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Ministry of Home Affairs

Manual for Restoration and Retrofitting of Rural Structures in Kashmir

How to Reduce Vulnerability of Existing Structures in Earthquake Affected Areas of Jammu and Kashmir

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Foreword and Acknowledgements

UNESCO's project on Natural Disasters and the Built Environment was initiated by UNESCO New Delhi in cooperation with UNESCO Islamabad in November 2005, following the tragic earthquake of October 2005. The project began with documentation and assessment of the damage to the built environment undertaken in collaboration with Ritsumeikan University of Kyoto, Japan, INTACH Jammu & Kashmir Chapter and students from the Bangalore School of Architecture. As a result of this initial reconnaissance, UNESCO identified the need to discuss and display a practical approach to the restoration and retrofitting of Kashmir's rural buildings.

UNDP and its Disaster Management Team (UNDMT) joined as a key partner in this initiative. UNDMT has been working in tandem with the Government of India to evolve a National Disaster Management Plan to combat natural disasters. The major goal of the UN mission in India has been to advocate for a reduction in vulnerability and engage with the Government of India in building capacity for disaster preparedness and management, thus reducing the incidence of complex emergencies and natural disasters and promoting sustainable recovery and transition after they occur. In this regard, UNDMT has been involved in relief, rehabilitation and capacity building programmes in Disaster Risk Management in earthquake prone states such as Gujarat and Kashmir, and has undertaken a large number of training workshops on repair and retrofitting of the built environment with the guidance of Prof. A.S. Arya, National Seismic Adviser to the Government of India.

International experts in seismic engineering and cultural heritage from around the world gathered in March 2006 to discuss and review a first draft of the present *Manual for Restoration and Retrofitting of Rural Structures in Kashmir* commissioned by UNESCO and prepared by the National Centre for People's-Action in Disaster Preparedness (NCPDP) of Ahmedabad. A UNDP/UNESCO workshop for engineers in Kashmir, held in June 2006 in Srinagar and supported by the Government of Jammu and Kashmir, helped to focus the manual on the composite rural structures of Kashmir. As a result the manual concentrates on buildings mainly constructed with load bearing stone and brick masonry with reminiscent of the traditional *Dhajji Dewari*, *Taaq* and wood constructions, altered and added to with non-traditional interventions such as concrete walls, floors and corrugated iron roofs. These mixed non-engineered structures are highly complex in their reaction to earthquakes and particularly dangerous for the people living in them. There is an urgent need for an engineers' analysis to understand their potential reaction to earthquakes, as well as an initiative to retrofit them for better earthquake performance in order to help reduce the risk of these structures collapsing and people dying under the rubble.

This manual is based on the experience gathered by the NCPDP team during several months of visiting the earthquake areas of Kashmir following the 2005 earthquake, as well as earlier visits to the earthquake shaken regions of Maharashtra, Uttarakhand, and Gujarat. During these visits, the team worked with the local population on the assessment of the damaged buildings, their restoration and retrofitting. The case studies displayed were developed with the kind support of Aga Khan Development Network (Daki in the Uri region of Kashmir) and the Building Materials and Technology Promotion Council (BMTPC), Government of India (Sub-District Hospital in Kupwada).

We would like to express our gratitude to the many institutions and individuals who generously supported this project, starting with Prof. Arya for his continuous guidance; the master building artisans Ustaad Nazir Ahmed, Ustaad Jalil Ahmed and Ustaad Mohmed Khalil and their teams, who retrofitted the Sultan Daki School; the J&K State Government for their partnership in the training of engineers, as well as the Ministry of Home Affairs, Government of India, for their assistance and cooperation in this effort. Thanks also go to the students of Bangalore School of Architecture, Mr Dakshath M Kidiyoor, Mr Kartnik Balla and Mr Rahul Kumar, to Mr Saleem Beg and Mr Hakim Sameer of INTACH J&K and the members of the UNDP team, Mr Sushil Kumar, Mr Sushil Chaudhary, Ms Ranjini Mukherjee and Ms Shafali Rajora. I also wish to thank my colleagues of the UNESCO team, Dr Ahmed Fahmi, Dr Rohit Jigyasu and Ms Nicole Bolomey. Last but not least, our deep appreciation goes to the authors of this manual, Mr Rajendra and Mrs Rupal Desai of NCPDP. The knowledge they have brought to bear from many years of research and field work has enabled UNESCO to disseminate through this publication the lessons learned from Kashmir. We hope they will be widely used by engineers, architects and construction companies as well as by the government officials concerned, to ensure together the future safety of the people who live in the beautiful region of Kashmir.

Minja Yang
Director and Representative
UNESCO New Delhi Office

1 July 2007

Preface

This manual has been prepared to assist in the restoration and retrofitting of structures located in the rural areas of earthquake affected Kashmir, situated in the northernmost area of India and in Pakistan. The earthquake that struck this area on 8 October 2005 destroyed and damaged several thousand houses and killed around one hundred thousand people.

The Kashmir region has witnessed frequent earthquakes in the past. But this earthquake demonstrated how extremely vulnerable the buildings in this region are. It also showed that when people build houses they do not seem to be aware of the threats posed by earthquakes.

As has been observed in other earthquakes, people are unable to assess the root causes of earthquake destruction. The 2005 earthquake shook the confidence of many Kashmiris in local building materials, and even in the techniques they had been using to build houses for centuries. The immediate reaction has been a strong desire to abandon traditional architecture and building systems and adopt cement- and steel-based construction, without understanding the long-term consequences as well as the viability of such introduced systems in the local context.

Some structures were totally destroyed by the earthquake. But many more were left standing, either damaged to varying degrees or with no damage at all. People in slightly damaged houses are likely to simply patch up the damage and continue living in them. But those in moderately damaged houses often think that these are beyond repair and thus want to demolish and rebuild them. Two main questions arise: 1) Is it really necessary to tear such a building down? 2) Are there enough resources and adequate knowledge to build a new earthquake-resistant structure? Financial assistance has been made available from a variety of sources, but the knowledge to assess the extent of the damage, to take decisions about restoration or new construction, and finally to decide on how to retrofit the existing structure or how to build a new earthquake resistant structure, is missing. This leads to a vicious circle in which post-earthquake construction perpetuates the vulnerability of buildings and their inhabitants to earthquakes.

There are simple ways to reduce the vulnerability of surviving buildings through a process known as retrofitting. This technique can be applied to buildings that appear to be severely damaged on account of delamination or collapse of their masonry walls, but whose roofs are completely intact and in place. In the absence of an awareness of the retrofitting option, most house owners will dismantle these houses at great cost and try to rebuild, usually at an even higher cost. This entails a huge and irrecoverable economic loss for the area, while people may end up with houses that are smaller and quite possibly unsafe.

Apart from being more cost-effective than rebuilding, retrofitting offers important advantages that make it a viable and attractive option. It can be done in phases depending upon the availability of funds, beginning with making a part of the house safer for immediate occupation. This eliminates the need for a temporary shelter. In addition, the expense of demolition and debris removal is completely eliminated and the cost for new material substantially reduced. Finally, by transporting less material, the process of post-earthquake reconstruction becomes more ecologically viable.

Kashmir is a seismically active area, and earthquakes big and small will continue to occur. It is not possible to predict when and where an earthquake will strike, nor its intensity. It is therefore hoped that this manual will be useful to engineers, architects, contractors, masons and people who may be planning to retrofit existing houses and public buildings to reduce their vulnerability to future earthquakes.

The retrofitting measures recommended in this manual are compatible with the sustainable use of the most commonly observed materials in the existing built fabric in rural areas. The manual does not focus on traditional structures but looks at the practical implications of the existing mixed types of constructions commonly observed in Kashmir today. Furthermore, at this stage of housing rehabilitation in the areas affected by the 2005 earthquake, newly built houses which do not conform to the code requirements for earthquake safety could be made less vulnerable to future earthquakes through the application of these retrofitting measures.

It is important to note that the recommendations for restoration and retrofitting given in this manual are intended for the most common composite structures in rural areas of the State that were affected by the 2005 earthquake. These measures are not designed for the basic conservation of traditional and vernacular heritage buildings.

This manual is based on (a) a study that was undertaken immediately after the earthquake by a team of experts from NCPDP; (b) retrofitting work carried out in the earthquake affected area by the same team, on behalf of Building Materials and Technology Promotion Council (BMTPC), Government of India and Aga Khan Development Network (AKDN); (c) the *Guidelines for Repair, Restoration and Retrofitting of Masonry Buildings in Earthquake Affected Areas of Jammu & Kashmir*, issued by National Disaster Management Division, Ministry of Home Affairs, Government of India. The preparation of this manual was given a firm foundation by the team's practical experience over the past one-and-a-half decades in retrofitting hundreds of vernacular structures in widely differing regions of the country, including Maharashtra, Uttarakhand, Gujarat and Kashmir.

The manual contains sketches and detailed instructions that will be required by the engineer as well as the contractor. It also contains two case studies of buildings that were restored and retrofitted, to facilitate better understanding of the concepts and the system. Finally, to save the reader from having to search for the government's guidelines on new construction as well as retrofitting, a condensed version of these is provided in tabular form along with useful quantitative information. It is hoped that all this information will be put to use to reduce the vulnerability of all buildings that have not been built to withstand any future earthquakes in Kashmir.

Rupal Desai
Rajendra Desai
NCPDP

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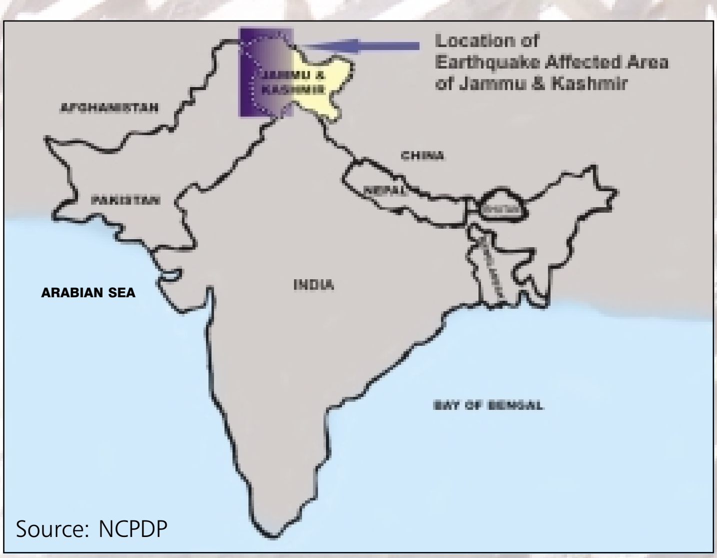
Chapter 1 Introduction to Area



Source: NCPDP

Kashmir is a region well-known around the world for its natural beauty and handicrafts. It is situated in the northern-most corner of the subcontinent with China along its eastern and northern boundaries. Since 1947 when India and Pakistan came into existence, the parts of Kashmir contiguous with Pakistan have been under Pakistan control and the rest have been under Indian control.

Access

Kashmir is reached from other parts of India by air, rail and road. Rail service, however, at present is up to Jammu, beyond which the other parts of the state are reached mainly by road. Although the main urban centres and the tourist centres are well connected by paved all-weather roads, far off places have unpaved steep roads. The hilly areas frequently experience landslides that block the roads for up to several days. Beyond these roads many villages are reached by foot or on horse. This involves negotiating steep hilly terrain along narrow footpaths often involving elevation gain or loss of a couple of thousand feet. In many places the access from the nearest motorable road is across a river that is crossed by either a pedestrian bridge or a manually pulled trolley suspended from a steel cable. House construction activity often involves complicated logistics since the materials are carried on a mule or on human back. This adds substantially to the time and the cost of construction.

Chapter 2 Rural Architecture of Kashmir

Rural buildings in Kashmir are generally made by the people for their own use without the help of architects. The various forms of construction have evolved over time with the input of each generation of artisans. Traditional rural buildings use locally available materials and skills.

2.1 Evolution of Constructions in Rural Kashmir

Rural buildings constructed in a traditional way by the people (often referred to as vernacular buildings) become an integral part of the local cultural heritage. These buildings often reflect the strength of the community to house itself independent of any outside intervention. They are a manifestation of architectural systems optimized over time for a particular context with regard to climate, soil or the threat of natural disasters. Constructed from local materials with local skills and a deep understanding of local social and economic constraints, traditional architecture is in many aspects sustainable architecture.

Traditional architecture in many places continues to evolve, and Kashmiri rural architecture is no exception. A number of building systems in various parts of Kashmir have developed over time to accommodate local natural and cultural factors, including the impact of earthquakes. These systems are not only part of the cultural heritage of Kashmir but also add to its beautiful landscape. Historically, the buildings have depended completely upon stone, mud, bricks and wood for roofing as well as walling. Until very recently, non-local materials did not represent a valid option for local constructions. They were expensive, and their use added logistical complications to the construction process. However, in recent times new materials have made their way into the valleys of Kashmir on account of their favorable economics as well as people's aspiration to modernity.


CGI roofing on timber with walls of wood planks and logs


Traditional flat mud roof on timber understructure with stone masonry walls

Until the 1970s the most common building systems in Kashmir were brick or stone walls. Some of them timber framed, with timber and mud roofs. But as durable wood like Deodar became very expensive, corrugated galvanized iron (CGI) sheets came to replace wood planks and shingles. In areas where it is easy to transport these sheets, the change has been so far-reaching that CGI sheeting now constitutes the most common form of roofing in the region. Even in areas where just twenty years ago houses were mainly built with flat mud roofs, CGI sheets have become the predominant roofing material. Apart from this, the reinforced concrete (RC) slab is gradually replacing the timber floor and load bearing masonry walls are replacing the timber framing. Again, changing economic forces as well as people's aspirations to a more contemporary lifestyle are encouraging such changes.

Architecture constantly adapts to suit the changing context so that it can best meet the common person's needs. There is, however, a risk that new materials and construction methods imported from outside may be introduced at a speed that does not allow for the traditional way of testing novelties over time and adapting them to the local situation. Furthermore, the social, climatic, economic and technical impacts of new interventions are often not fully understood, and this may have negative effects on people's lives. These impacts include the reaction of buildings to earthquakes and other natural disasters. RC, for example, is a material that requires a high level of engineering, but the people who use this material often know little about this. This is why, in many cases, new materials and techniques applied in an unprofessional way will threaten the safety of buildings and the people who live in them.

Thatch roofing on timber and burnt brick masonry wall

CGI sheet roofing on timber and burnt brick masonry wall

CGI sheet roofing on stone masonry and timber wall

CGI sheet roofing on timber and stone masonry wall

2.2 Aspects of Rural Architecture

Factors governing the popularity of construction methods and materials are (a) **economics** in relation to people's spending capacity, (b) easy **maintenance** by the common person and (c) effective response to **local natural conditions** such as extreme cold, strong winds or high earthquake risk.

Economics

This is demonstrated most clearly by the use of brick for construction, which is most economical in the plains of the Kashmir Valley, and the use of stone, which is most economical in the hills, on account of their easy availability in the respective areas. The valley has soil that is most suitable to make bricks, baked or unbaked. The mountains, on the other hand, offer very little soil but have lots of stone and rock. When people in the hills consider switching from stone to brick, these economic factors become very relevant. The cost per brick, which is Rs.1-2 in Baramulla town (in the valley), can be Rs.3-4 at a roadside village 60 km away, or even as high as Rs.5-6 in a village a mere 2 km away from the road side where it has to be transported on mule back. Where roofing is concerned, even today CGI sheets have made no inroads where timber is cheaply available and where access to the area is only by foot over long distances and steep terrain. In other areas, cheaper timber varieties with shorter life are gaining acceptability, since the CGI roofing protects such timber from the natural elements and timber no longer gets exposed as it did when it was used for shingles or plank roofing.

Maintenance

Maintenance requires materials and skills. Since these are no different from what is required in construction, the maintenance of rural structures is easy and within the reach of ordinary people. However, if materials from outside the locality were to be used, the maintenance of the structure would become expensive.

Local Natural Conditions

Winter cold is the most common natural factor governing most of Kashmir. Thick walls of brick and stone with mud plaster provide excellent protection against this, as does a thick mud-timber roof. The lighter, pitched roof made of timber and CGI sheets in combination with the attic floor also ensures livable conditions inside the house in winter and summer. The steep pitch of the light roof permits little accumulation of snow and prevents any water leakages.

Wood shingle roofing on timber placed on brick masonry and dhajji walls

2.3 Architecture by Region

From the point of view of architecture, Kashmir can be divided into several regions with the following characteristics:

The Valley of Kashmir - Rural

The major factors that dictate the local architecture are (a) easy access to good soil for brick-making, and to water and timber, (b) snow in winter, and (c) possibility of earthquakes. As a result, walls are made mainly out of timber and bricks, baked or unbaked.

Burnt and unburnt brick masonry walls with CGI roofing on timber

The most common wall types are load bearing: (a) baked brick (external wall) masonry with mud or cement mortar, with or without plaster, (b) unbaked brick (internal wall) with mud mortar and mud plaster, or (c) unbaked brick with baked brick veneer (external wall) masonry with mud mortar, with or without plaster, or (d) *Dhajji* timber framed constructions with infill of baked brick in cement mortar or unbaked brick masonry in mud mortar, both 4" thick with timber frame. Many structures which are typically single- and double-storey have *Dhajji* walls in the upper storey and the gables.

Roofs slope steeply in two directions. Although planks or shingles of hardwood like Deodar were formerly the main roofing materials, today CGI sheets on timber supports have become the most common type of roofing.

CGI sheet roofing dots the scene

Dhajji *wall with baked bricks*

Baked brick wall

Unbaked brick wall with timber element

Unbaked brick with baked brick veneer

The Valley of Kashmir - Urban

The urban areas of the Valley have architecture that is distinct from all other areas. The main factor determining this architecture is the high density of development. This calls for vertical growth, resulting into three to four-storey structures. The two most common walling systems observed are (i) *Dhajji* type, with timber frame and infill consisting of baked or unbaked bricks, and (ii) *Taaq* type, consisting of brick masonry interlaced with heavy timber bands supported on large masonry piers made of baked bricks. The timber frames in the *Dhajji* walls are generally well laid out with a system of diagonal bracings that provide a distinct path to the ground for the stresses caused by lateral seismic forces. In addition, the walls are lightweight and hence have less mass and less lateral seismic loads. Thus this type of wall is able to withstand ground settlement and major earthquakes without suffering much damage. The *Taaq* type of construction has a large number of windows ("*Taaq*" means window), one in each gap between the piers. The roofs are two- and four-sided pitched. The wood shingle roofing that was once used in most structures has been replaced by the CGI sheeting on account of economics and availability.

Structures with *Dhajji* walls, as well as those with the *Taaq* system of construction, are known to resist earthquake forces effectively. Hence, old structures that have withstood many quakes are still standing.

