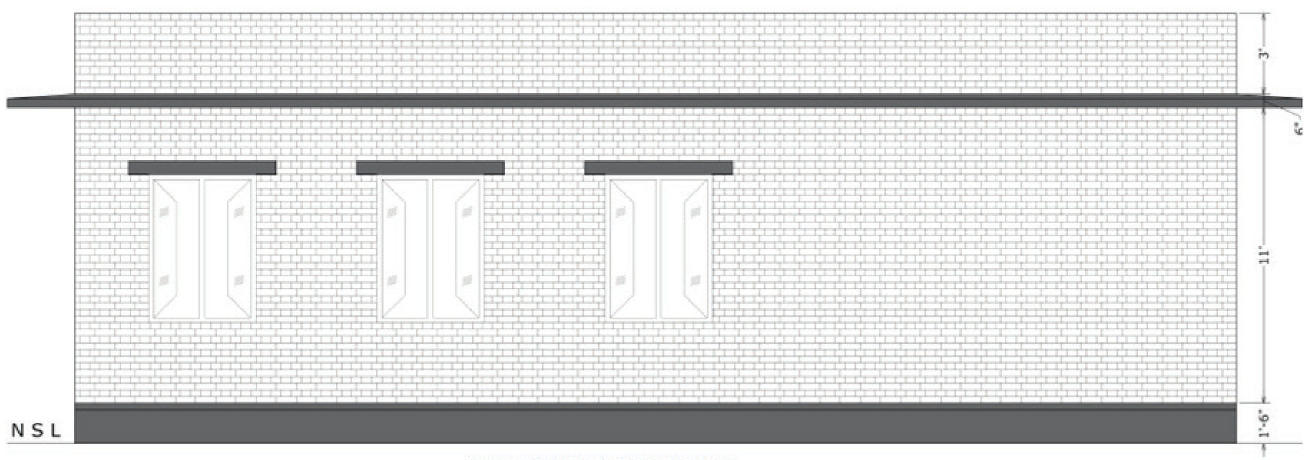
EXISTING PLAN



EXISTING SECTION A-A

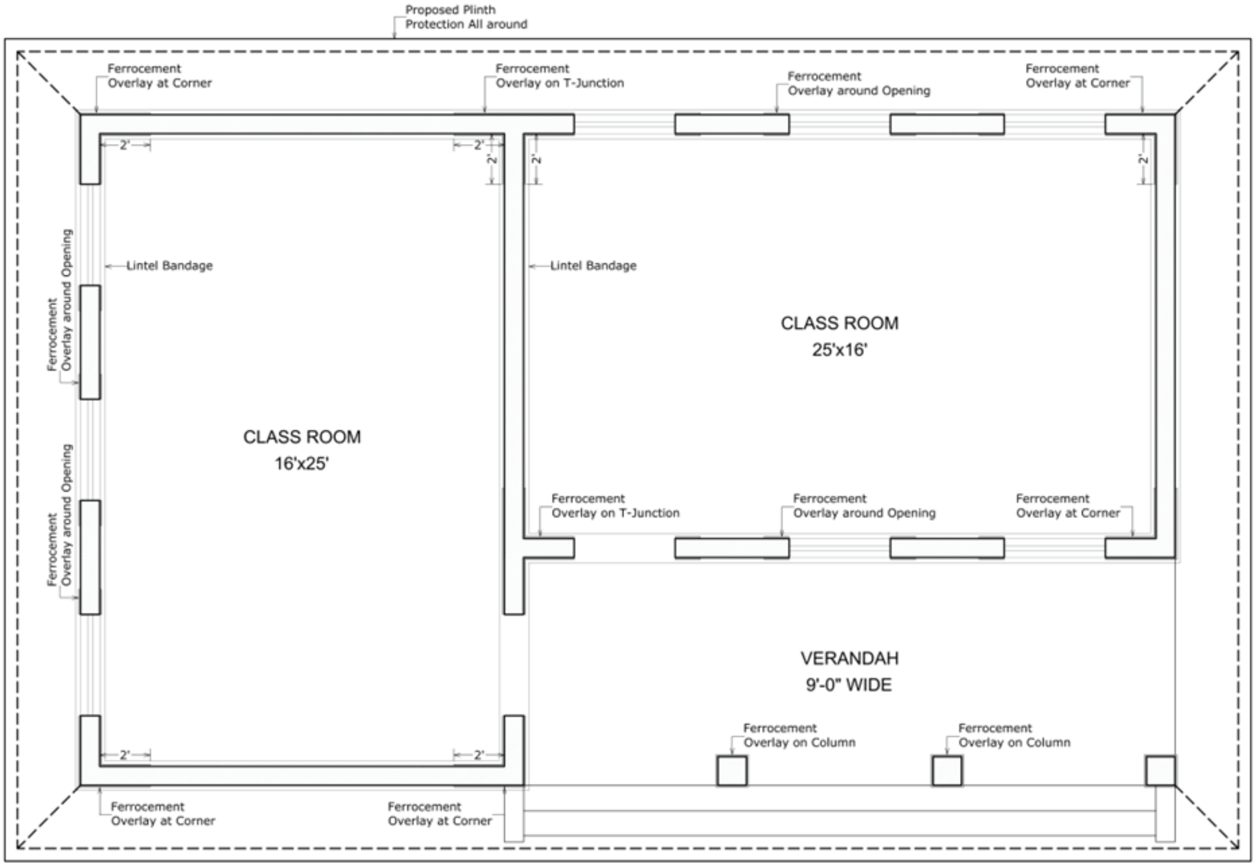


EXISTING FRONT ELEVATION

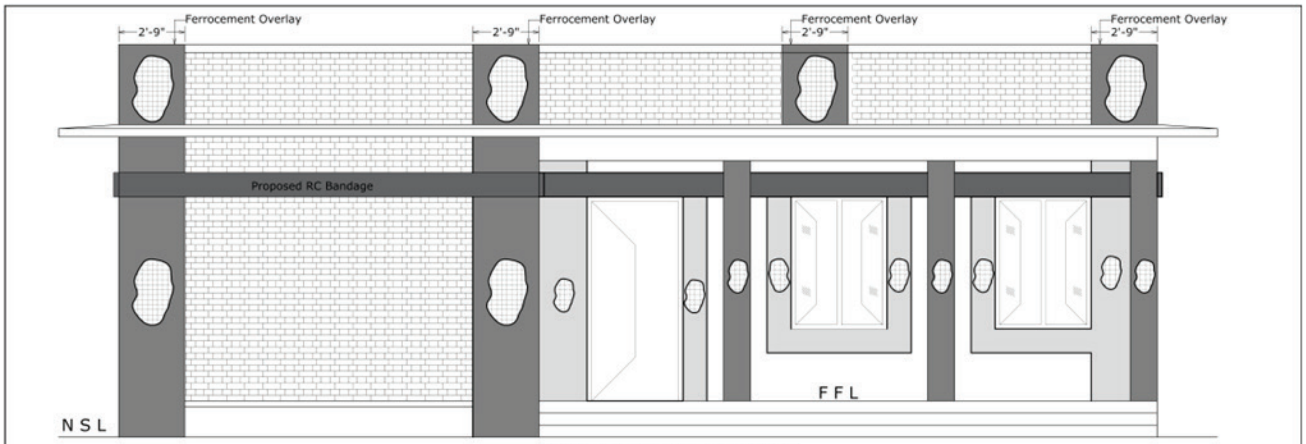


EXISTING BACK ELEVATION

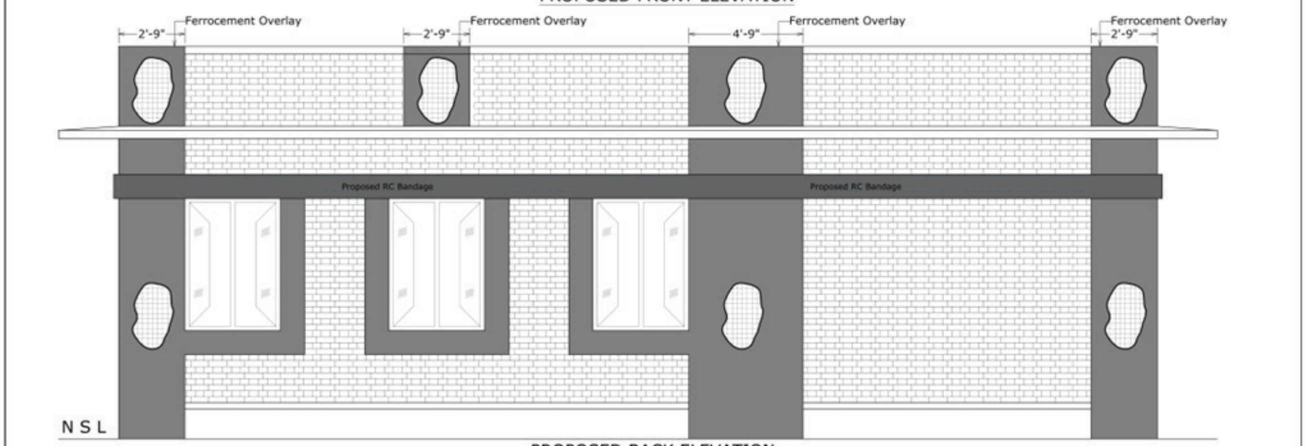
Retrofitting Drawings



PROPOSED RETROFIT PLAN



PROPOSED FRONT ELEVATION



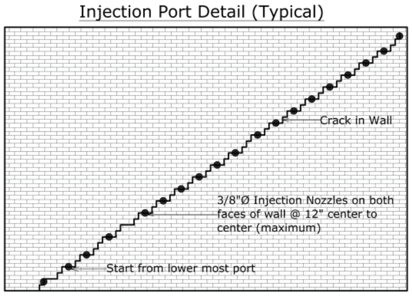
PROPOSED BACK ELEVATION

TYPICAL DETAIL OF GROUT INJECTION

SPECIFICATION FOR GROUT INJECTION:

- All cracks in masonry walls shall be filled with cement based grout injection from both sides of walls.
- Injection grout shall be prepared by weight as 10 parts of Portland cement, one part of lime and ULTRA expansion grout @ 250 g per 50 kg bag of cement with water cement ratio of 0.9. Any equivalent ready to mix grout may be used.
- The injection nozzles shall have a diameter of 3/8" and length of 4" (100 mm). Threads for the stopper shall be provided at outer end of the injection ports.
- The distance between the injection ports shall not be greater than 12" (300 mm) for cracks with thickness exceeding 1/4" (6 mm) and 6" (150 mm) for cracks below 1/8" (3 mm) thickness.
- Injection nozzles shall be fixed in pre-drilled holes with fast binding ready-to-mix mortar. The depth of drilled holes shall be greater than half of the wall thickness.
- Initially the injection pressure shall be kept about 2 bars. When the flow of grout stops, the pressure shall be gradually increased to about 4 bars. The pressure shall be kept applied for a couple of minutes to consolidate the grout.
- Inspection cores of 2" (50 mm) diameter shall be taken, at least one from each component and at location where internal cavities are suspected, to insure proper injection in the field.