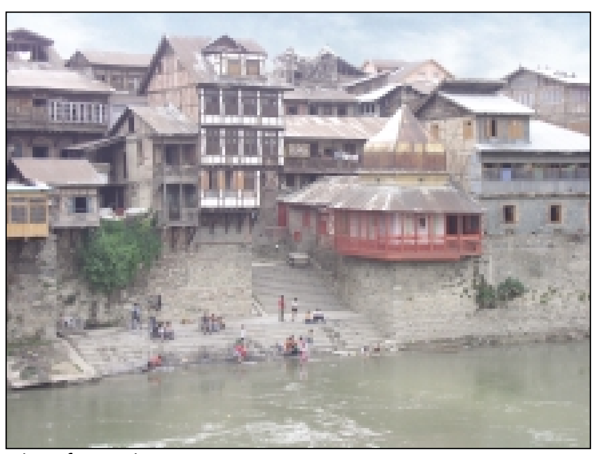
Taaq *type construction*

This manual does not cover the traditional *Dhajji Dewari* and *Taaq* constructions since these have heritage value and thus call for a different approach to restoration and retrofitting than half-modern/half-traditional composite rural constructions.

Four sided CGI roof on un-plastered Dhajji *walls*

House with timber balconies and two sided pitched roof

Taaq *type construction*



River front view

High-Elevation Hilly Regions Surrounding the Valley

The major factors that dictate the local architecture in this zone are (a) easy access to building-quality stone, (b) limited availability of topsoil, (c) varying availability of water, ranging from abundant to very little, (d) better availability of timber than in other zones due to lesser deforestation, (e) difficulty in carting non-local materials, (f) heavy snow in winter, and (g) possibility of earthquakes. The most common wall types are (a) coursed random rubble masonry with or without mud mortar, with or without mud plaster, and (b) *Dhajji* wall made of timber frame with small stones and plenty of mud mortar as infill, mainly for the interior walls. The roof can be sloping or flat. The flat roof, as shown earlier, made with timber understructure supporting the mud and vegetal roofing is often used for summer dwellings in high altitude pastures. It is also used in animal shelters in this region on account of the warmth that it can provide. This type of roofing requires extraordinarily heavy roofing elements on account of heavy snow buildup in winter. More commonly, roofing consists of pitched CGI sheet roof on timber supports, since it encloses a large volume which provides insulation in the cold winters on account of the attic floor.

Four sided CGI roof on random rubble walls

Two-sided CGI roof on timber and random rubble walls

Four-sided CGI roof on timber and random rubble walls

Low-Elevation Hilly Regions (Surrounding the Valley and Other Parts of the State)

The main factors that dictate the local architecture in this zone are (a) easy access to building quality stone, (b) limited availability of topsoil, (c) greatly varying availability of water, (d) varying availability of timber, (e) little snow in winter, and (g) possibility of earthquakes. The most common wall types are (a) coursed random rubble masonry with or without mud mortar, with or without mud plaster, since availability of mud and water vary greatly. Historically, the flat roof has been the most popular on account of low snowfall. Even today, this type of roof is visible in plenty along the Jammu-Srinagar route as well as in many parts of Poonch area. However, the escalating cost of timber along with the easy availability of CGI sheeting has made the latter the most popular roof type in this region also.

Mud roofing on timber deck placed on rubble masonry walls

Coursed random rubble masonry with plaster

Coursed random rubble masonry without plaster

Coursed random rubble masonry without plaster & brick Dhajji *gable*

Coursed random rubble masonry without plaster

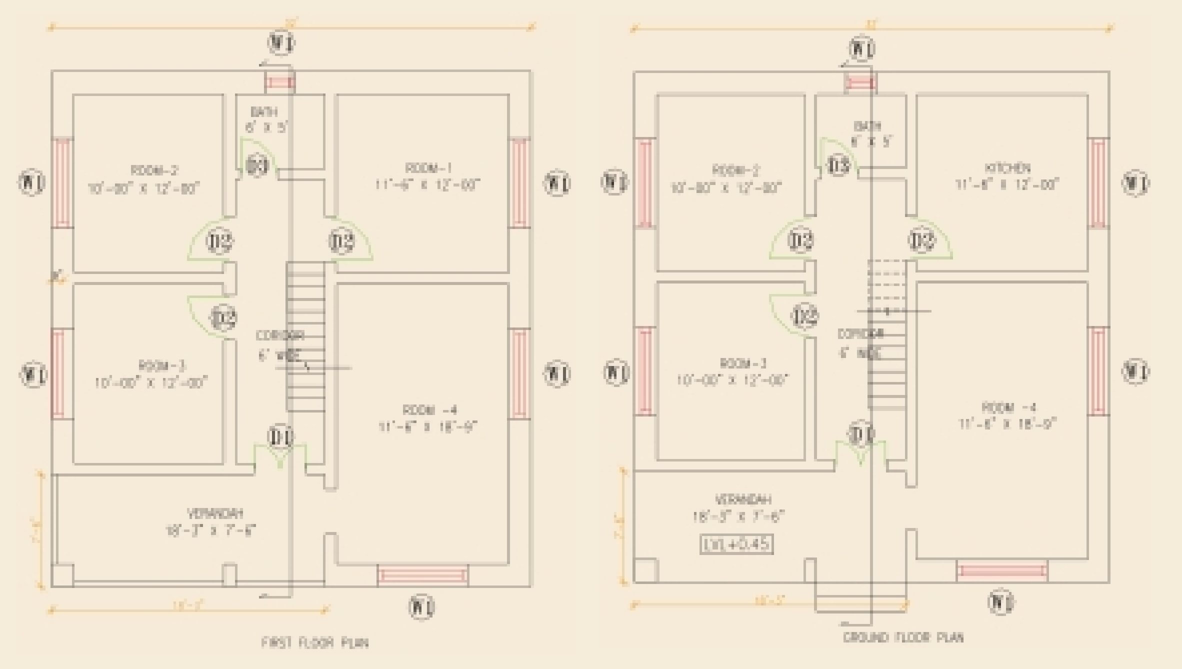
Dhajji *wall in-filled with stone*

Typical Kashmir House in Rural Areas

A typical rural Kashmiri house today is a large two-storey structure, with an aspect ratio generally not exceeding 1.2 to 1.3, with walls that are not plastered from outside and a shining CGI roof that is pitched, with one or more projections. In the ground storey it has approximately four rooms including a kitchen and a front verandah, with a central corridor stretching from the main entrance in front to a large bathroom-cum-toilet in the rear. The stairs lead from the front end of the corridor to the upper storey. The upper storey has a similar arrangement of rooms and passage as found on the ground floor, and also has stairs that lead to the attic. The number of storeys depends on the resources at the disposal of the owner. Unlike in other parts of the country, where rooms are gradually added as and when the need arises, here the basic

Typical house with random rubble wall & CGI roof

Ground and first floor plans



structure is built in one go. But the upper storeys are enclosed and finished at a later date.

The ground-storey rooms are used as a sitting area, bedrooms, and kitchen. The upper storey rooms may be used as for storage as well as bedrooms. On account of the joint-family system with several families living under one roof, there is often more than one kitchen in the house. The attic area is invariably used for storage, since the people are predominantly agriculturists. In the case of single-storey houses, the attic space is often divided with lightweight internal walls to create more utilizable spaces.

Traditionally, timber has been the most used domestic fuel in the region. Wood-burning stoves are made from mud by the lady of the house. An ingeniously efficient water heating system used to be incorporated in the construction of the kitchen wall just to one side of the stove. The system consisted of a copper vessel embedded in the masonry wall with openings for a water inlet and outlet. A cavity is made in the wall such that the hot gases from the stove go round the tank and heat its content. While cooking is in progress the water is heated continuously. In recent years, however, with cooking gas slowly replacing wood, people have been heating water on a gas stove. Electric water heaters have begun to come in, too.

For space heating, traditionally the houses had fireplaces. But today, the simple wood-burning space heating stoves called *Bukhari*, made out of galvanized iron sheets, have become very popular since they do not involve additional expense in construction.

Bukhari space heater

Built-in water heating system in kitchen

Copper tank for water heater ready for embedment in wall

Chapter 3 Earthquake Damage: Types, Process, Categories

Earthquakes leave behind a trail of damage and destruction. People's lives are affected by the loss of loved ones, destruction of property, economic losses, physical hardship and mental agony.

3.1 Earthquake Damage in Load Bearing Masonry Walls: Process

Causes of Earthquake Damage

During an earthquake when a structure is shaking, it gets damaged if it is not sufficiently strong and/or flexible. The extent and degree of damage depend on how weak and/or rigid it is. The type of damage depends on a number of factors including the type, direction and duration of the earthquake forces, the frequency of the ground motion, the natural frequency of the building, the nature of the underground geology and soil deposits, the shape of the structure, the type of building technology, etc.

The Damage Process

Damage to a structure is not an instantaneous event. It occurs over a span of several seconds as a continuous process during the period of earthquake shaking. The degree of damage can range from a low level to a high one that may include partial or total collapse. In this chapter, the range of damages is presented in the accompanying diagrams: First we introduce stages of damage to demonstrate the process leading to the damage. Later, we introduce the generally used system of damage categorisation into grades which indicate the severity of damage.

Figure 1

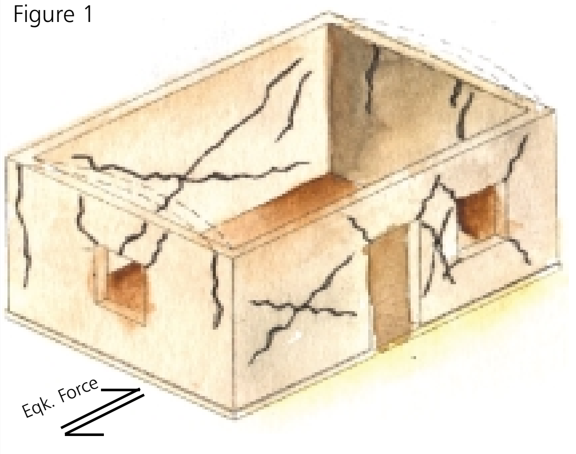
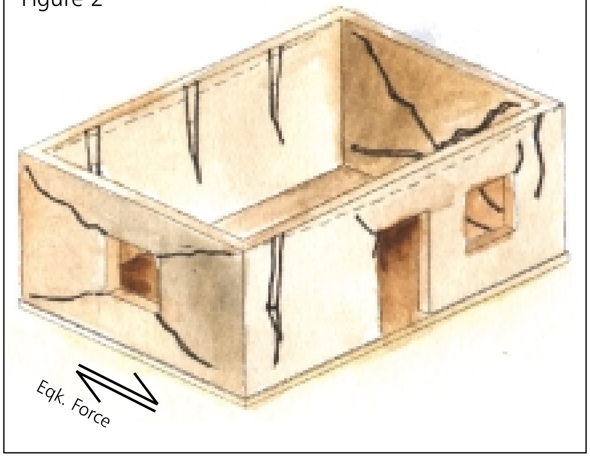


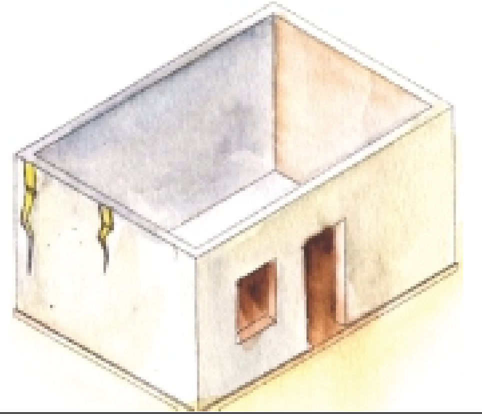
Figure 2



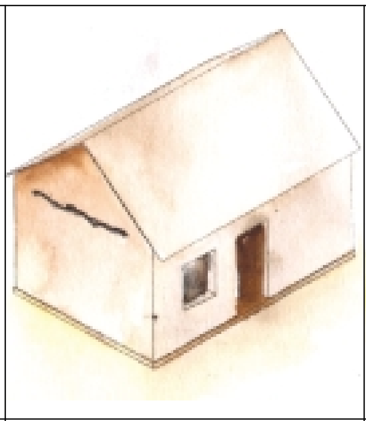
The type of damage in a masonry wall depends largely upon the direction of the seismic forces with respect to the alignment of the wall. Figure 1 and Figure 2 show how the direction of forces affects various walls in a building. Where the forces are perpendicular to a wall, vertical cracks develop in that wall. Where the forces are parallel to a wall, diagonal cracks develop. Thus an earthquake force in a particular direction will cause different types of damage to different walls.

Damage Process: Stage I: Cracks are less than 10mm wide

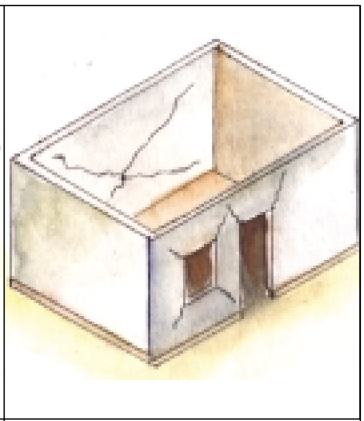
When the intensity of the force is mild and/or the duration of shaking is short, the damage may remain limited to Stage I.



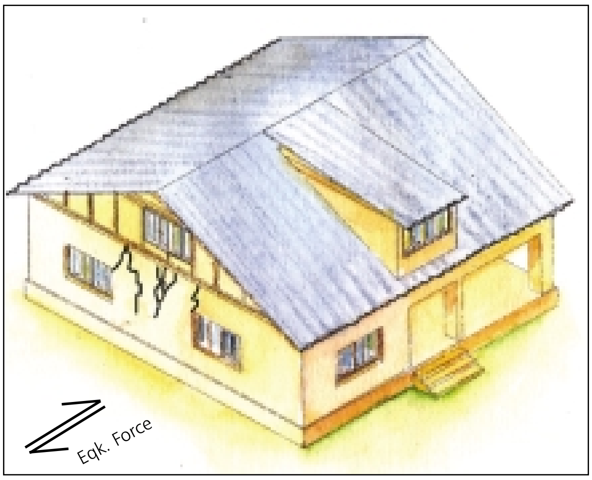
Vertical cracks in the middle of long walls and at corners

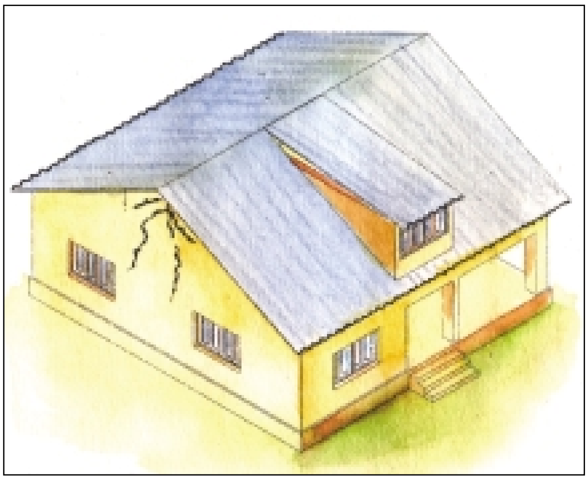


Crack at the base of the gable wall



Diagonal cracks in shear walls and at openings, corners



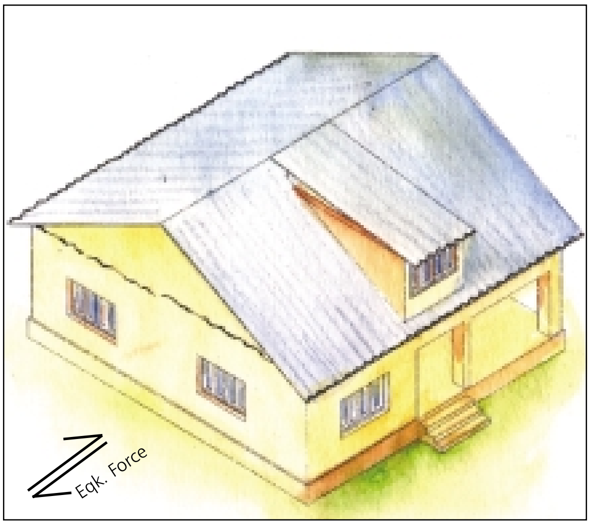


In the Middle of Long or Tall Walls

Walls are held at corners by the adjacent walls. Hence, in an earthquake when the shaking is perpendicular to a wall, its portion away from the corner will shake the most. Such shaking can result in vertical cracks near the mid-length of the wall. The longer the wall the more it will shake, and the greater will be the chances of it cracking and suffering damage. Similarly, if a wall is extra tall it will shake more. Such a wall will develop horizontal cracks when shaken.

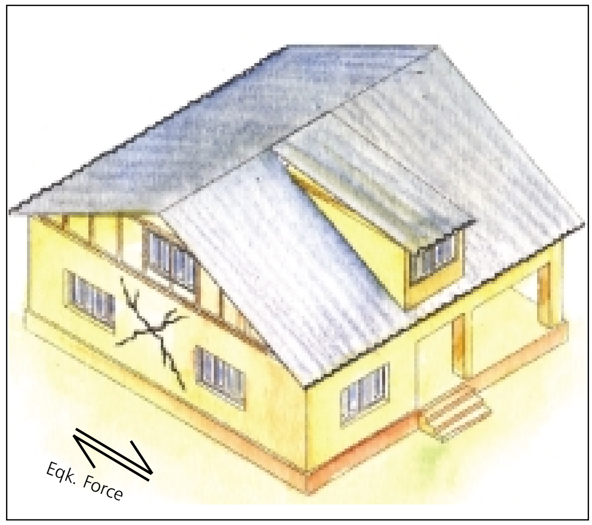
Under the Floor and Ridge Beams (Concentrated load Points) when Supported Directly on Masonry

Since the earthquake force is an inertial force, its magnitude on a particular part of a structure will depend directly upon the mass of that part plus the mass supported by that part. Hence, when a beam from a floor or a roof is supported on masonry wall it exerts a high concentrated lateral load on the wall. This often results in a vertical crack starting downward from the point of beam support embedment.



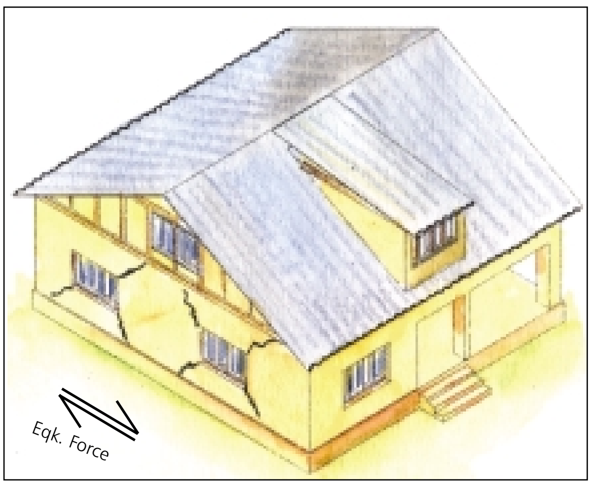
Gable Base

In case of gable wall the triangular part of wall has no restraint. Hence, when the force is in perpendicular direction it shakes excessively. Under such pull and push a crack develops along the base of gable walls. In heavy shaking it can also collapse. This could lead to roof collapse if any roof beam is supported on gable.



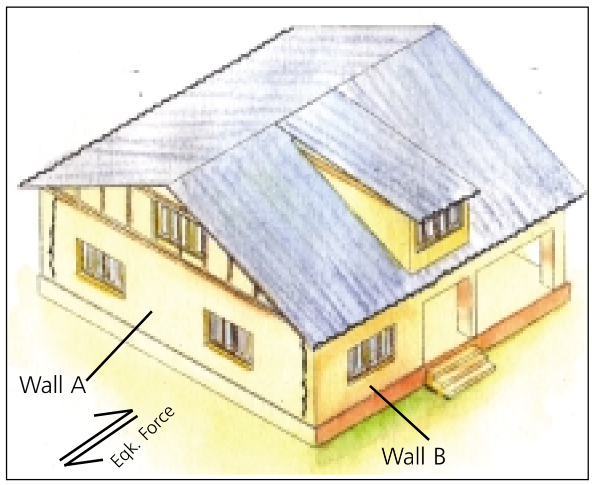
Diagonal Cracks in Shear Walls

When the earthquake force is parallel to the wall, the wall gets so deformed that the diagonal lengthens. This results in to tension along a line perpendicular to the diagonal. Since the masonry wall is weak in tension, it tends to tear along this line.



Diagonal Cracks from the Opening Corners

When the earthquake force is parallel to the wall, there are openings in the wall, they create areas of extra weakness. Hence, the tearing in diagonal direction begins from the corners of the opening.

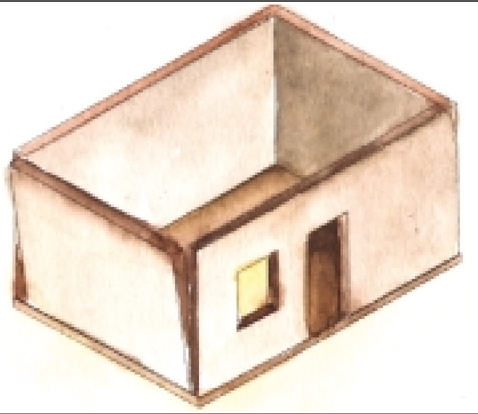


Vertical Cracks at Room Corners

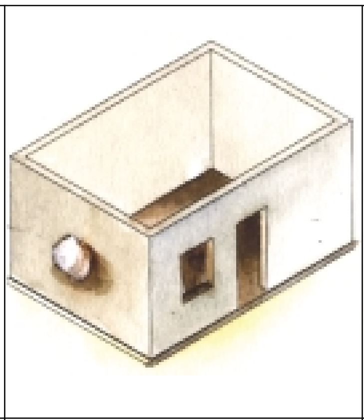
When the earthquake force is perpendicular to the wall 'A' it (the wall) is pushed and bent. At a corner this wall deforms more than the wall 'B' that is perpendicular to it. As a result wall 'B' tends to hold back wall 'A' from bending. This causes tension in wall to wall joint. Generally this joint is weak since one wall is built first with toothing left out for facilitating a connection with the adjacent wall when it is built. Hence, vertical crack develops at the junction of two walls as they separate from each other.

Damage Process: Stage II: Walls going out of plumb or bulging, State of impending collapse

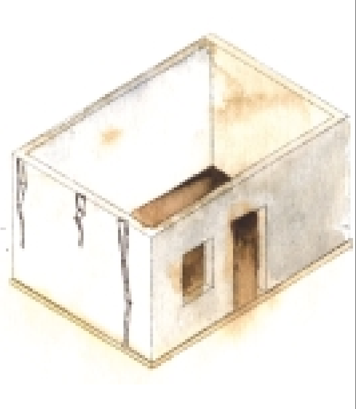
When the intensity of the force is higher and/or the duration of shaking is longer, damage may reach Stage II. The damage is intensified when the construction is of poor quality.



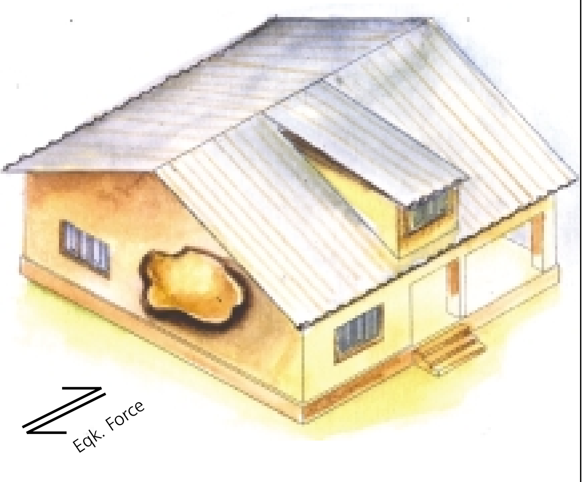
Wall going out of plumb



Bulging of stone wall or thick brick wall



Very wide crack - more than 10mm wide



Walls Going out of Plumb

When shaking increases the crack widens and a part of the wall adjacent to crack goes out of plumb. This happens, especially at weak areas in the wall since the weak spots are not able to withstand the forces generated by shaking. In such a case weaker portion shakes more and then goes out of plumb. This often happens at cracked corners since walls have lost support of each other. It also happens in the upper portion of a long wall near the mid-length since this part of wall has minimum restraint.

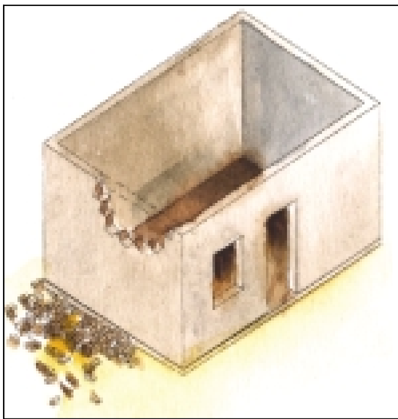
Bulging of Thick Walls

Stone Walls: A face of stonewall begins to separate from other face resulting in a bulge when shaken by an earthquake. This is because of inadequacy or absence of interlocking due to improper placement of stones as well as absence of bond stone or through stones or "headers" in the masonry. Through stones provide stitching between the outside and inside faces of a wall.

Brick Walls: In brick walls 350mm and thicker the bulging is caused due to separation between the outer and inner faces. This occurs when the mortar is weak or if the joints are inadequately filled with mortar, and when the bricks are improperly arranged such that there is poor interlocking between the faces.

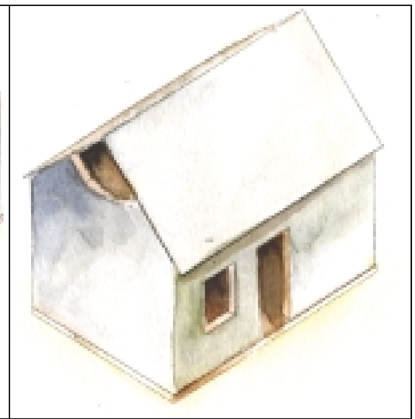
Damage Stage III: Delamination, or Partial Collapse

When the intensity of the force is very high and the duration of shaking is even longer, the damage may reach Stage III.

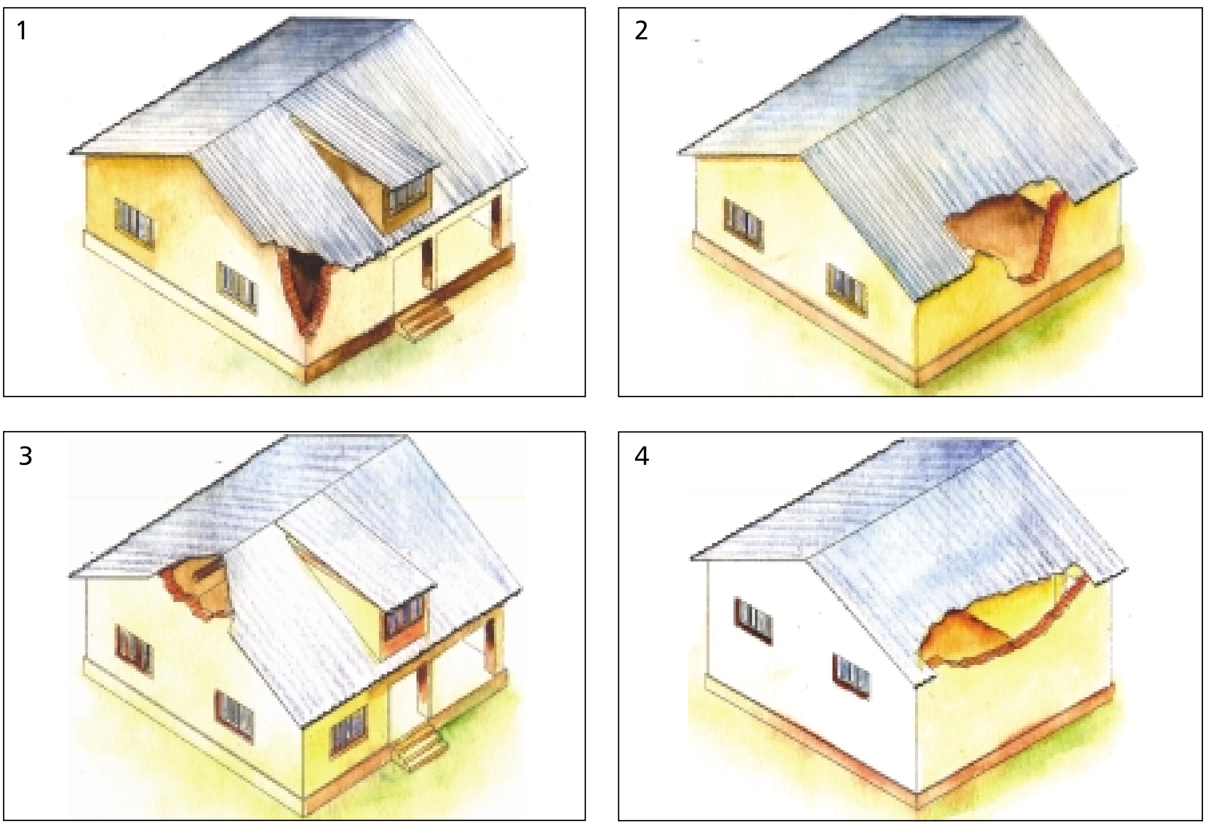


Collapse of large part of wall in the middle of long walls or delamination

Collapse of corner



Gable collapse



Note: Portions of roof have been removed to give un-obstructed view of the damage

Collapse of a Portion of Wall Due to Excessive Shaking

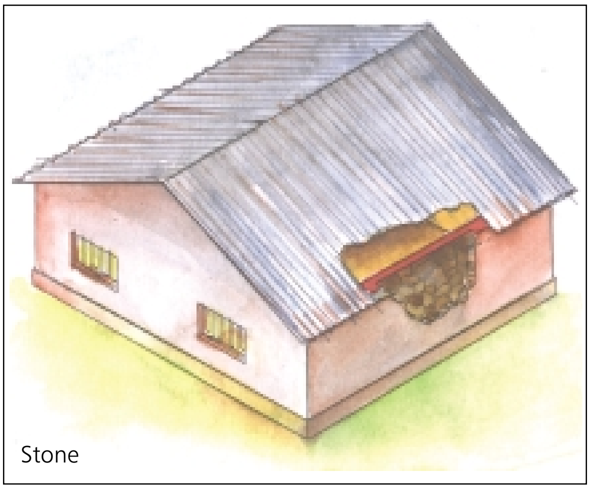
With excessive shaking the portion of wall that is first cracked, and then has gone out of plumb can collapse if the shaking continues.

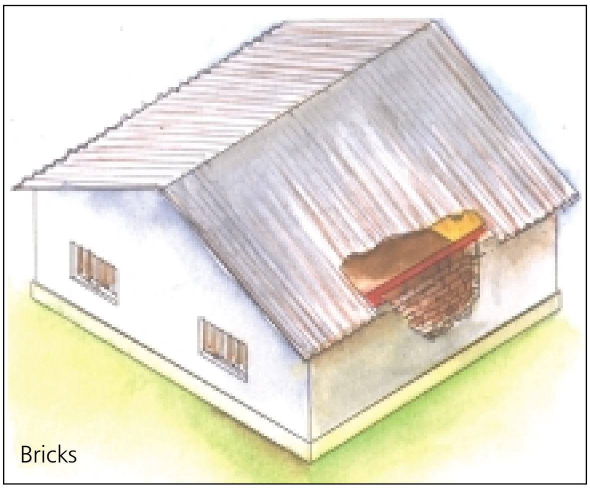
In other words, in the areas where weaknesses are induced due to initial shaking the stresses generated by further shaking leads to collapses. This can be at …

1. Corner
2. Middle portion of long walls at mid-length
3. Gables
4. Upper portion of extra high walls

Delamination of a Portion of Wall

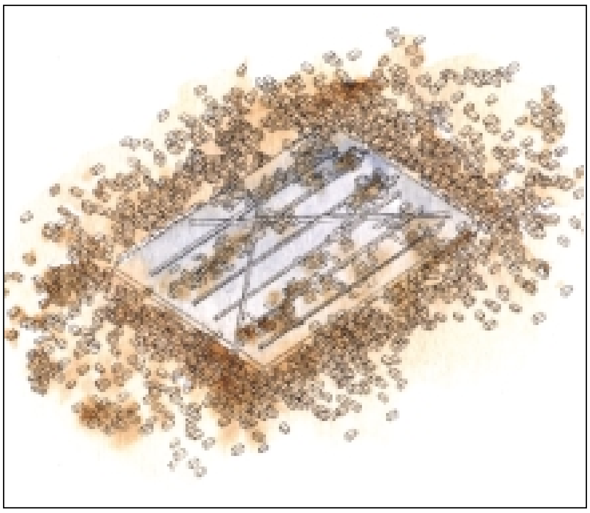
In the portions of walls that are bulged in the initial shaking, the face of wall that has separated collapses with one face still standing if the shaking continues. This is called delamination, and it occurs in thick stone and brick walls.

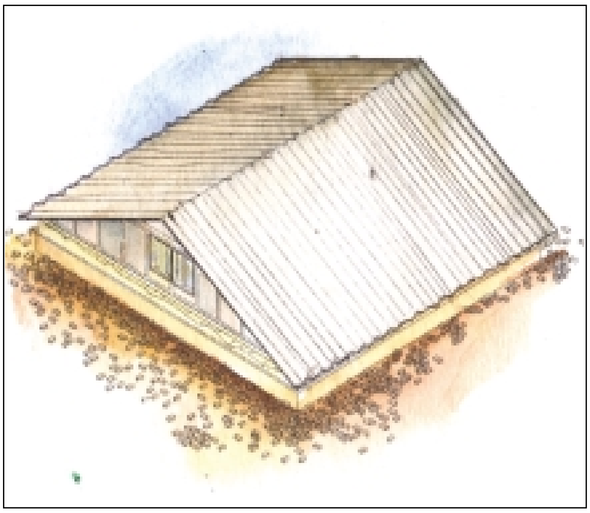




Damage Stage IV : Total Collapse

Further increase in intensity and duration of the force may lead to total collapse of the structure.


Total collapse


Whole roof lying on ground because of total collapse of walls

3.2 Categorisation of Earthquake Damage Grades in Load Bearing Masonry Walls

All Stages of Damage are Categorized as G1 to G5

Grade G1: Slight Non-Structural Damage (G1 Occurs During Stage 1)

Thin hairline cracks in plaster, falling of some plaster.

These fine cracks in plaster are one-dimensional and are only measured in length.

Grade G2: Slight Structural Cracks (G2 Occurs Late During Stage 1)

Small cracks max. 5mm (1/4") wide in walls, falling of plaster over large areas, damage to non-structural parts like chimneys, parapets, etc. The load carrying capacity of the structure is not reduced appreciably.

These cracks are often across the full thickness of the wall. These are two-dimensional. Hence, length as well as width are measured.

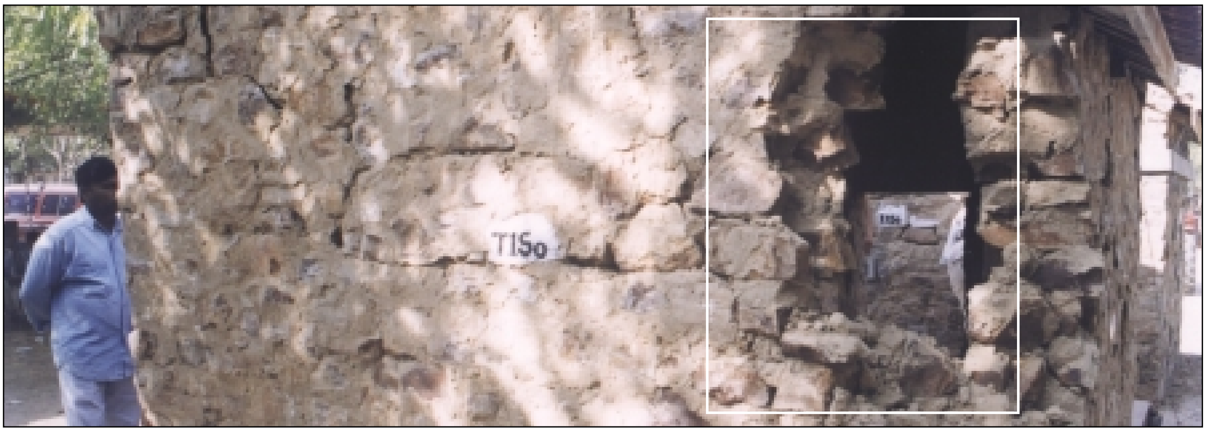
Grade G3: Moderate Structural Damage (G3 Occurs at the end of Stage 1)

Large and deep cracks 6mm to10mm (1/4" to 1/2") in walls, widespread cracking of walls, columns, and piers, and tilting or failing of chimneys. The load carrying capacity of the structure is partially reduced.

These cracks are generally across the full thickness of wall. They are three-dimensional. Hence, its length, width and depth, Categorized as G1 to G5 are measured.

Grade G4: Severe Structural Damage (G4 Occurs During Stage II & III)

Portions of wall are about to collapse due to tilting, bulging, delamination or major cracks, or are already collapsed. The building is unsafe and can collapse further.