- Prepare grout mix just before injection. Grout shall be continuously agitated during injection. The injection shall be started from the lower most nozzle and continue in the upward direction. Grout coming out of other ports shall be plugged with stoppers.

Injection Port Detail (Typical)



The following steps shall be followed to ensure proper consolidation and bonding of cracks within masonry walls:

A. Surface Preparation:

- Remove existing plaster from both faces of the wall along the cracked area.
- Clean and repoint the cracked joints by removing all loose or deteriorated mortar and refilling with fresh mortar.

B. Nozzle Installation:

- Drill holes along the cracks at specified spacing:
  - 6" (150 mm) for cracks narrower than 1/8" (3 mm).
  - 12" (300 mm) for cracks wider than ¼ (6 mm).
- Install injection nozzles (Figure 4.1a) securely using a fast-setting mortar (Figure 4.1b).
- The depth of each drilled hole should be at least half the wall thickness.

C. Surface Sealing:

- Apply a ferrocement overlay or equivalent sealing layer on both wall faces to confine the masonry and prevent grout leakage during injection (Figure 4.1c).

D. Pre-Injection Preparation:

- After about 14 days (when overlay gains strength), flush clean water through the ports starting from the top to bottom (Figure 4.1d):
  - Moisten the masonry,
  - Verify connectivity between ports, and
  - Remove dust and debris.
  - Saturate the wall by surface watering 24 hours before injection to reduce suction and improve grout penetration.

E. Grouting Operation :

- Prepare grout immediately before use and keep it continuously agitated during injection.
- Start injection from the lowest nozzle, proceeding upward. Seal each port as grout emerges from the next one.
- Begin injection at approximately 2 bars pressure, gradually increasing up to 4 bars when the flow stops. Maintain pressure for several minutes to ensure complete consolidation.

TYPICAL DETAIL OF FERROCEMENT OVERLAY

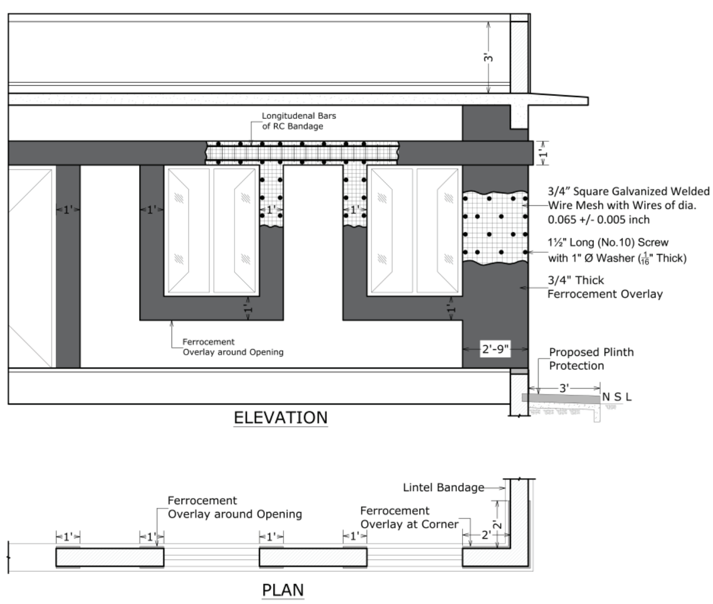
A. SPECIFICATIONS FOR FERROCEMENT OVERLAY:

- **Mesh Size:** 3/4" square hot-dipped galvanised welded wire mesh with wire having dia. 0.065 +/- 0.005 inch (1.65 +/- 0.15mm) and 65 g/m2 zinc coating as per ASTM A641 Class 1.
- **Mesh Wire Strength:** Minimum 30 ksi
- **Screws:** 1.5" (38 mm) or 2" (50 mm) long no. 10 screws spaced at 12 to 14 inch (300 to 350 mm) c/c staggered horizontally and 9 inch (225 mm) vertically. at edges and terminations a line of screws at 9 inch (225 mm) c/c shall be provided.
- **Washers:** 1/16"±1/64 (1.6±0.4 mm) thick, 1.0"±0.2 (25±2.5 mm) in diameter, made with ms steel (astm a36)
- **Plastic Expansion Plug:** compatible with 1.5 inch (38 mm) or 2 inch (50 mm) long and no.10 (3/16 inch, 4.8 mm) screws.
- **Mortar Mix:** The ferrocement layer shall be 3/4"–1" (20-25 mm) thick, composed of Cement–Sand Mortar: 1 part Cement : 3 parts Coarse Sand

B. APPLICATION SEQUENCE FOR FERROCEMENT OVERLAY:

Following steps shall be followed in application of the ferrocement overlay:

- Terminate main electrical connections during execution of retrofitting works.
- Electrical fixtures will be removed where retrofitting work is required, other elec. fixtures, doors, windows & ventilators must be covered with polythene sheet to protect against mortar spills.
- If any electrical conduit damage/broken during the chiseling work, whole length must be replaced.
- Any loose, damaged, or chisel-cut masonry to be removed and reinstated with whole or saw-cut bricks (as required) and fresh 1:4 cement-sand: mortar. no cutting with chisel is permitted.
- Clear the wall surface, remove any loose joint mortar and refill the joint with fresh 1:4, cement-sand: mortar.
- Mark location of drilled holes on masonry wall spaced at 12 to 14 inch (300 to 350 mm) c/c staggered horizontally and 9 inch (225 mm) c/c staggered vertically.
- Connect the mesh with wall surface properly using screws, washers, spacers and plastic expansion plugs as per detail given in the drawings.
- Additional holes may be drilled to avoid wrinkles in the mesh.
- Thoroughly wet the masonry wall surface to saturation by sprinkling water.
- Apply cement slurry to the wall surface before application of plaster.
- Apply first coat of plaster on surface saturated masonry wall to fill gaps between the mesh.
- Apply second coat of plaster after 24 hours to get a smooth wall surface keeping the total thickness of plaster from 0.75 to 1.0 inch.
- Maintain a moist surface of plaster for at least 4 days using hessian and polythene sheet.
- Any existing fixtures, damaged during the retrofitting works, shall be rectified at the contractor's own cost.



Typical Details of Ferrocement Overlay

MATERIAL SPECIFICATIONS:

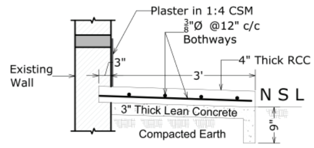
- **Reinforced Concrete:** The 28 days cylinder compressive strength of reinforced concrete in plinth protection and RC bond beam on parapet wall shall be 3000 psi. The maximum aggregate shall be 1/2". Slump shall be 3"-4" (75-100 mm).
- **Lean Concrete:** The 28 days cylinder compressive strength of lean concrete in plinth protection shall be 1800 psi.
- **Micro Concrete in Bandages:** The 28 days cylinder compressive strength of micro concrete in lintel bandages shall be 3000 psi. The maximum aggregate shall be 1/4". Slump shall be 4"-6" (100-150 mm).
- Reinforcement: All longitudinal and transverse bars, and cross ties shall be deformed bars conforming to ASTM A615 Grade-60 with minimum yield strength equal to 60 ksi (410 MPa)

BANDAGE CONSTRUCTION:

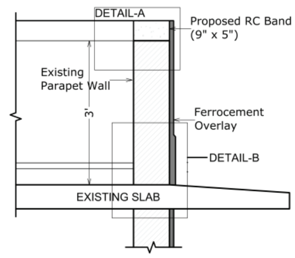
- After fixing the mesh for the ferrocement overlay, mark the hole locations as shown in the drawings and drill 3/8" diameter holes at the marked points.
- Install the longitudinal bars and insert the U-shaped cross ties into the drilled holes as indicated in the drawings. Bend the ends on the opposite side of the wall by 90° to form the required shape. Longitudinal bars shall be provided with 90° bend at the intersection of walls.
- Set up the formwork in the designated areas and place the micro-concrete, ensuring proper compaction and vibration.
- Remove the formwork after a 2-day curing period, and keep the concrete surface moist for at least 7 days by covering it with hessian and a polythene sheet.