Grade G5: Collapse (G5 Occurs During Stage IV of the Earthquake)

A large part of, or whole of building is collapsed

Ref: NCPDP shock table test programme, year 2002

Examples of Damage in Walls: G2-G4


Minor damage in Dhajji *wall*


G3 damage crack in random rubble wall


G3 damage crack in brick wall


G4 damage in combination of stone and brick wall


G4 damage cracks in brick wall


G4 damage in random rubble wall

Examples of Damage in Walls: G5

G5 damage in traditional mud roof building

G5 damage in random rubble walls and CGI roof

G5 Damage, severely damaged walls with damaged roof in place

G5 damage in random rubble wall

G5 damage, total collapse

G5 damage walls heavily damaged, roof intact

G5 damage in random rubble wall

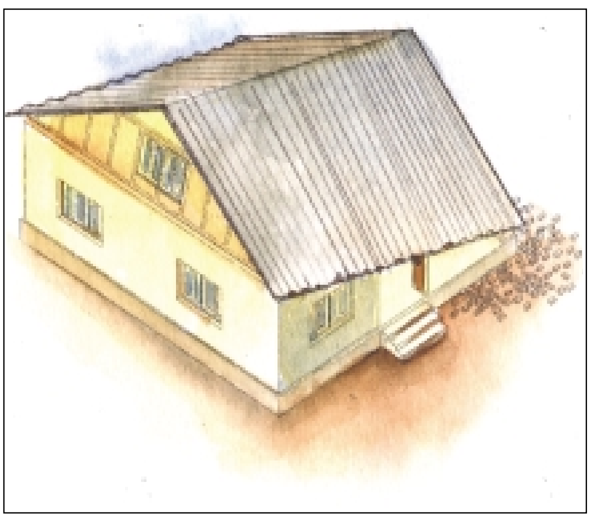
3.3 Earthquake Damage in Roofs and Floors

Flat Mud Roofs

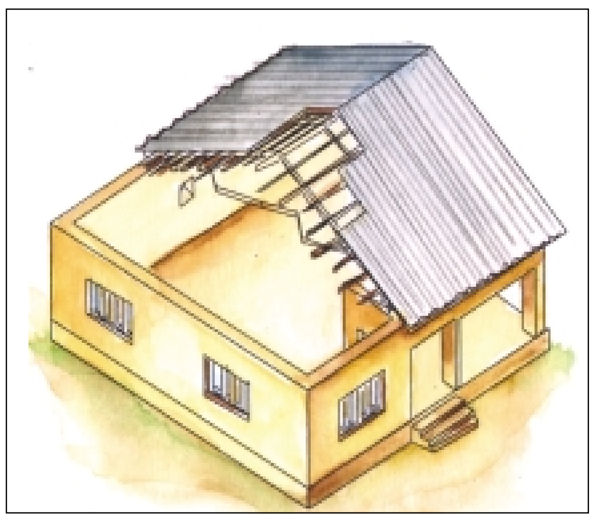
Since traditional mud roofing is being replaced with CGI sheets, the percentage of buildings with this type of roof is very low and decreasing. Hence the restoration of damaged mud roofs is not discussed in this chapter.

Pitched CGI Roof

Most of the CGI sheet roofs survived the 2005 earthquake well. Even when walls collapsed, the whole roof just slid down to the ground, sometimes remaining intact. Damage was found in cases where some of the supporting walls collapsed. This resulted in tilting of the roof frame or collapse of a portion of the roof accompanied by snapping of the timber frame.



Tilting of roof



Collapse of a portion of roof

Examples of Earthquake Damage in CGI Roofs

Collapse of roof because of wall collapse

Roof slid down because of total wall collapse

All walls collapsed but the roof is intact

Roof destroyed due to wall collapse

Tilted roof because of partial wall collapse

Tilted roof because of wall collapse

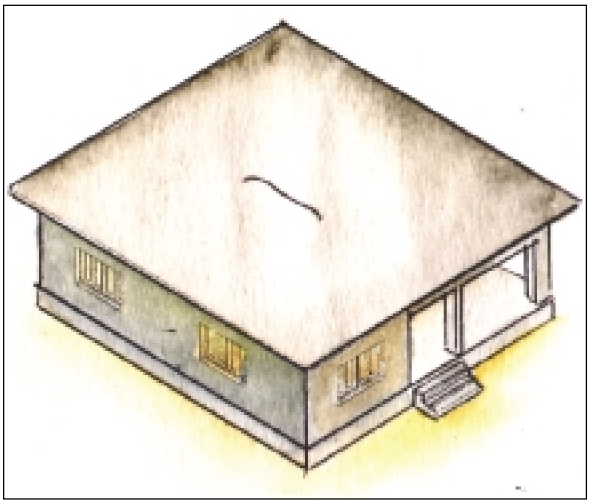
RCC roofs and Floors:

Construction Problems

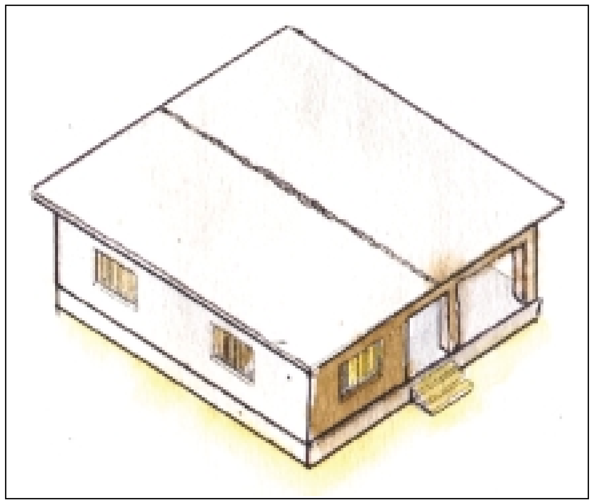
In rural areas, masons often do not understand the structural behavior of concrete slabs. As a result they make common mistakes which lead to cracks. The most common mistakes are:

a. Absence of cranking of bars upwards in the vicinity of supports.
b. Continuing bottom bars in a slab over support wall into the cantilever portion.
c. Poor curing of slab.

In all the above cases cracks can develop even in the absence of earthquake. An earthquake aggravates the situation. Rain water seepage can further damage the slab.



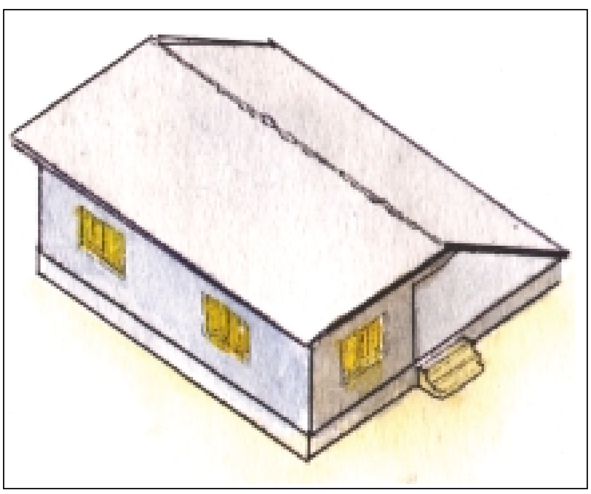
G1 / G2 type minor crack



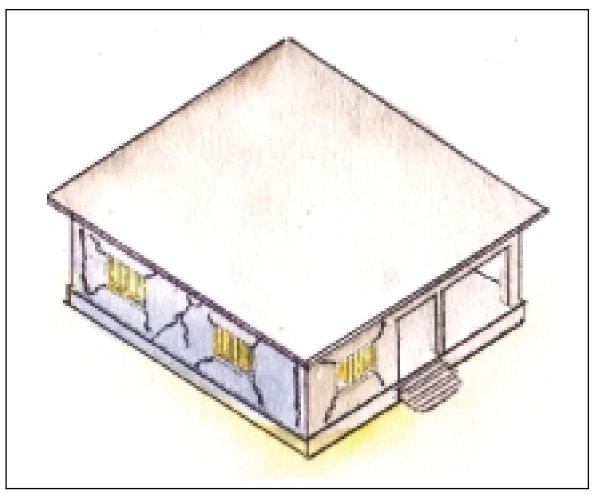
G3 / G4 type structural crack

Why the RCC Roof or Floor Cracks

a. When the wall vibrates because of the earthquake forces or when the wall settles, G1/G2 minor cracks develop in the RCC slab.
b. When the walls are damaged more, the slab bends a little on one side, resulting in wider and longer cracks. In some cases chunks of concrete fall off from the underside of the slab. This is G3/G4 structural damage.
c. When one or two walls supporting the slab collapse, a part of the slab also collapses. This results in bending and exposing of bars with chunks of concrete falling off. This is G5 structural damage.
d. Sometimes the walls supporting the RCC roof are badly damaged. The RCC roof itself may be damaged or undamaged, but a structure with G4 damage is in a precarious condition.



G5 type structural damage



G4 / G5 type wall damage but roof intact

Examples of Earthquake Damage in RCC Roofs

Fine crack

Wrong rebar arrangement at stair causing damage

Slab failure due to collapse of support wall

Collapse of a portion of slab due to collapse of some support walls

Undamaged RCC roof with badly damaged support walls

Timber Floors

In most houses the timber floor is of good quality. Damage can occur as follows:

a. Collapse of supporting walls results in snapping of timber joists, leading to collapse of whole or part of the floor.

b. The walls of the upper storey collapse on top of the floor below, resulting in damage to the floor.

Snapping and collapse of timber floor joists

Damage to floor due to movement in support walls

Collapsed support wall causing snapping of timber floor elements

Breaking of timber floor under the impact of collapsed wall

Chapter 4 Vulnerability Assessment

The seismic vulnerability of a structure is its weakness in the face of anticipated earthquakes in the region. A structure with higher vulnerability is likely to suffer severe damage. Vulnerability reduction requires retrofitting.

4.1 The Need for Vulnerability Assessment

The seismic vulnerability of a structure is its weakness in the face of anticipated earthquakes. A structure with higher vulnerability is likely to suffer severe damage. Vulnerability reduction requires retrofitting.

The seismic vulnerability of a building depends upon the choice of building materials, the construction technology adopted, and the quality of the construction practice. In Kashmir, many types of construction practices are used with a variety of materials. These include local materials such as mud, straw, wood, stone, and bricks. Industrial materials such as concrete blocks, cement and steel are now also commonly used. Both industrial and local materials, if used according to good construction practice, have the capacity to withstand earthquakes. It is the appropriate use of these materials, and the employment of the requisite level of skills and engineering, that make all the difference and lead to safe or unsafe constructions.

Industrial materials have less variation in their performance standards because they are produced in conformity with established norms and standards. It is however important that so-called engineered constructions are made with due reference to good engineering and construction practice (i.e. the correct ratio of water to cement and the minimum cement coverage of steel reinforcements). In local "non-engineered" constructions, there are wide variations in structural quality. These depend in part on the quality of the material found on site (mud used for mortar, for example, can vary a great deal from place to place, as can the quality of stone or wood). An important aspect of "non-engineered" vernacular construction practices is that they are time-tested, having developed through centuries of experience. Vulnerabilities have arisen in recent decades where traditional practices have been diluted and knowledge and skill have been lost. Futhermore, materials such as wood have become scarce today and are thus being replaced by other materials. Traditionally, the skills of master craftsmen were passed from father to son. But this practice has dwindled as the demand for craftsmen has increased. Today, many craftsmen who build houses are yesterday's labourers. In constructing houses, many of them do not possess traditional construction knowledge and do not take into consideration the force of large earthquakes that could occur in the area.

The vulnerability of buildings in rural Kashmir can thus be very high, both with local and newly introduced materials. In the absence of good construction practices and engineering inputs even new buildings may be at risk. It is therefore very important to check the earthquake vulnerability of all existing buildings of mixed traditional and modern construction in Kashmir, whether damaged or undamaged, since all of these are located in Seismic Zones IV or V. If buildings are found to be vulnerable, measures to reduce this vulnerability must be taken. In this way the hardships that people would face in the event of an earthquake can be eliminated or significantly reduced.


Are these new building safe in an earthquake?

4.2 Methodology

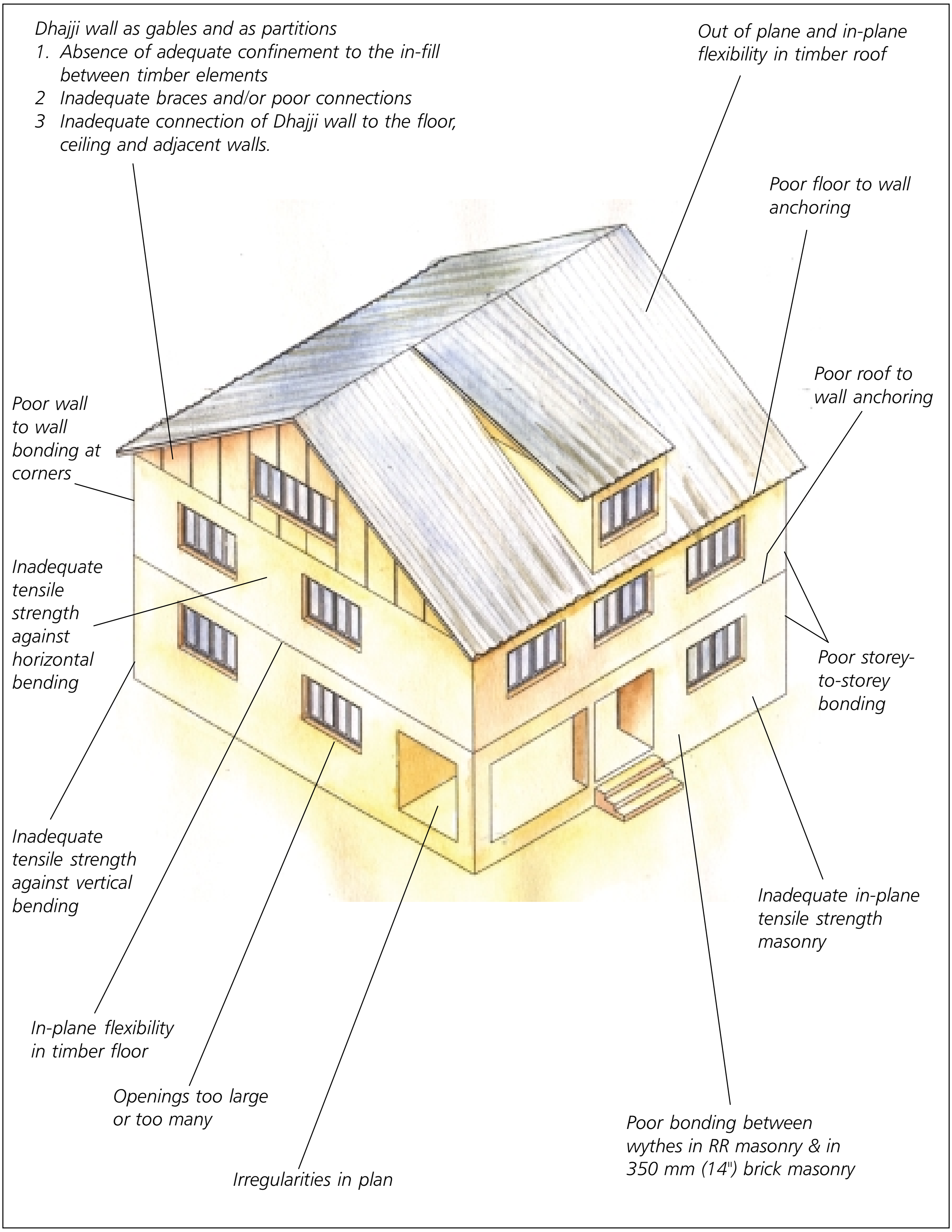
A simple method to carry out Vulnerability Assessment involves visual evaluation of the building from the viewpoint of damage that it could suffer in the event of an earthquake. This will help in deciding the retrofitting requirements for the building. The assessment is aided by the following series of questions which will determine the need for corresponding retrofitting measures.