CONSTRUCTION OF PLINTH PROTECTION:

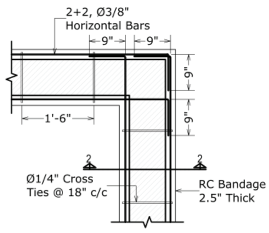
- Excavate the soil around the building to the specified width and depth as shown in the drawings. If any damaged plinth protection exists, dismantle and remove it.
- Level the excavated area and compact the soil surface by hammering.
- Place, level, and compact a 3" thick layer of lean concrete as per the specifications. Ensure the top surface of the lean concrete has an outward slope of 1 in 16.
- After a curing period of 24 hours, fabricate the reinforcement as indicated in the drawings.
- Fix the formwork, prepare the concrete, and place and compact it properly.
- Remove the formwork after 24 hours, and maintain moisture on the concrete surface for at least 7 days by covering it with hessian and a polythene sheet.



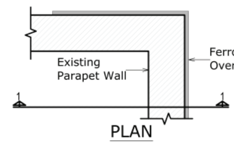
Proposed Plinth Protection



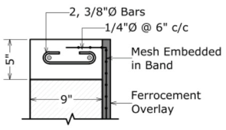
SECTION 1-1
Parapet Retrofitting



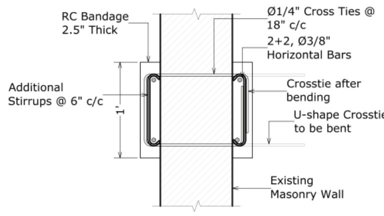
PLAN
Lintel Bandage



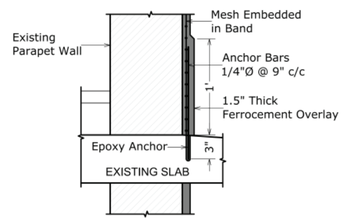
PLAN
Parapet Retrofitting



DETAIL-A



SECTION 2-2
Lintel Bandage

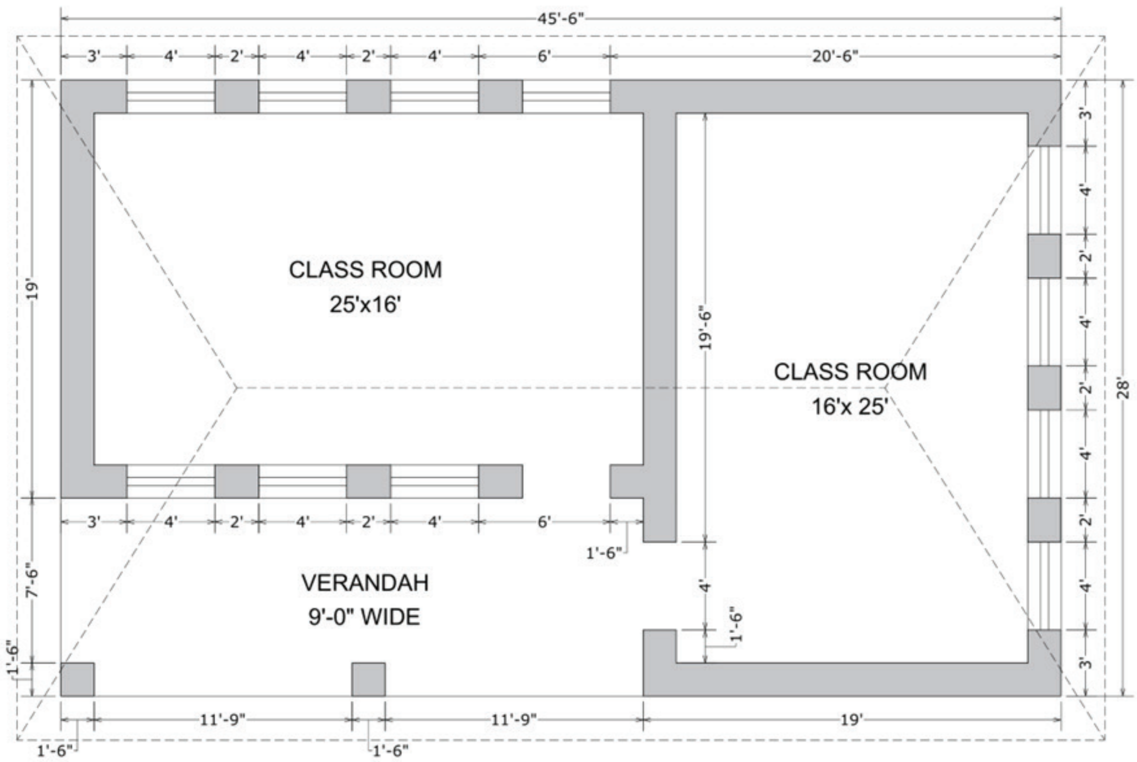


DETAIL-B

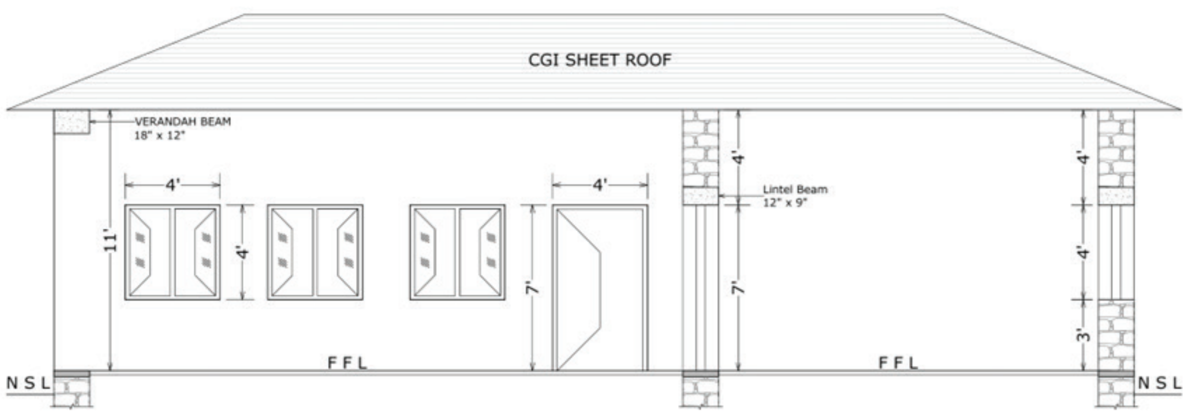
Appendix 9b: Case Study Retrofitting Drawings: Stone Masonry Building

CASE STUDY BUILDING
RETROFITTING OF GGPS GARAM CHASHMA
LOWER CHITRAL

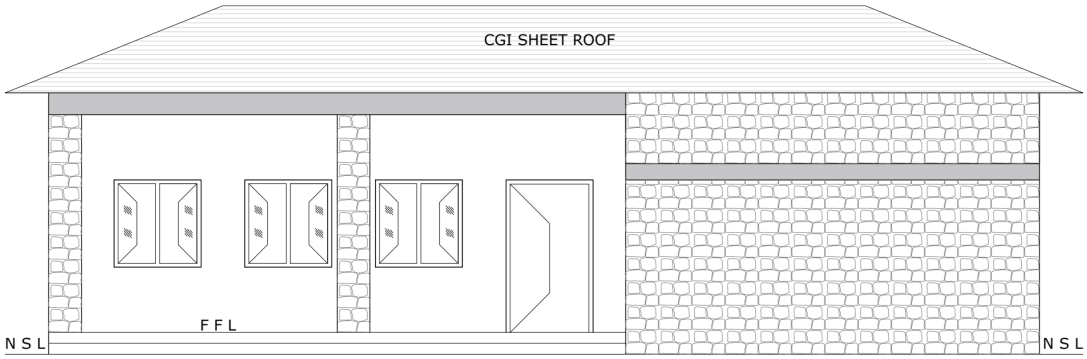
EXISTING DRAWINGS



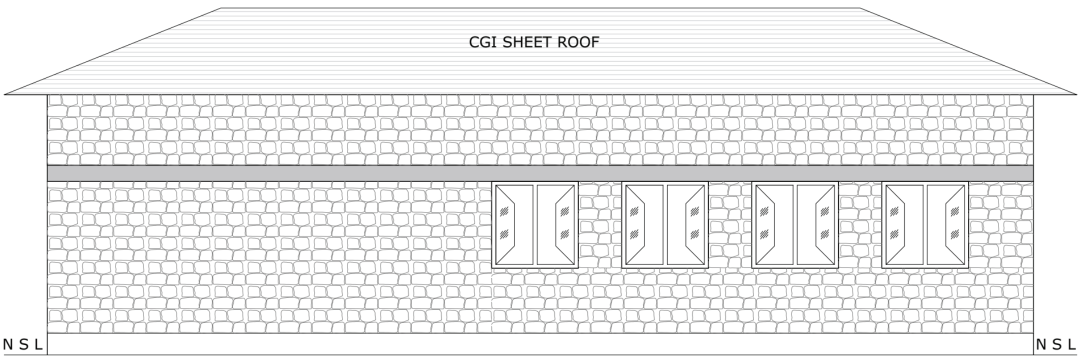
EXISTING PLAN



SECTIONAL VIEW A-A



FRONT ELEVATION

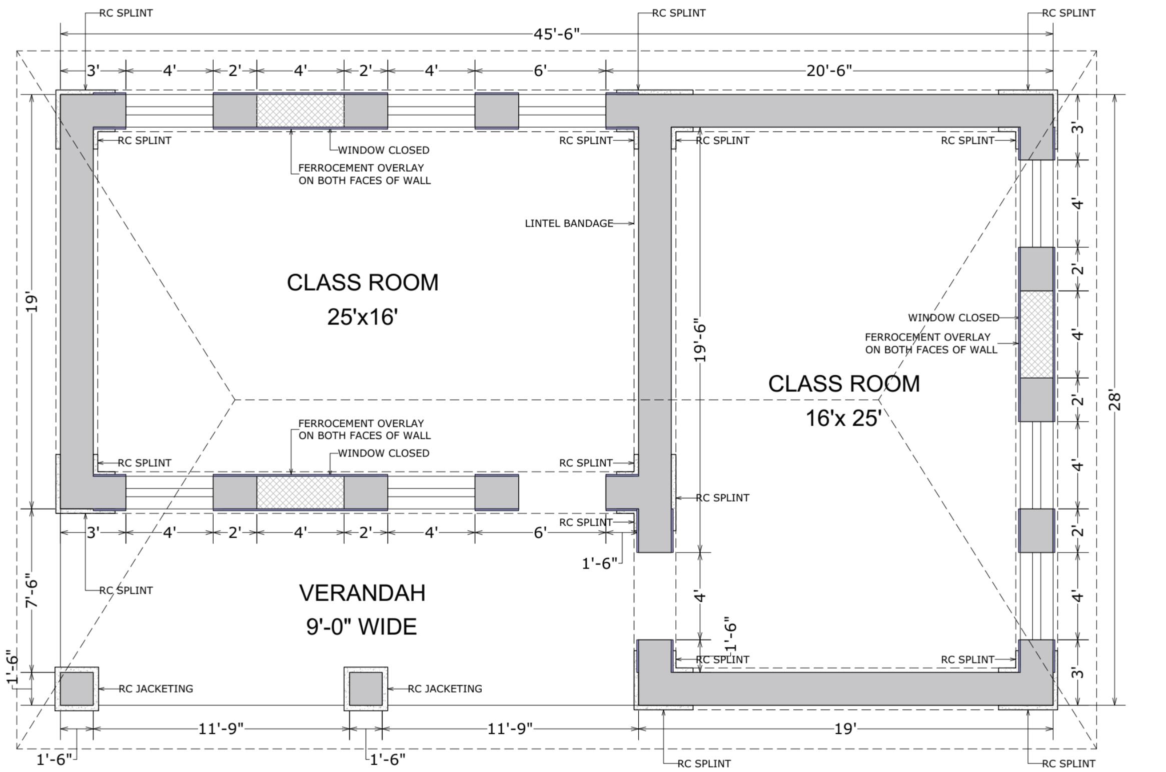


BACK ELEVATION

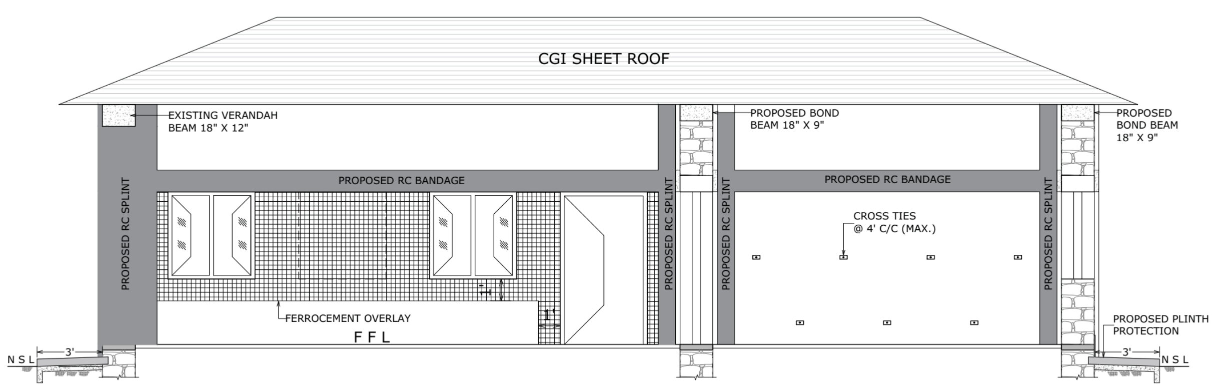
Case Study Building

Retrofitting of GGPS Garam Chashma Lower Chitral

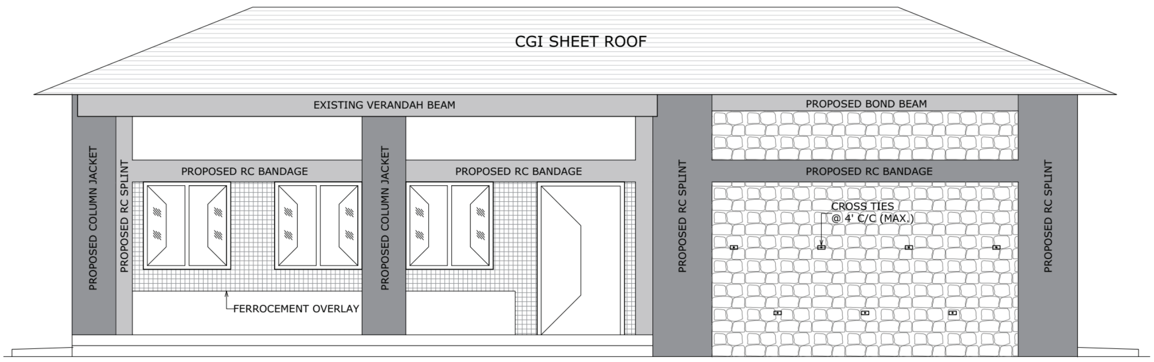
Retrofitting Drawings



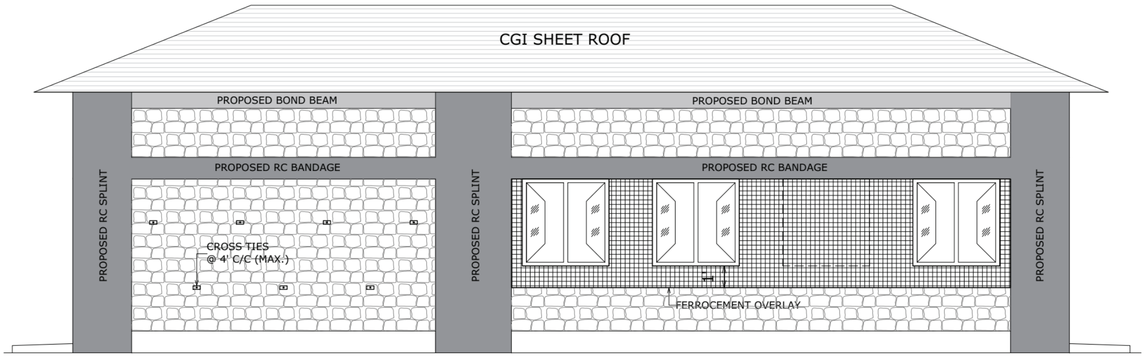
RETROFITTED PLAN



SECTIONAL VIEW A-A (RETROFITTED)



FRONT ELEVATION (RETROFITTED)



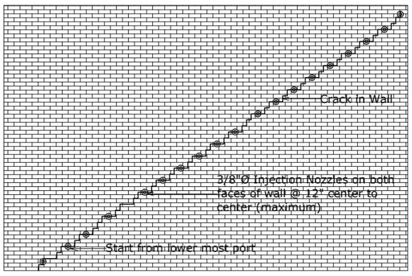
BACK ELEVATION (RETROFITTED)

TYPICAL DETAIL OF GROUT INJECTION

SPECIFICATION FOR GROUT INJECTION:

- All cracks in masonry walls shall be filled with cement based grout injection from both sides of walls.
- Injection grout shall be prepared by weight as 10 parts of Portland cement, one part of lime and ULTRA expansion grout @ 250 g per 50 kg bag of cement with water cement ratio of 0.9. Any equivalent ready to mix grout may be used.
- The injection nozzles shall have a diameter of 3/8" and length of 4" (100 mm). Threads for the stopper shall be provided at outer end of the injection ports.
- The distance between the injection ports shall not be greater than 12" (300 mm) for cracks with thickness exceeding 1/4" (6 mm) and 6" (150 mm) for cracks below 1/8" (3 mm) thickness.
- Injection nozzles shall be fixed in pre-drilled holes with fast binding ready-to-mix mortar. The depth of drilled holes shall be greater than half of the wall thickness.
- Initially the injection pressure shall be kept about 2 bars. When the flow of grout stops, the pressure shall be gradually increased to about 4 bars. The pressure shall be kept applied for a couple of minutes to consolidate the grout.
- Inspection cores of 2" (50 mm) diameter shall be taken, at least one from each component and at location where internal cavities are suspected, to insure proper injection in the field.