4.3 Vulnerability Assessment: Step by Step

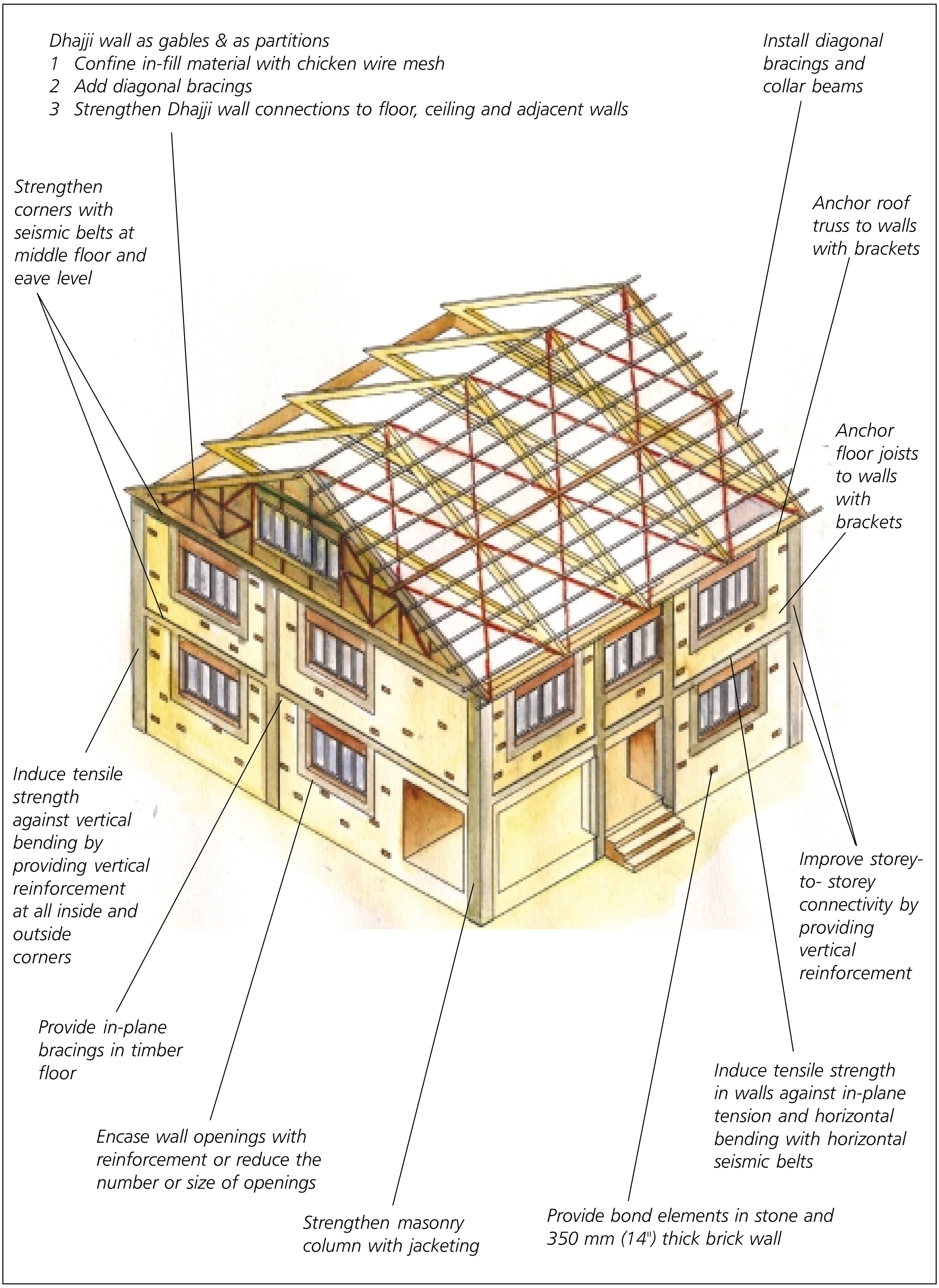
Ques. No.	Question	Answer Y/N	Decision	Priority
Q.1	Are there RC Bands at lintel or roof level in all the walls?		If 'Yes' then go to Q.5	
Q.2	Does house have pitched CGI roof?		If 'Yes' , then install **Seismic Belt at eave level** on all the walls except *Dhajji* walls.	1
Q.3	Does house have RC roof?		If 'Yes' then install **Seismic Belt at lintel level** on all the walls except *Dhajji* walls.	1
Q.4	With CGI roof is the gap between leave level and lintel level 900 mm or more?		If 'Yes' then install **Seismic Belt at lintel level** on all the walls except *Dhajji* walls.	1
Q.5	Is there any vertical reinforcement in walls?		If 'Yes' then go to Q.6	
			If 'No' then install **Vertical Reinforcement** at all room corners.	2
Q.6	Is there any reinforcement surrounding the window and door openings?		If 'Yes' then go to Q.7	
			If 'No' then install **Seismic Belts** around all openings for **Opening Encasement.**	3
Q.7	Are the walls made of Random Rubble Masonry?		If 'No' go to Q. 10	
Q.8	Are there Through Stones, at least one in every 8 sq ft of wall?		If 'No' , then install **Cast in-situ RC Bond Element, one in** every 8 sq ft	4
Q.9	Are both the wythes of wall interlocked?		If 'No' , then install **Cast in-situ RC Bond Element, one in** every 8 sq ft	4
Q.10	Are the walls made of bricks 350 mm thick or thicker?		If 'No' go to Q.13	
Q.11	Is the mortar weak?		If 'Yes' , then install **Cast in-situ RC Bond Element, one in** every 8 sq ft	4
Q.12	Are vertical joints not filled with mortar properly?		If 'Yes' , then install **Cast in-situ RC Bond Element, one in** every 8 sq ft	4
Q.13	Are there *Dhajji* walls in the building?		If 'No' then go to Q.18	
Q.14	In *Dhajji* wall is there a complete system of struts and bracings in all panels and is the wood in good condition?		If 'Yes' then go to Q.15	

Ques. No.	Question	Answer Y/N	Decision	Priority
			If 'No' then install missing **bracings and struts and or exchange rotten elements.**	5
Q.15	In *Dhajji* wall is the infill anchored to timber framework?		If 'Yes' then go to Q.16	
			If 'No' then install **Chicken Wire Mesh** all both faces of wall securely attaching it all timber elements.	5
Q.16	Is *Dhajji* wall properly connected to masonry walls?		If 'Yes' then go to Q.17	
			If 'No' then install **positive connection between two walls.**	4
Q.17	Is *Dhajji* wall properly connected to timber floor and timber roof?		If 'Yes' then go to Q.18	
			If 'No' then install **positive connections between *Dhajji*** wall and timber roof/floor.	5
Q.18	Is attic floor and/or intermediate floor made of timber?		If 'No' then go to Q.21	
Q.19	Is the timber floor anchored securely to the walls?		If 'Yes' then go to Q.20	
			If 'No' then install **special MS angle bracket connectors** between main floor joists and the roof.	6
Q.20	Does timber floor have diagonal bracing system?		If 'Yes' then go to Q.21	
			If 'No' then install **bracings and struts on the underside of the floor** in an arragement such as to increase in-plane stiffness.	7
Q.21	Is roof made of CGI sheeting?		If 'No' then the assessment is complete.	
Q.22	In CGI roof do the main rafters have trusses?		If 'Yes' then go to Q.23	
			If 'No' then install **Collar Beam connecting opposite** rafters at 2/3 roof height.	7
Q.23	In CGI roof are there bracings under the roof between trusses?		If 'Yes' then the assessment is complete.	
			If 'No' then install **bracings on underside of roof** stretching from one end of roof to other end.	8

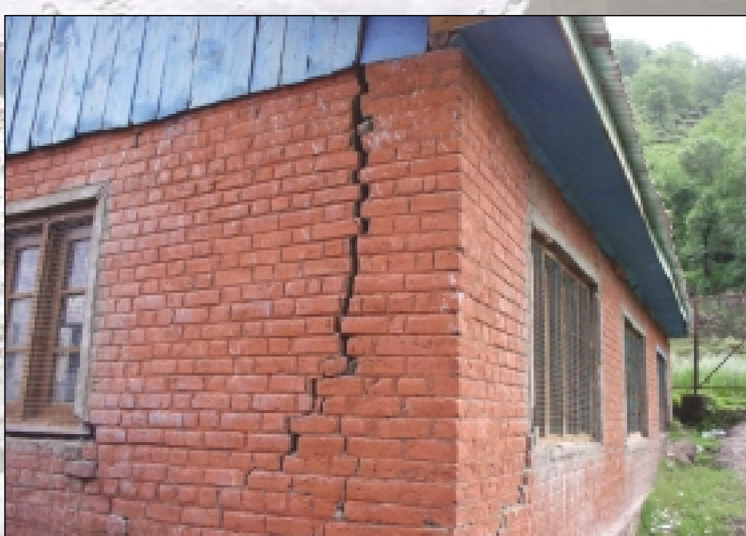
Vulnerability of a Typical Kashmiri Rural House



Vulnerability Reduction Measures for Rural Buildings



Chapter 5 Restoration of Damaged Structures



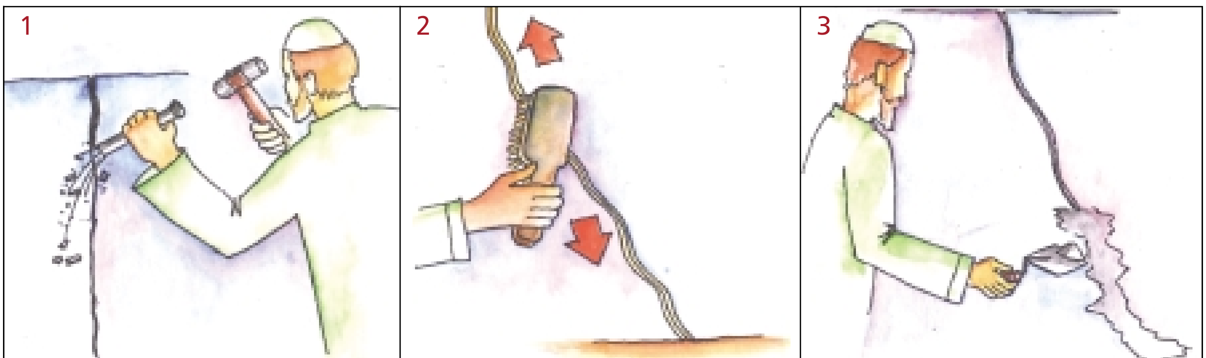
Bringing back a damaged structure to its pre-earthquake state and original strength is called restoration. This is the first step of building rehabilitation. Smaller interventions such as painting, plastering or changing floor tiles are not considered restoration.

5.1 Restoration Procedure for Damaged Load Bearing Masonry Walls

Grade G1 Damage

Hairline cracks

G1 crack



1	2	3
Making 'V' notch	*Cleaning crack with wire brush*	*Sealing crack with cement mortar*

Sealing of Cracks

1. Make a 'V' notch along the crack
2. Clean the crack with a wire brush.
3. Fill the gap with 1:3 cement mortar. Finish the restored parts to match the surrounding wall surface.

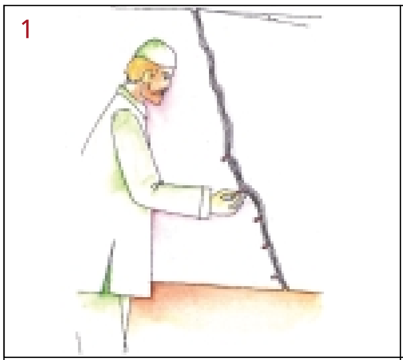
Grade G2 and G3 Damage

G2: Cracks are up to 5 mm wide (1/4 ")

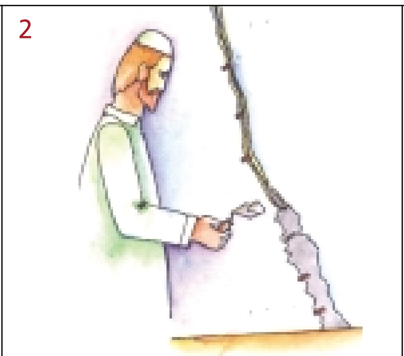
G3: Cracks are between 5 mm (1/4") and 10 mm (1/2") wide

School with wall having G2 cracks

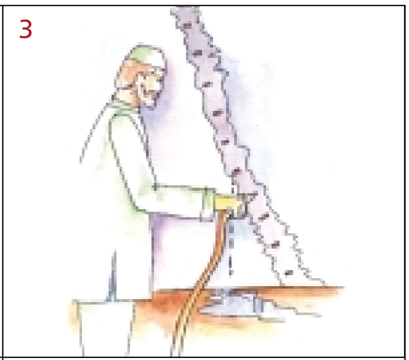
G2 cracks



1 *Fixing grouting nipples*

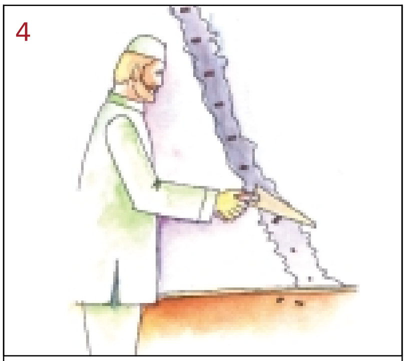


2 *Sealing crack with cement mortar*



3 *Injecting cement slurry*

Sealing and Grouting of Cracks



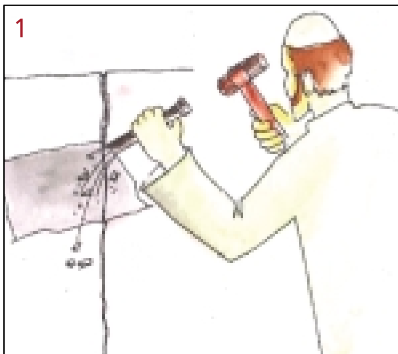
4 *Cutting of nipples*

1. Make a 'V' notch along the crack, clean it with a wire brush
2. Fix grouting nipples in the 'V' groove, projecting 50 mm from the crack on both faces of wall, at a spacing of 150 mm to 200 mm.
3. Clean crack with compressed air through nipples to remove the fine, loose particles inside the crack. (if available).
4. Seal the crack with 1:3 cement mortar, with nipples still projecting, and allow it to harden for some time.
5. Inject water into crack through the topmost nipple, and then repeat with the lower nipples in succession.
6. Make cement slurry with 1:1 (non-shrink cement : water) and begin injecting it into the nipple, starting with the lowest nipple until the slurry comes out of the next higher nipple. Next inject into the successively higher nipples, one after the other.
7. Cut off the nipples, seal the holes with 1:3 cement mortar and finish the surface to match the adjacent surface.

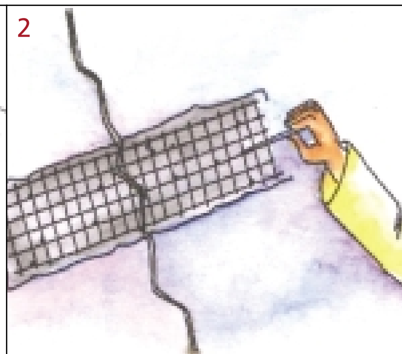
Grade G3 Damage

Cracks with width more than 5 mm (1/4") and less than10 mm (1/2")

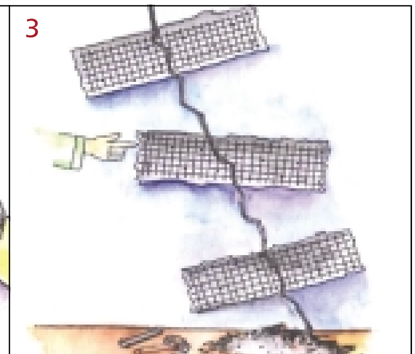
G3 cracks



Making 'V' notch



Fixing WWM with wire nails



Ferrocement splices accross cracks

Applying cement plaster on splices

Curing

1. Make a 'V' notch along the crack, clean it with a wire brush.
2. Clean crack with water to remove the fine, loose particles inside the crack.
3. Prepare masonry surface on both faces of the wall for fixing 200 mm wide ferrocement splices across the crack as shown in the diagram, by removing the plaster, raking the joints up to 12 mm depth, and cleaning it with water, extending on both sides of the crack to a minimum of 450 mm length.
4. Fill the crack with 1:3 cement mortar (non-shrink cement : fine sand) with just enough water to permit pushing in of mortar as far in as possible, from both faces of the wall.
5. Install the 150 mm wide 25x25 14 gauge galvanized welded wire mesh (WWM) (2.03 mm diameter) with 100 mm long wire nails inserted at spacing no greater than 300 mm in a staggered manner.
6. A gap of 10 mm must be maintained between the mesh and un-plastered wall.
7. Plaster over the mesh with two 12 mm coats of 1:3 cement plaster.
8. Cure it with water for 15 days.

Grade G4 Damage

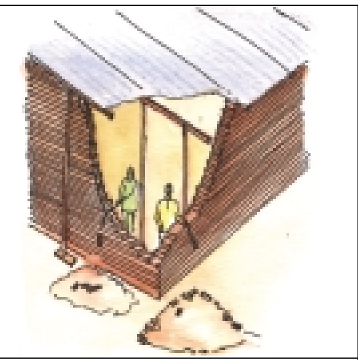
Cracks wider than 10 mm (1/2") OR

Out-of-plumb wall that is unstable OR collapsed corner

Collapsed corner

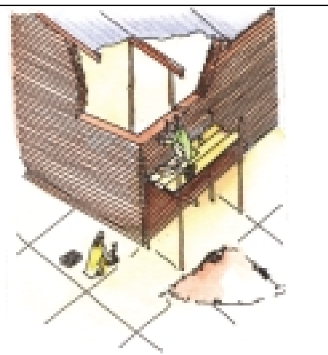
Out-of-plumb wall

1



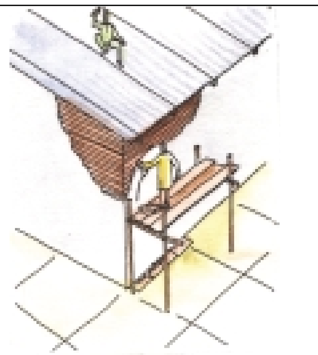
Propping up roof and removing damaged portion

2



Rebuilding the wall

3



Finishing to match the existing wall

1. Mark the damaged portion of the wall.
2. Mark 600 mm (2') extra on all sides from the damaged portion for removal.
3. Support with timber or steel props the roof or the floor above the portion of the wall which is to be removed. Provide additional supports to prevent any accidental collapse of structure.
4. Slowly remove the marked portion of the wall in stepped manner.
5. Separate and stack reusable material properly. Discard all material that is unsuitable for construction like small round stones.
6. Rebuild the wall with the salvaged material or new material. Use mortar that is the same as that used in the existing construction. If the existing wall is built with stone in mud mortar then it is best to use stone in mud mortar in rebuilding, or stone in lime mortar, but not with bricks.
7. Adhere to the basic rules of earthquake-resistant masonry construction while rebuilding the wall. If the wall is built in stone, use through stones at every 0.9 sq m (9 sq ft) both ways and staggered vertically.
8. If cement is used in construction or plaster, cure it for at least seven days.
9. Remove the props once the rebuilt portion has adequate strength.
10. Finish the wall to match the adjacent parts of existing house.

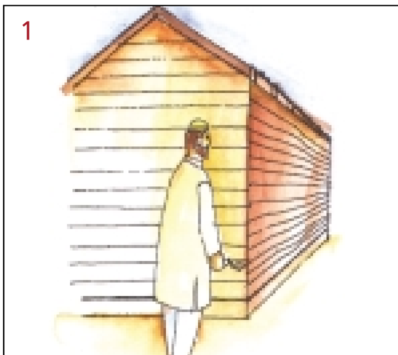
Grade G4 Damage (Cont.)

Bulging OR delaminated wall OR partially collapsed wall

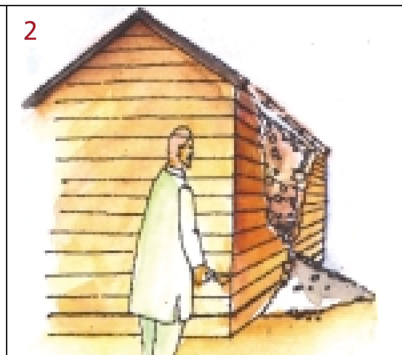
Bulged wall

Delaminated wall

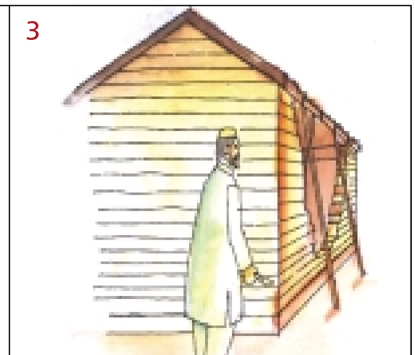
Partially collapsed wall



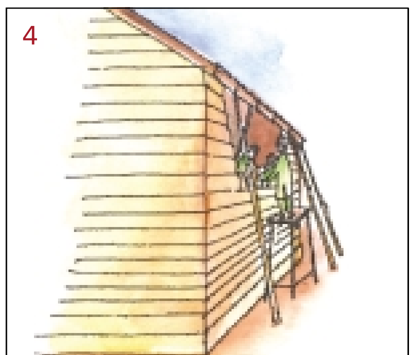
Bulged wall



Partially collapsed wall



Propping up roof and removing damaged portion of wall



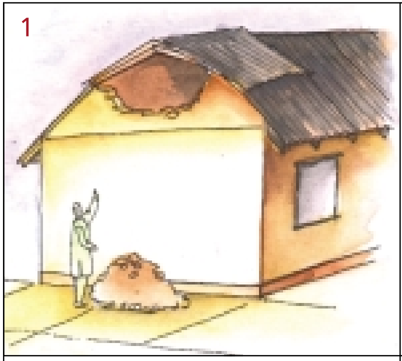
Rebuilding the wall

1. Mark the damaged portion of the wall.
2. Mark 600 mm (2') extra on all sides from the damaged portion for removal.
3. Support with timber or steel props the roof or the floor above the wall which has to be removed. Provide additional supports to prevent any accidental collapse of structure.
4. Slowly remove the marked portion of the wall in stepped manner.
5. Separate and stack reusable material properly. Discard all material that is unsuitable for construction like small round stones.
6. Rebuild the wall with the salvaged material or new material. Use mortar that is the same as that used in the existing construction. If the existing wall is built with stone in mud mortar then it is best to use stone in mud mortar in rebuilding, or stone in lime mortar, but not with bricks.
7. Adhere to the basic rules of earthquake-resistant masonry construction while rebuilding the wall. If the wall is built in stone, use through stones at every 0.9 sq m (9 sq ft) both ways and staggered vertically.
8. If cement is used in construction or plaster, cure it for at least seven days.
9. Remove the props once the rebuilt portion has adequate strength.
10. Finish the wall to match the adjacent parts of existing house.