- Prepare grout mix just before injection. Grout shall be continuously agitated during injection. The injection shall be started from the lower most nozzle and continue in the upward direction. Grout coming out of other ports shall be plugged with stoppers.

Injection Port Detail (Typical)



The following steps shall be followed to ensure proper consolidation and bonding of cracks within masonry walls:

A. Surface Preparation:

- Remove existing plaster from both faces of the wall along the cracked area.
- Clean and repoint the cracked joints by removing all loose or deteriorated mortar and refilling with fresh mortar.

B. Nozzle Installation:

- Drill holes along the cracks at specified spacing:
  - 6" (150 mm) for cracks narrower than 1/8" (3 mm).
  - 12" (300 mm) for cracks wider than ¼ (6 mm).
- Install injection nozzles (Figure 4.1a) securely using a fast-setting mortar (Figure 4.1b).
- The depth of each drilled hole should be at least half the wall thickness.

C. Surface Sealing:

- Apply a ferrocement overlay or equivalent sealing layer on both wall faces to confine the masonry and prevent grout leakage during injection (Figure 4.1c).

D. Pre-Injection Preparation:

- After about 14 days (when overlay gains strength), flush clean water through the ports starting from the top to bottom (Figure 4.1d):
  - Moisten the masonry,
  - Verify connectivity between ports, and
  - Remove dust and debris.
  - Saturate the wall by surface watering 24 hours before injection to reduce suction and improve grout penetration.

E. Grouting Operation :

- Prepare grout immediately before use and keep it continuously agitated during injection.
- Start injection from the lowest nozzle, proceeding upward. Seal each port as grout emerges from the next one.
- Begin injection at approximately 2 bars pressure, gradually increasing up to 4 bars when the flow stops. Maintain pressure for several minutes to ensure complete consolidation.