Grade G4 Damage (Cont.)

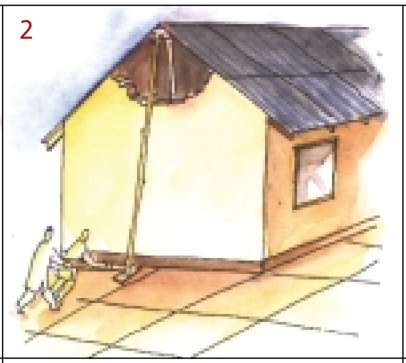
Partially Collapsed Gable Wall

Collapsed gable wall



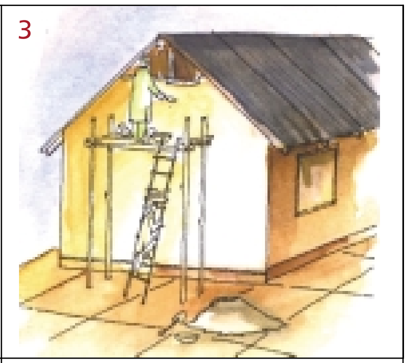
1

Collapsed gable wall



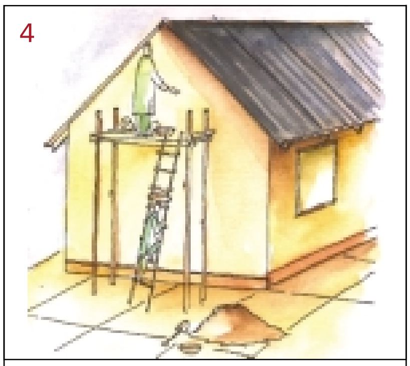
2

Propping up roof



3

Removing damaged portion & rebuilding it



4

Finishing the wall

1. Mark the damaged portion of the wall.
2. Mark 600 mm (2') extra on all sides from the damaged portion for removal.
3. With timber or steel props support the roof or the floor above the wall which has to be removed. Provide additional supports to prevent any accidental collapse of structure.
4. Slowly remove the marked portion of the wall in stepped manner.
5. Separate and stack reusable material properly. Discard all material that is unsuitable for construction like small round stones.
6. Rebuild the wall with the salvaged material or new material. Use mortar that is the same as that used in the existing construction. If the existing wall is built with stone in mud mortar then it is best to use stone in mud mortar in rebuilding, or stone in lime mortar, but not with bricks.
7. Adhere to the basic rules of earthquake-resistant masonry construction while rebuilding the wall. If the wall is built in stone, use through stones at every 0.9 sq m (9 sq ft) both ways and staggered vertically.
8. If cement is used in construction or plaster, cure it for at least seven days.
9. Remove the props once the rebuilt portion has adequate strength.
10. Finish the wall to match the adjacent parts of existing house.

Examples of Restorable Buildings with G4 Damage

Restorable buildings: Many buildings at first glance seem unsalvageable. The fear - psychosis in most people, and, even in some engineers, makes them opt for demolition. But if planned properly, these buildings can be restored. Damaged portions can be rebuilt, while all undamaged walls and roofs can be salvaged. All the buildings shown here can be restored and retrofitted with systematic planning and action.

Collapsed walls need to be rebuilt

Roof needs to be jacked up and propped, followed by rebuilding of collapsed walls and repairing of damaged ones

Damaged portions of walls need to be repaired and rebuilt

Roof needs to be jacked up, collapsed portion of walls need to be rebuilt

Damaged walls need to be restored

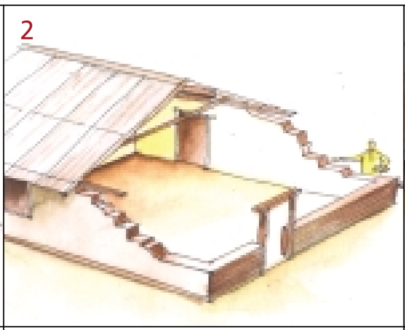
The roof, intermediate floor and ground floor walls including the foundation can be salvaged while rebuilding collapsed walls and repairing damaged ones

5.2 Restoration Procedure for Roof Damage

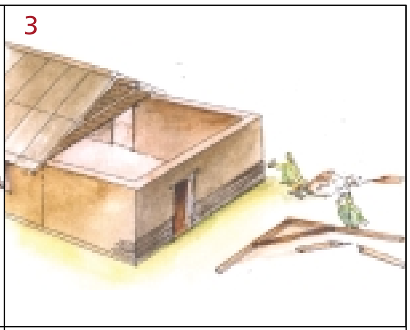
Restoration of Damaged CGI Sheet Roof and Timber Attic Floor Damaged Timber Elements

Damaged roof

Removing CGI sheets from damaged portion of roof



Removing damaged portion of wall



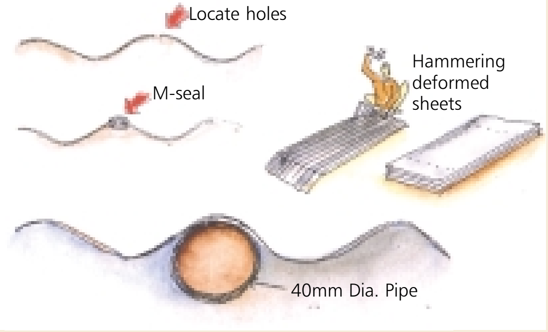
Reconstructing damaged portion of wall

Roof Damage is frequently caused by severely damaged walls. In such cases, the following steps must be taken:

1. Remove all the sheets.
2. Clear the damaged portion of roof and attic floor.
3. Clear the severely damaged portions of the walls and reconstruct them adhering to practice of good construction.
4. Repair the cracks and other minor damage.
5. Replace the severely damaged timber elements including truss top chords, rafters, purlins, floor joists and planks.
6. Repair the cracked elements other than the planks by nailing or splicing with the help of metal straps or MS flats. Drill holes in old timber for nails to prevent damage from cracking.
7. Replace CGI sheets unless they are damaged or deformed.

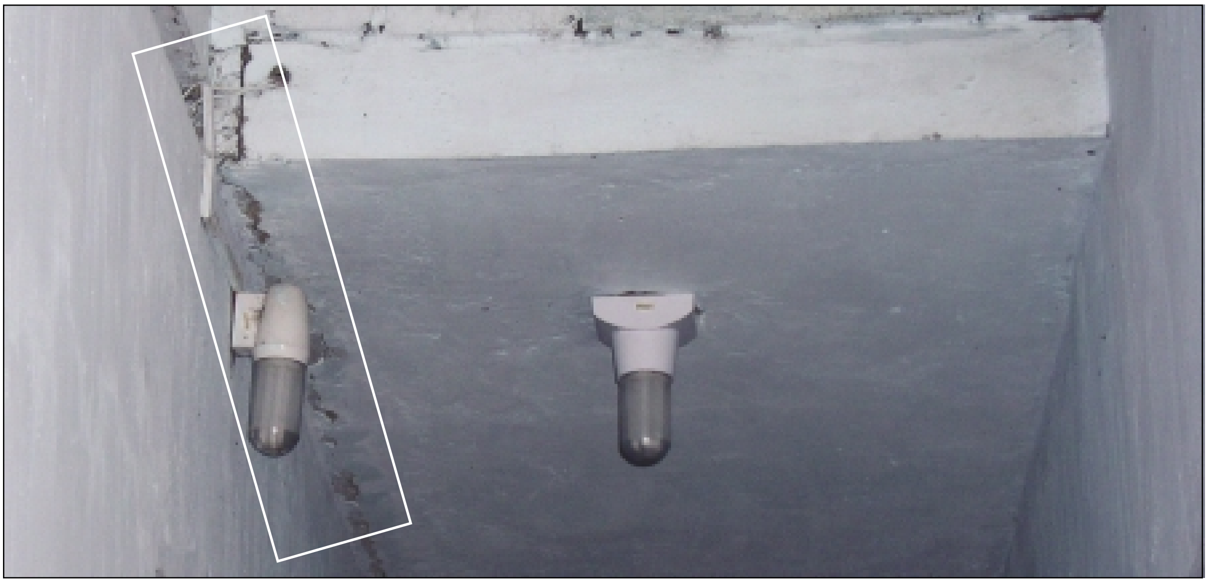
Deformed CGI Sheets

1. Remove any rusted edges around the existing nail/ bolt holes with a file or hammer.
2. Seal all open holes with M-seal.
3. Straighten out bent sheets using wooden hammer.
4. While hammering, place 40 mm diameter pipe under the sheeting to ensure proper corrugation,



Restoration of Damaged RCC Slabs

Sealing of Fine (G1) Crack



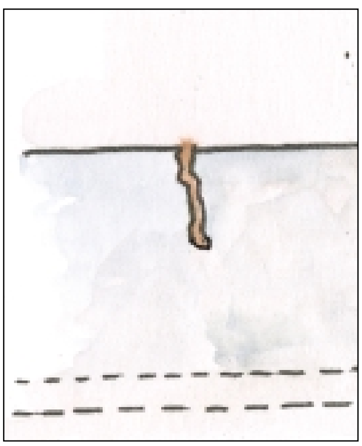
G1 Crack in RCC floor

1	2	3
G1 crack	*Cleaning widened crack surface*	*Filling widened crack with cement slurry*

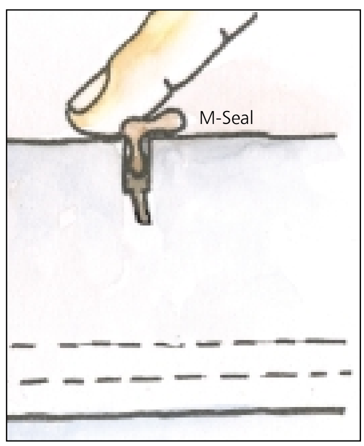
1. Clean the crack with a wire brush.
2. Fill the crack with cement slurry. The cement : water ratio must be kept at 1:3.
3. Cure the cement slurry for at least 15 days.

Sealing of Moderate (G2) Non-Structural Crack

1. Rake the crack with chisel and widen the crack.
2. Clean the crack with a wire brush.
3. Seal crack with M-seal. Before applying the M-seal, make sure the crack is absolutely dry. Apply M-seal with thumb pressure so that no space is left out.
4. Remove excess sealant and let it harden.



G2 crack

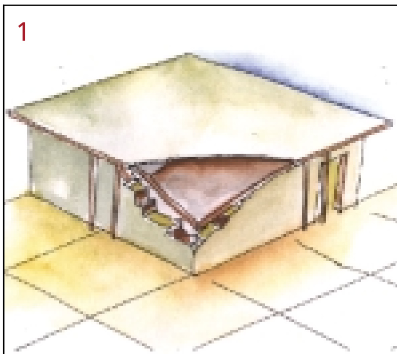


Sealing crack with M-Seal

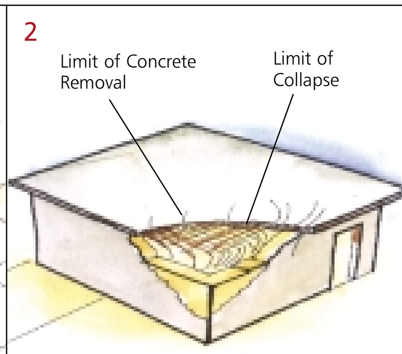
Restoration of Partially Collapsed RCC Roof

When a portion of a slab is bent with a wide crack exposing the reinforcing bars

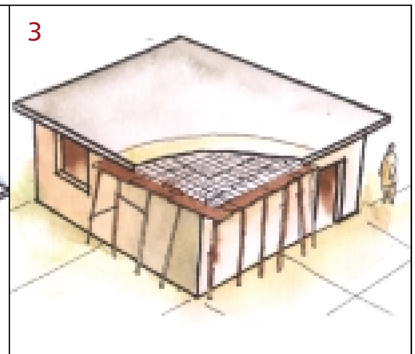
Partially collapsed RCC roof



Supporting undamaged portion of slab with props

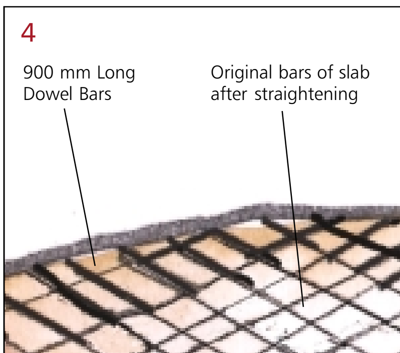


Limits of concrete removal from collapsed portion

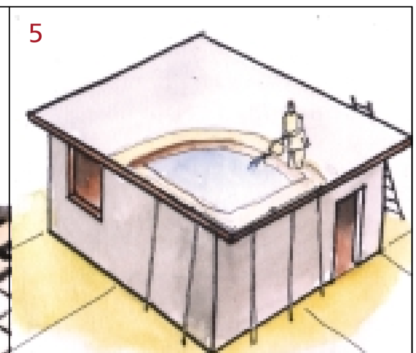


Installing shuttering

1. Support the undamaged portion of the slab with timber poles and wooden planks to prevent further cracking in slab.
2. Mark off a line on the undamaged part of the slab at 600 mm (2') from the damaged area periphery.
3. Break off concrete from the collapsed portion to reduce the weight andexpose the damaged steel bars.
4. If the walls are damaged or collapsed, restore them following the basic rules of earthquake-resistant construction.
5. Install shuttering for casting of damaged portion of slab.
6. Straighten out the bars to the correct alignment.
7. In order to repair the damage to the steel bars in the slab, tie steel dowel of the same diameter with length equal to 52 times the bar diameter, overlapping on the damaged portion of each rebar and keeping the mid-point of the dowel at the point of bending in the rebar. Tie dowels at several points with binding wire.
8. Apply bonding agent at the exposed edge of the undamaged slab.
9. Pour concrete and finish it to match the existing slab.
10. Build a soil bund all around the new slab to retain water for 15 days for curing.



Tying dowels to exposed rebars

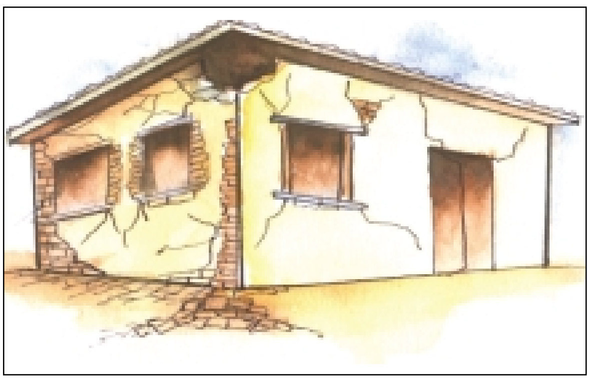


Casting slab and curing it

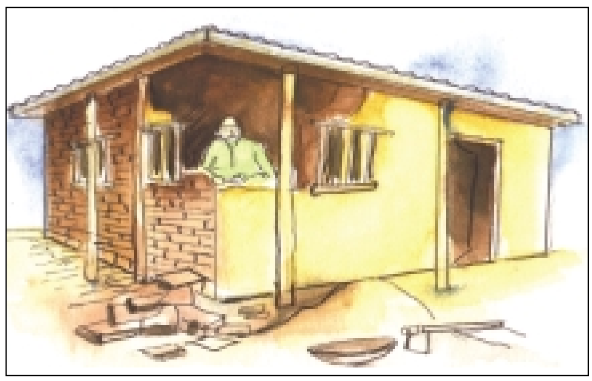
Restoration of Severely Damaged Walls Supporting an Undamaged RCC Roof

The damaged walls must be restored carefully in a systematic manner so that the stability of the whole structure is not undermined.

Undamaged RC slab on severely damaged wall



Undamaged RC slab on severely damaged wall



Systematically propping up slab, removing portions of damaged walls and rebuilding them

1. Prop up the slab all along its supporting walls with horizontal planks supported by vertical and sloping posts on both sides of the building, as seen in the photo and sketch.
2. Supports must be strong and wedged to make sure that the slab is resting on them. The slant supports will help in preventing lateral sway of the slab. Take care not to raise the slab to prevent cracking in top surface.
3. Mark the portion of wall to be removed, beginning at the corner. The length of the portion should not exceed ¼ of the total length of the wall or 3 m (10'-0"), whichever is less.
4. Begin removal of the marked portion of wall with extreme caution.
5. Start construction of the new wall from the corner following rules of earthquake-resistant construction. Build it in a stepped manner to ensure proper bond with the next portion to be constructed.
6. Remove another 2 m (6'-6") length of wall.
7. Continue the process till all damaged walls have been restored.
8. If cement mortar is used for construction, cure it for 15 days.
9. If the slab has developed cracks, follow the instructions given earlier to restore it.
10. When all the walls are restored, remove all the supports, and retrofit the entire structure as deemed necessary. Follow the instructions for retrofitting from the retrofitting chapter.

Chapter 6 Seismic Retrofitting: Principles

Seismic retrofitting means enhancing the capacity of a structure in a scientific manner to resist the forces of an earthquake expected in future. Retrofitting should be done on all vulnerable structures. This may be necessary even if a structure has not been damaged in a past earthquake. This is generally the most cost- and time-efficient way to ensure the safety of the building's occupants.

6.1 Retrofitting of Existing Masonry Walls

Weakness in Random Rubble Walls: Delamination of Wythes in thick Walls

Delamination of wythes


Bulging

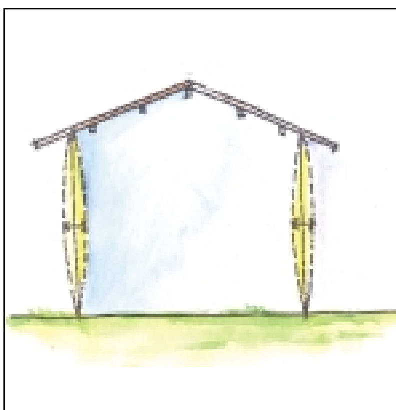

Bulging

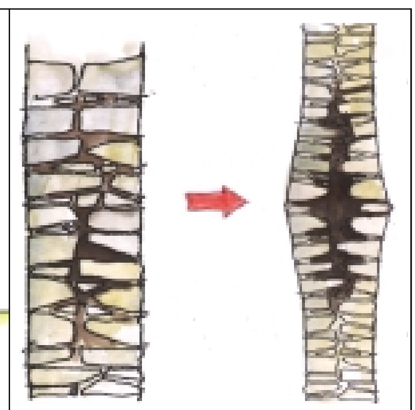
Installing Bond Elements for RR Wall

Installing cast in situ reinforced concrete (RC) bond elements can prevent delamination of existing random rubble (RR) walls.

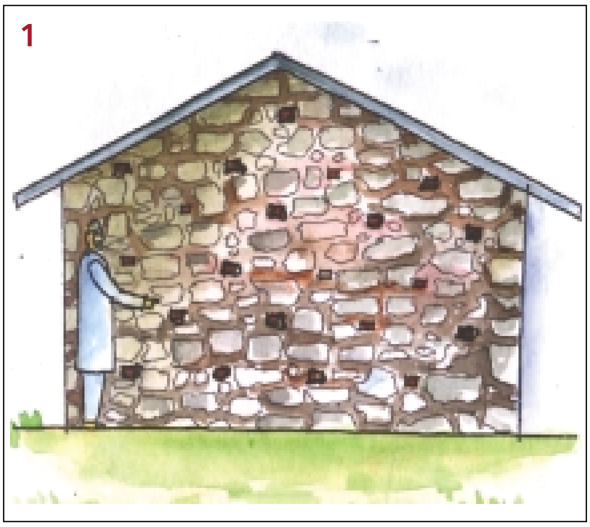
Advantages of Installation of Cast in Situ RC Bond Element

1. It binds both wythes of a wall together, thus preventing bulging and delamination.
2. It helps reduce vulnerability of RR wall.

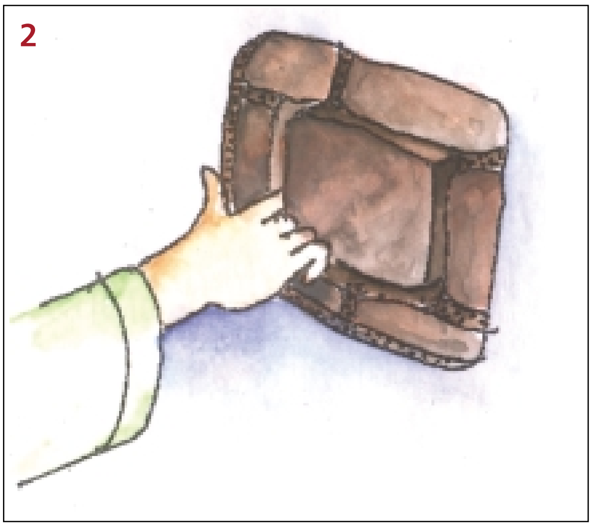

Sideway shaking of walls due to earthquake


Bulging

How to Install Cast in situ Reinforced Concrete Bond Elements



Marking points for bond elements



Removing mortar around stone

Loosening the stone by small rod

Pull out stone and remove loose materials behind stone

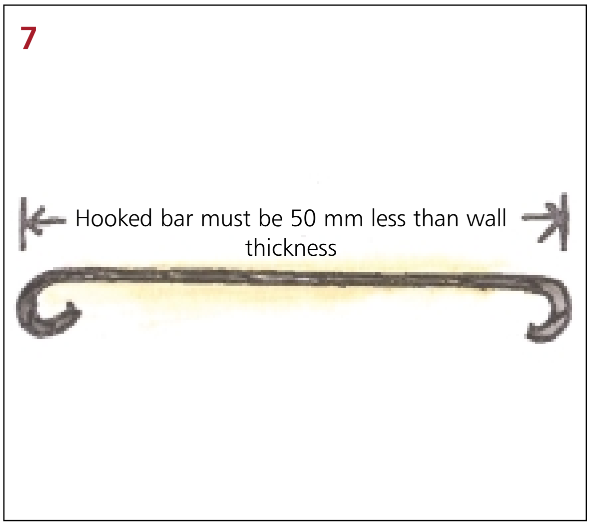
1. Mark points spaced horizontally and vertically 1 m apart, with a horizontal stagger of 500 mm, thus having one point per 1 smt (10 sft) of the wall area.
2. Remove a patch of surface plaster of approximately 220 mm x 220 mm (9" x 9") at each point and expose the stones. Gently remove the mortar around the stone to a sufficient depth to expose the sides of the stone to loosen it from the wall.
3. Loosen the stone, gently yanking it from side to side and up and down by means of a small rod with tapered end, being careful not to disturb the stones around it. The rod should be 12 mm in diameter and 750 mm (2’6") in length, with one end flattened and one end pointed.
4. Pull out the stone slowly, holding it with both hands.
5. Remove the material behind the stone gradually to make a hole of 75 mm (3") diameter through the wall till the stone on the other face is reached.
6. Tap that stone to identify it from the far side. Remove this slowly from the other side by the same careful process.

Exercise extreme care not to weaken the wall while making holes

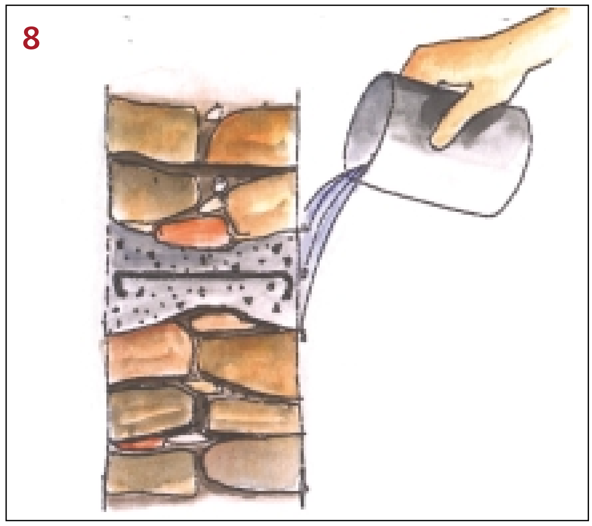
How to Install Cast in Situ Reinforced Concrete Bond Element (Cont.)

Making dumb-bell shaped hole through wall

Placing concrete and rebar in the hole



Length of the bar must equal wall thickness minus 50 mm



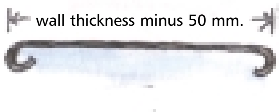
Cure concrete thoroughly

7. The hole should be bigger in size at both faces and narrower in the wall core, resembling a dumb-bell. It dose not matter if the hole is inclined instead of level.
8. Splash water in the hole to clean off loose material from the surface of the stones.
9. Place concrete of 1:2:4 mix to fill half the height of the hole from both sides. Place an 8 mm diameter TOR bar hooked at both ends in the hole. Fill the hole completely with concrete to fully encase the bar. Suitable polymer additive should be used to make non-shrink concrete.
10. Make sure the entire length of the bar is covered with concrete. The hooked bar must be 50 mm shorter than the thickness of the wall to ensure full encasing.
11. Cure for a minimum of 10 days by sprinkling water on the exposed surfaces on both sides. Finish the wall to match the existing wall. Follow the same procedure to make all the bond elements in walls.

Do not make more than 6 holes at a time in a single wall, and fill them up with concrete on the same day.

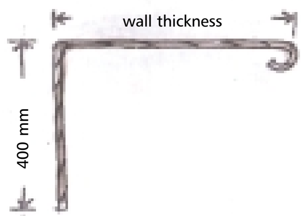
How to Install Cast in Situ Reinforced Concrete Bond Element (Cont.)

The function of the bond element dictates the characteristics of the reinforcing bar used.

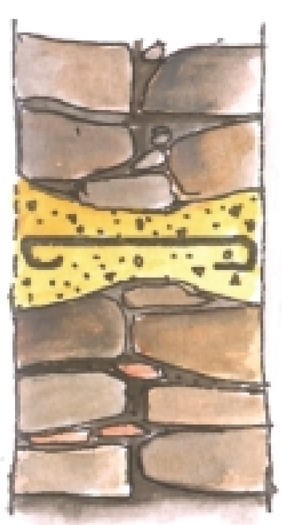


Stitching element Bar: Used to stitch together the wythes of a thick wall.

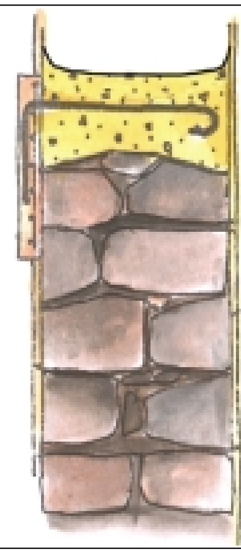
Seismic Belt Shear Connector Bar: Used to anchor WWM seismic belt in masonry wall.



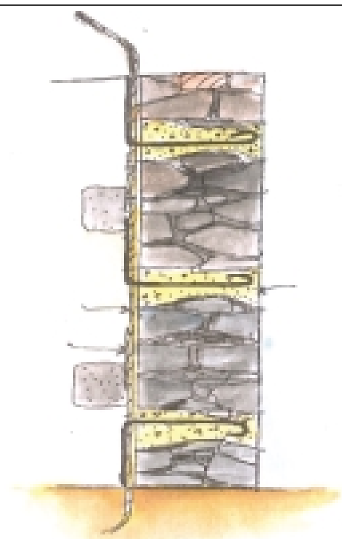
Vertical Reinforcement Shear Connector Bar: Used to anchor vertical reinforcing bar onto wall corner.



Stitching element



Seismic belt shear connector



Vertical reinforcement shear connector

Varients of Bond Elements

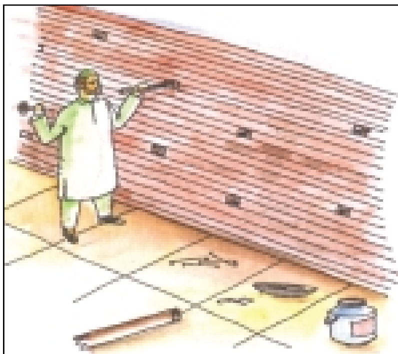
a. Stitching wall wythes: Both ends of the bar must be hooked. Length of the bar after bending must be 50 mm (2") shorter than the thickness of the wall

b. Seismic belt shear connector: One end of the bar must be bent like a hook and the other like an 'L' to which welded wire mesh (WWM) is tied. The length of the bent portion must be 150 mm (6"). The length of the bar after bending must be equal to the thickness of the wall.

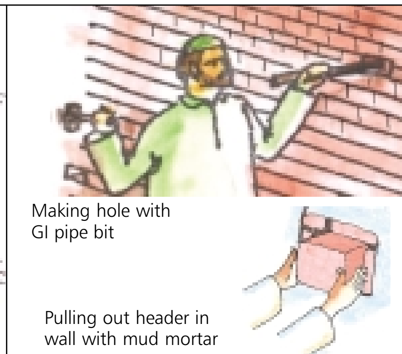
c. Vertical reinforcement shear connector: One end of the bar must be bent like a hook and the other end bent like an 'L' to which the vertical rod or WWM is tied. The length of the bent portion must be 400 mm (16"). The length of the bar after bending must be equal to the thickness of the wall.

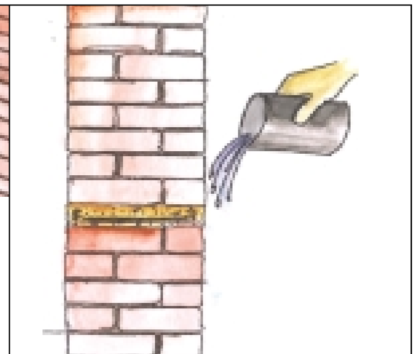
Weakness in 350 mm (14") thick or thicker Brick Masonry Walls: Delamination of Inner and Outer Faces

Delamination



Marking point for bond elements and making hole





Cure bond elements

How to Install Bond Elements in 350 mm (14") Brick Wall

1. Mark points spaced horizontally and vertically 1 m, with a stagger of 500 mm, thus having one point per 1 sq m (10 sq ft) of the wall area.
2. In a wall built with cement mortar, use a 350 mm long piece of 35 mm diameter GI pipe with a slit end as a punch to make a through hole. In a wall built with mud mortar, mark the header to be removed and rake off mud from the joint all around it. Loosen the brick slowly and remove it.
3. Splash water in the hole to clean off loose material from the surface of the bricks.
4. Fill bottom half of the hole from both sides using non-shrink micro concrete of 1:1½:3 proportions. Place an 8 mm diameter TOR bar in the hole and fill the remaining void completely. Suitable polymer additive (CICOP Non-Shrink Polymeric Waterproof Grouting Compound or other equivalent) should be used to make non-shrink grout.
5. Make sure the entire length of the bar is covered with mortar. The bar must be 50 mm shorter than the thickness of the wall to ensure full encasing.
6. Cure for a minimum of 10 days by sprinkling water on the exposed surfaces on both sides. Finish the wall to match the existing wall. Follow the same procedure to make all the bond elements in walls.

Bond Element variants can be used as Shear Connectors under RR walls as wall

Weaknesses in Brick or Stone Masonry Walls: Poor Wall-to-Wall Bonding, Inadequate In-Plane Tensile Strength, Vulnerability of Extra-High/Extra-Long Walls Resulting in a Variety of Cracks and Damage

Install Horizontal Seismic Belt

Installing a seismic belt improves the capacity of walls to resist earthquake forces and helps prevent cracks and other damage.

Damage in extra long wall

Damage due to inadequate in-plane tensile strength

Damage in extra high wall

Damage due to poor wall-to-wall bonding

How Does a Seismic Belt Work?

a. Like tape or a string tied to a box, this belt binds all walls together and helps reduce cracking in corners.
b. It helps prevent walls from going out of plumb.
c. It also reduces bending of wall due to forces perpendicular to the plane of the wall, and thus helps prevent vertical cracks in the middle of the wall.
d. It resists tension caused by earthquake forces parallel to the wall and thus helps prevent diagonal cracks, especially those emanating from corners of doors and windows.

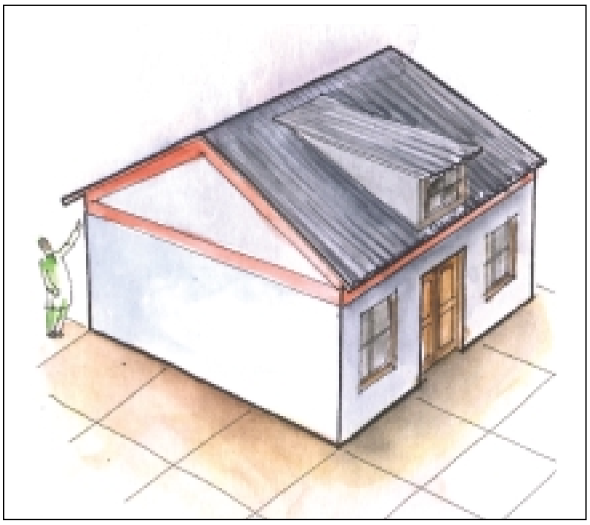
Seismic Belt Locations for Buildings with Common Types of Masonry

Uninterrupted Seismic Belts are to be Provided on all Walls

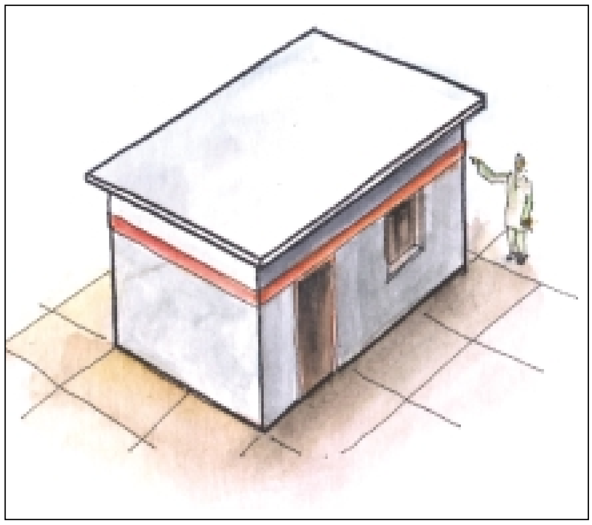
- Just below eave level.
- Just above lintels of doors and windows, unless the gap between eave level and lintel is less than 900 mm, in which case lintel belt is not needed.
- Just below floor level.
- Just below the sloping top edge of gable walls.

Some Additional Rules

- In case of RC roof, the eave level belt is not required.
- In case of RC floor, the floor level belt is not required
- If the wall length is 3 m to 4 m, install a tie rod at mid-length. For lengths between 4 m and 5 m, install two tie rods equally spaced.



Seismic belts for pitched roof building



Seismic belt for slab roof building

Specifications of Seismic Belts

The seismic belt is made with reinforcement consisting of galvanized welded wire mesh (WWM) and TOR/MS bars that are anchored to the wall and fully encased in cement plaster or micro-concrete. The width of the belt should be 30 mm more than the width of the WWM.

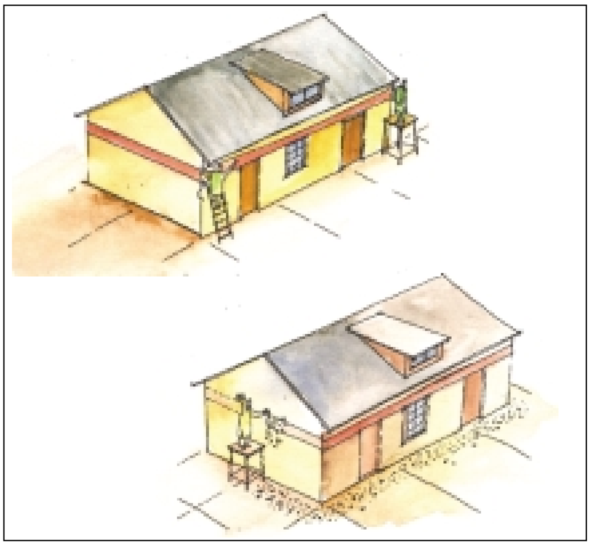
Reinforcement Requirements for Different Building Categories
(Note: For rooms with Wall Length no Greater than 5 m only ***)

Building Category	Galvanized Welded Wire Mesh	MS Rods
Zone IV House	13 gauge 250 mm wide with 8 longitudinal wires	2-6 mm dia. bars
Zone V House	13 gauge 250 mm wide with 10 longitudinal wires	2-6 mm dia. bars
Zone IV & V School, Police Station, PHC Etc.	13 gauge 250 mm wide with 10 longitudinal wires	2-6 mm dia. bars

Note: 1) *13 gauge WWM is recommended since 10 gauge is too stiff to handle.*
2) In WWM the transverse wires should not be spaced at more than 75 mm.