TYPICAL DETAIL OF FERROCEMENT OVERLAY AND CROSS-TIES

A. SPECIFICATIONS FOR FERROCEMENT OVERLAY:

- **Mesh Size:** 3/4" square hot-dipped galvanised welded wire mesh with wire having dia. 0.065 +/- 0.005 inch (1.65 +/- 0.15mm) and 65 g/m2 zinc coating as per ASTM A641 Class 1.
- **Mesh Wire Strength:** Minimum 30 ksi
- **Screws:** 1.5" (38 mm) or 2" (50 mm) long no. 10 screws spaced at 12 to 14 inch (300 to 350 mm) c/c staggered horizontally and 9 inch (225 mm) vertically. at edges and terminations a line of screws at 9 inch (225 mm) c/c shall be provided.
- **Washers:** 1/16"±1/64 (1.6±0.4 mm) thick, 1.0"±0.2 (25±2.5 mm) in diameter, made with ms steel (astm a36)
- **Plastic Expansion Plug:** compatible with 1.5 inch (38 mm) or 2 inch (50 mm) long and no.10 (3/16 inch, 4.8 mm) screws.
- **Mortar Mix:** The ferrocement layer shall be 3/4"–1" (20-25 mm) thick, composed of Cement–Sand Mortar: 1 part Cement : 3 parts Coarse Sand

B. APPLICATION SEQUENCE FOR FERROCEMENT OVERLAY:

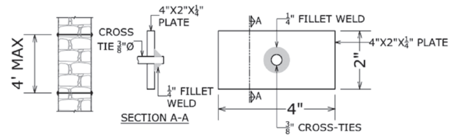
Following steps shall be followed in application of the ferrocement overlay:

- Terminate main electrical connections during execution of retrofitting works.
- Electrical fixtures will be removed where retrofitting work is required, other elec. fixtures, doors, windows & ventilators must be covered with polythene sheet to protect against mortar spills.
- If any electrical conduit damage/broken during the chiseling work, whole length must be replaced.
- Any loose, damaged, or chisel-cut masonry to be removed and reinstated with whole or saw-cut bricks (as required) and fresh 1:4 cement-sand: mortar. No cutting with chisel is permitted.
- Clear the wall surface, remove any loose joint mortar and refill the joint with fresh 1:4, cement-sand: mortar.
- Mark the locations of the cross-ties accurately and install them in accordance with the details provided in the drawings, ensuring proper alignment, spacing, and secure fixing as specified.
- Mark location of drilled holes on masonry wall spaced at 12 to 14 inch (300 to 350 mm) c/c staggered horizontally and 9 inch (225 mm) c/c staggered vertically.
- Connect the mesh with wall surface properly using screws, washers, spacers and plastic expansion plugs as per detail given in the drawings.
- Additional holes may be drilled to avoid wrinkles in the mesh.
- Thoroughly wet the masonry wall surface to saturation by sprinkling water.
- Apply cement slurry to the wall surface before application of plaster.
- Apply first coat of plaster on surface saturated masonry wall to fill gaps between the mesh.
- Apply second coat of plaster after 24 hours to get a smooth wall surface keeping the total thickness of plaster from 0.75 to 1.0 inch.
- Maintain a moist surface of plaster for at least 4 days using hessian and polythene sheet.
- Any existing fixtures, damaged during the retrofitting works, shall be rectified at the contractor's own cost.

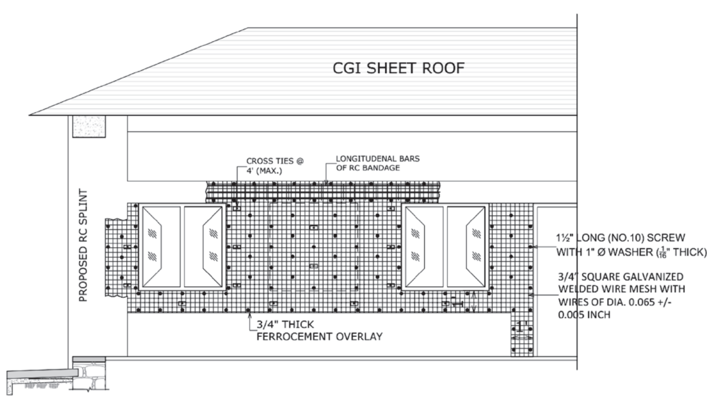
C. APPLICATION SEQUENCE FOR CROSS-TIES:

Following steps shall be followed in application of the ferrocement overlay:

- After removal of the plaster, mark the locations of the cross-ties accurately and install them in accordance with the details provided in the drawings, ensuring proper alignment, spacing, and secure fixing as specified.
- Cross-ties shall be installed prior to the placement of the welded wire mesh, ensuring that they are properly fixed and aligned so as to provide the required support and connectivity as detailed in the drawings.
- Any damage to the stone masonry walls occurring during the installation of cross-ties shall be carefully repaired using stones set in 1:4 cement–sand mortar, ensuring proper filling, bonding, and restoration of the wall to its original strength and condition.



CROSS-TIE DETAIL



MATERIAL SPECIFICATIONS:

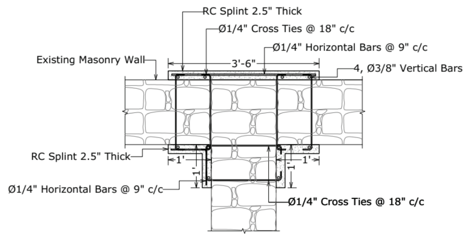
- **Reinforced Concrete:** The 28 days cylinder compressive strength of reinforced concrete in plinth protection shall be 3000 psi (21 MPa). The maximum aggregate size shall be 1/2" (12 mm). Slump shall be 3"-4" (75-100 mm).
- **Lean Concrete:** The 28 days cylinder compressive strength of lean concrete in plinth protection shall be 1800 psi (12 MPa).
- **Micro Concrete in Splints and Bandages:** The 28 days cylinder compressive strength of micro concrete in splints and lintel bandages shall be 3000 psi (21 MPa). The maximum aggregate shall be 1/4" (6 mm). Slump shall be 4"-6" (100-150 mm).
- Reinforcement: All longitudinal and transverse bars, and cross ties shall be deformed bars conforming to ASTM A615 Grade-60 with minimum yield strength equal to 60 ksi (410 MPa)

SPLINT AND BANDAGE CONSTRUCTION:

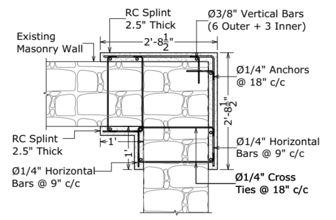
- After fixing the mesh for the ferrocement overlay, mark the hole locations as shown in the drawings and drill 3/8" diameter holes at the marked points.
- Install the longitudinal bars and insert the cross ties into the drilled holes as indicated in the drawings. Bend the ends of cross ties on the opposite side of the wall to the required shape. Longitudinal bars shall be provided with 90° bend at the intersection of walls.
- Set up the formwork in the designated areas and place the micro-concrete, ensuring proper compaction and vibration.
- Remove the formwork after a 2-day curing period, and keep the concrete surface moist for at least 7 days by covering it with hessian and a polythene sheet.

CONSTRUCTION OF PLINTH PROTECTION:

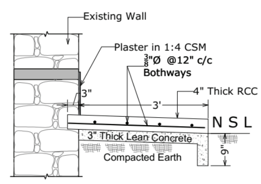
- Excavate the soil around the building to the specified width and depth as shown in the drawings. If any damaged plinth protection exists, dismantle and remove it.
- Level the excavated area and compact the soil surface by hammering.
- Place, level, and compact a 3" thick layer of lean concrete as per the specifications. Ensure the top surface of the lean concrete has an outward slope of 1 in 16.
- After a curing period of 24 hours, fabricate the reinforcement as indicated in the drawings.
- Fix the formwork, prepare the concrete, and place and compact it properly.
- Remove the formwork after 24 hours, and maintain moisture on the concrete surface for at least 7 days by covering it with hessian and a polythene sheet.



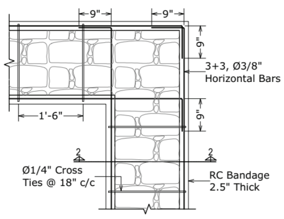
SPLINT DETAIL AT T-JUNCTION



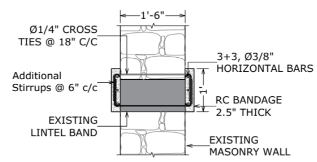
SPLINT DETAIL AT CORNER



PROPOSED PLINTH PROTECTION



PLAN LINTEL BANDAGE



SECTION 2-2, LINTEL BANDAGE

MATERIAL SPECIFICATIONS:

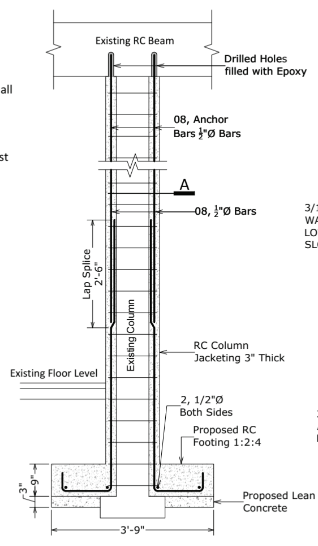
- **Reinforced Concrete:** The 28 days cylinder compressive strength of reinforced concrete in plinth protection and RC bond beam shall be 3000 psi (21 MPa). The maximum aggregate size shall be 1/2" (12 mm). Slump shall be 3"-4" (75-100 mm).
- **Lean Concrete:** The 28 days cylinder compressive strength of lean concrete in plinth protection shall be 1800 psi (12 MPa).
- Reinforcement: All longitudinal and transverse bars, and cross ties shall be deformed bars conforming to ASTM A615 Grade-60 with minimum yield strength equal to 60 ksi (410 MPa)
- The steel to concrete bond strength of epoxy to fix the anchors, under pull-out test, shall be at least 25% more than the specified yield strength of steel.
-

CONSTRUCTION OF BOND BEAM:

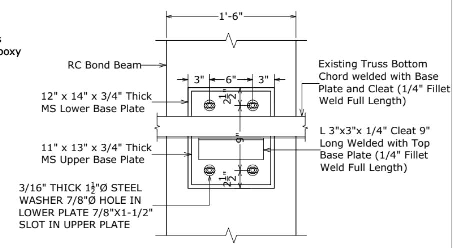
- After completion of wall strengthening, identify the locations of the roof truss supports on the walls and disconnect them from the walls if any anchorage exists.
- Provide temporary supports to facilitate the installation of the jack system for roof lifting, and raise the roof to the required height to create adequate working space.
- Fabricate the reinforcement cages and U-shaped anchor bolts strictly in accordance with the approved drawings, ensuring correct dimensions, spacing, and detailing as specified.
- Fix the formwork in position, prepare the concrete mix as specified, and place it carefully within the formwork, ensuring thorough compaction to achieve proper bonding, strength, and a sound finished surface.
- Remove the formwork after 2-days, and maintain moisture on the concrete surface for at least 7 days by covering it with hessian and a polythene sheet.

CONSTRUCTION OF COLUMN JACKETING:

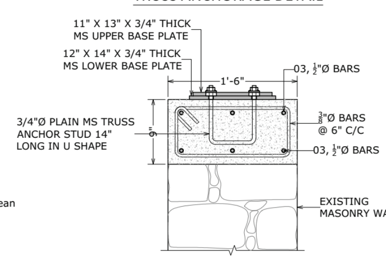
- Remove plaster from the existing stone masonry column.
- Clear the wall surface, remove any loose joint mortar and refill the joint with fresh 1:4, cement-sand: mortar.
- Excavate the soil around the column to the specified width and depth as shown in the drawings. Level the excavated area and compact the soil surface by hammering.
- Place, level, and compact a 3" thick layer of lean concrete as per the specifications. Ensure the top surface of the lean concrete has an outward slope of 1 in 16.
- After a curing period of 24 hours, fabricate the reinforcement as indicated in the drawings. Also fix the anchor bar with bond beam.
- Fix the formwork in position, prepare the concrete mix as specified, and place it carefully within the formwork, ensuring thorough compaction to achieve proper bonding, strength, and a sound finished surface.
- Pour concrete in two stages of height not exceeding 6 ft. Concrete shall be compacted with vibrator.
- Remove the formwork after 2-days, and maintain moisture on the concrete surface for at least 7 days by covering it with hessian and a polythene sheet.



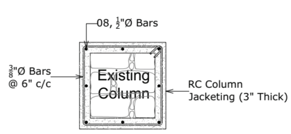
Column Long Section



TRUSS ANCHORAGE DETAIL



BOND BEAM SECTION



Section A-A

UN-HABITAT

UNITED NATIONS HUMAN SETTLEMENTS PROGRAMME

1st Floor, UNMOGIP Building, Plot 5-11, Diplomatic Enclave
Islamabad- Pakistan
Website: https://unhabitat.org.pk