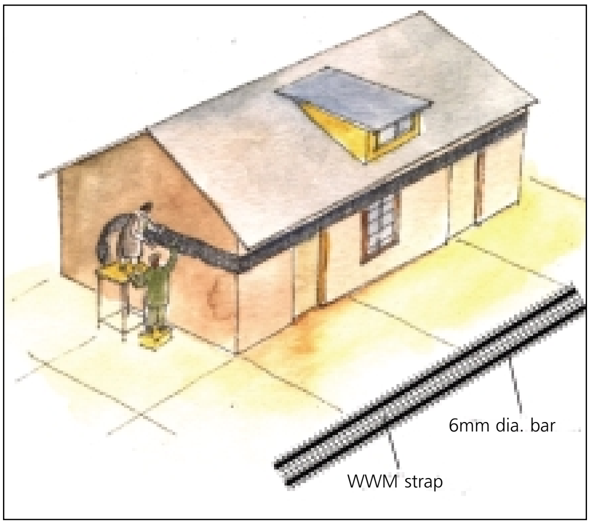
**** For all other situations see National Disaster Management Division, Govt. of India Guidelines for J&K.*

How to Install WWM Seismic Belt



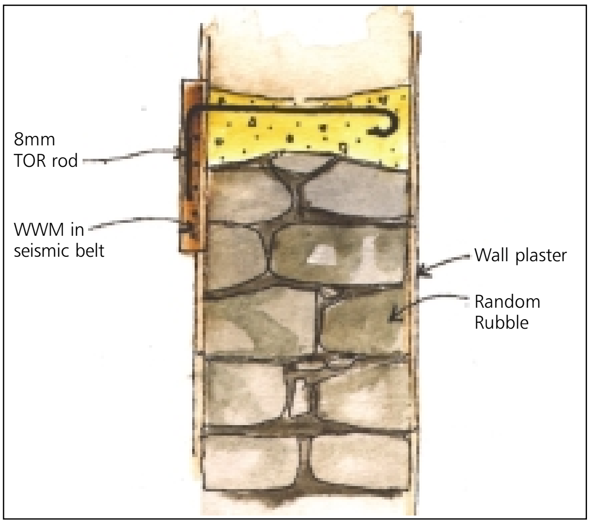
Preparing for seismic belt installation

1. Study the building and decide the alignment of the belt taking into consideration the presence of obstructions such as openings, RC elements, etc.
2. Mark the top and bottom edge of belt on wall using string and tube level.
3. Where the wall is plastered, use electric grinder if available to cut the plaster precisely along the top and bottom limits of the belt and to prevent extra plaster removal.
4. Remove the plaster between the marked area and expose the wall surface.
5. Rake all the mortar joints to a depth of 12 mm (½") by chisel or electric grinder. Clean the surface with wire brush and water.



Installing seismic belt

6. Prepare the mesh as per required length and attach it with binding wires to the pre-cut 6 mm bars that are bent as required.
7. Install WWM on the prepared surface. In brick or concrete block wall, use 100 mm (4") to 150 mm (6") length wire nails spaced at about 300 mm (12") in a staggered fashion in two rows to fix the mesh to the wall. Nails must be driven into mortar joints. Provide spacers 15 mm (½") thick of any suitable material between the wall surface and the mesh to ensure full encasement of mesh in plaster.

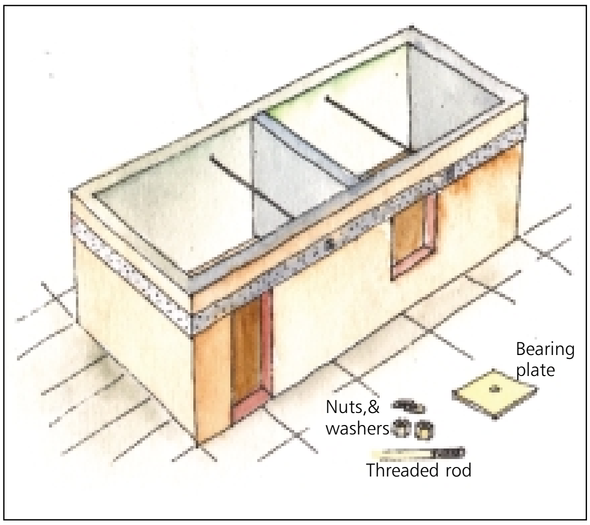


Shear connector for seismic belt

8. In the case of rubble walls, install cast in situ RC shear connectors with 'L' shaped dowel bar every 1.25 m (4') to 1.5 m (5'). Once the concrete hardens, attach WWM to the bar with binding wire. In addition, use 100 mm long (4") square-headed nails at 150-300 mm (6"-12") spacing. Install WWM as described earlier. If a nail bounces back, move it and reinstall it.
9. Ensure continuity of WWM and bars through a minimum 300 mm (12") long lap joints. If no overlap of WWM is preferred, install one additional overlapping bar for splicing with an overlap of 300 mm.

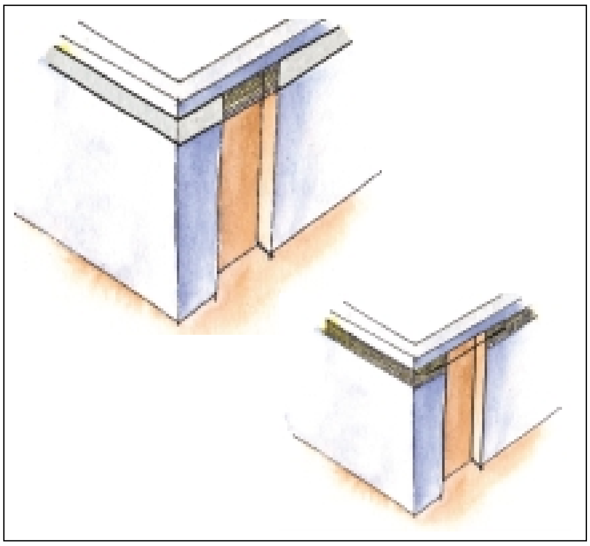
Make sure that corners do overlap

How to Install Seismic Belt (Cont.)



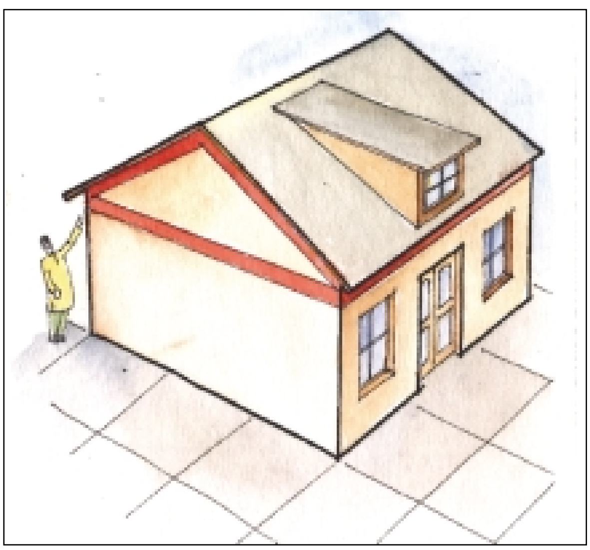
Tie rod installation

10. Tie rod should be 12 mm diameter MS bar with each end threaded over along an adequate length along with two nuts and a 100 mm x 100 mm MS bearing plate. Tie rod is installed level from the belt on one wall to the belt on the opposite wall, passing clear through a conduit placed in both walls and the belts. The rod shall be made taut with the help of two nuts tightened adequately at each end of the rod.



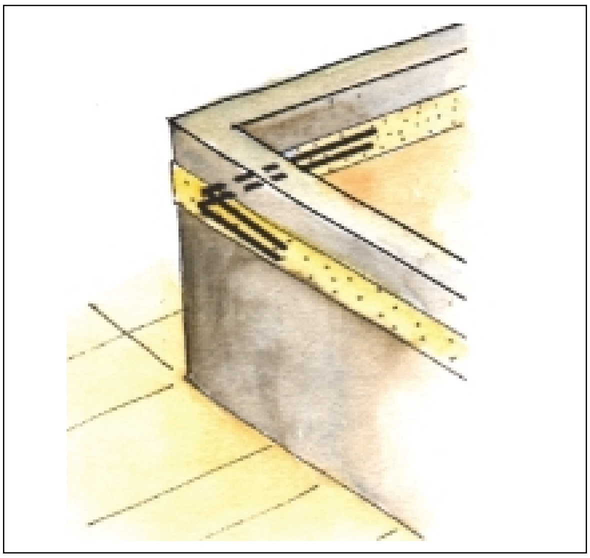
Belt reinforcement at opening

11. Where the belt alignment crosses an opening there are two options:
    - Continue the reinforcement including the bars and the WWM without plaster.
    - Discontinue the reinforcement and replace it with a 12 mm rod across the opening with adequate overlap.
12. All tie rods must be in place and made taut, and all holes must be filled with grout, before plastering the belt.
13. Splash the exposed wall surface with water to remove all dust and also to wet it properly.



14. While still wet, apply neat cement slurry followed by a first coat of cement : sand (1:3) plaster of 12 mm (½") thickness. After 1 to 2 hours, apply second coat of plaster with same mix and with enough thickness to provide 16 mm (5/8") cover over the reinforcement.
15. If the coat is too thick, the plaster will tend to fall off shortly after it is applied. Hence, the thickness of a coat should not exceed 16mm.
16. Cure the plaster for 15 days.

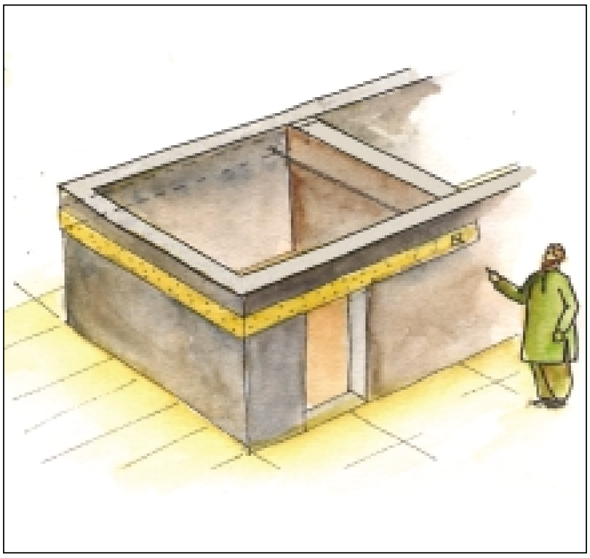
How to Install Seismic Belt (Cont.)



Using dowels for belt continuity through wall

Seismic Belt Ending on One Face of Wall to be Connected to Belt on Other Face

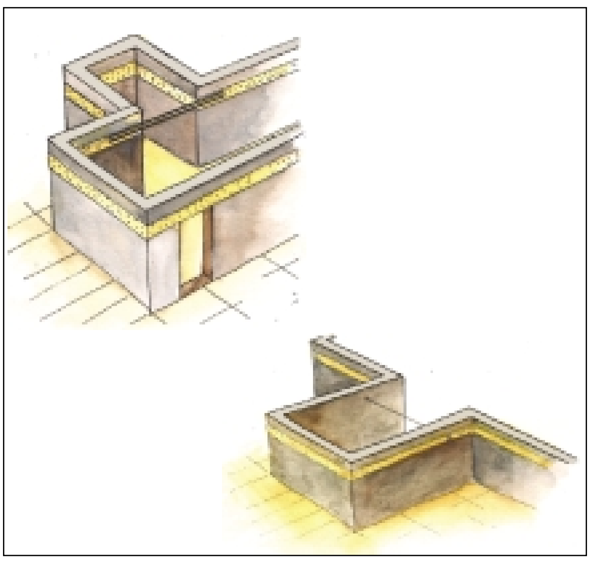
1. Make hole through the wall connecting the two belts.
2. Prepare two 8 mm diameter TOR bars, either 'L' shaped or straight as the situation requires. The length of the bars should permit 450 mm overlap with the WWM on both faces.
3. Insert the rods through the hole and connect them to the WWM of the concerned belts, tying binding wire at a minimum of two locations at both faces.



Ensuring continuity with tie rod on 4th wall

Ensuring Belt Continuity when Belt is Installed Around Only Three Walls

1. Install the belt reinforcement, including the WWM on three walls. Extend the reinforcement of the belts as close to the fourth wall as possible.
2. Make through holes (similar to that of bond element) within the belt alignment on both the walls as close to the fourth wall as possible.
3. Install a 12 mm diameter MS tie rod through these holes in order to restrain the free end of the seismic belts.



Ensuring continuity across small wall projections

Ensuring Belt Continuity Across Small Masonry Projections from the Main Wall

This situation arises with narrow masonry structures projecting out from the main structure, e.g. small passages or enclosures like bathroom or toilet.

1. Continue the seismic belts around the structural projection.
2. Install tie rod across the beginning of the projection.
3. Tie rod may be installed through the opposite walls.
4. If the seismic belt is on the inside wall-face of the main structure, then the continuity across the passage may be provided by simply placing a tie rod over the ends of the belt at the projection with adequate overlap on the belt.

Weaknesses in Brick or Stone Masonry Walls: Poor Storey-to-Storey Bonding, Poor Wall-to-Roof Bonding and Inadequate Resistance to Vertical Bending in Masonry

This Results in Horizontal Cracks, Collapse of Walls, and Sliding of Roof with Respect to the Lower Storey.

Installation of Vertical Reinforcement

Vertical reinforcement within the masonry wall will help prevent such failures.

Inadequate bending strength in masonry

Poor storey-to-storey bonding

Poor wall-to-roof bonding

Poor wall-to-roof bonding

How does Vertical Reinforcement work?

- It improves the bending strength of the wall to control the horizontal cracks, reducing the possibility of the walls going out of plumb or collapsing.
- It helps bond the roof to the walls, providing support to the wall and controlling its shaking in an earthquake.
- It helps improve the bond between adjacent storeys, which also strengthens the walls.

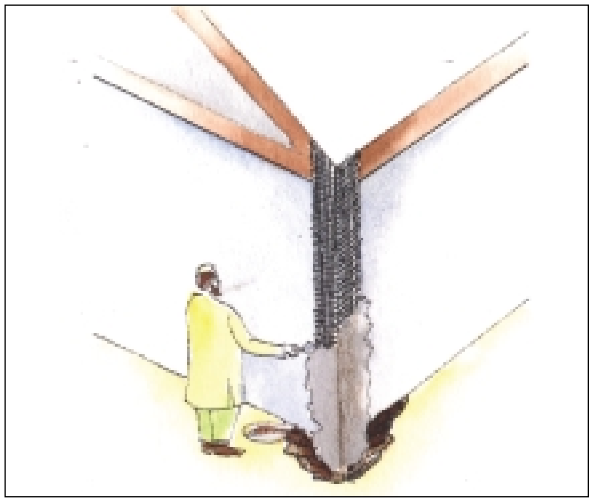
Vertical Reinforcement Location

Vertical reinforcement within masonry should be installed in all buildings in Kashmir:

- At all junctions of walls.
- At 'T' junctions, on one side of the junction only.
- In all storeys.

Types of Vertical Reinforcement

Single vertical bar



Vertical belt made of welded wire mesh

1. Single Vertical Bar

A bar must be installed at the inside corner of a wall-to-wall 'L' type junction. In the case of a 'T' junction it may be installed on either side of the junction.

2. Vertical Belt with Welded Wire Mesh

A strap of WWM is installed in an 'L' configuration on the outside of 'L' type wall-to-wall junction and in a flat configuration on the outside of a 'T' type junction.

Single Reinforcing Bar Requirement for Different Situations ***

		House		Public Building
		TOR Bar Dia.		TOR Bar Dia
No. of Storeys	Storey	Zone IV	Zone V	Zone IV & V
One	Ground	10	12	12
Two	First	10	12	12
	Ground	12	16	16

Welded wire Mesh Requirement for Different Situations for Zone V ***

		House		Public Building	
		WWM 13 gauge		WWM 13 gauge	
No. of Storeys	Storey	N*	B**	N	B
One	Ground	10	300	14 Plus 2 bars of 6 mm dia.	400
Two	First	10	300	14	400
	Ground	14	400	14 Plus 2 bars of 6 mm dia and 1 bar of 12 mm dia	400

* *No. of longitudinal wires in mesh.*

** *Width of finished vertical belt WWM made of 13 gauge wires is recommended here since 10 gauge wire mesh is too stiff to handle.*

*** *For all other situations see National Disaster Management Division, Govt. of India Guidelines for J&K.*

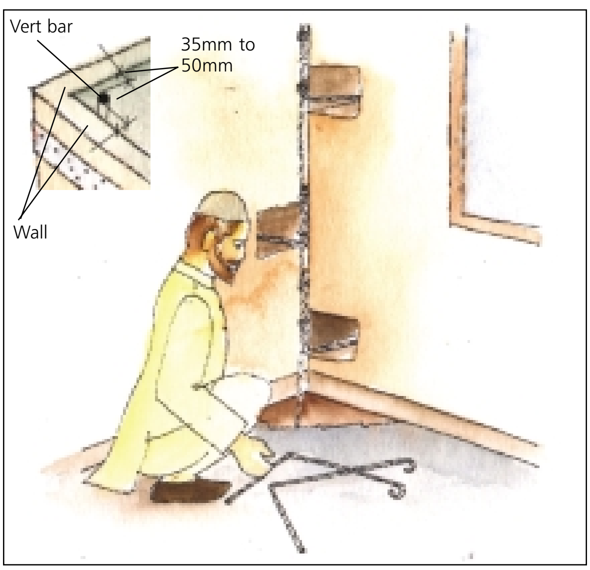
How to Install Vertical bar in a Corner

Marking boundaries of vertical rod concreting

1. Identify the inside corner for installation of vertical bar. Select appropriate location to maintain vertical continuity between storeys in case of a multi-storey structure.
2. Mark the area where the bar is to be installed. Using plumb-bob, demarcate a 100 mm (4") wide patch at the corner on both walls as the limits of concreting for encasing the rod.
3. Use electric grinder if available, cut the plaster along vertical boundary of both the patches to restrict the removal of plaster.

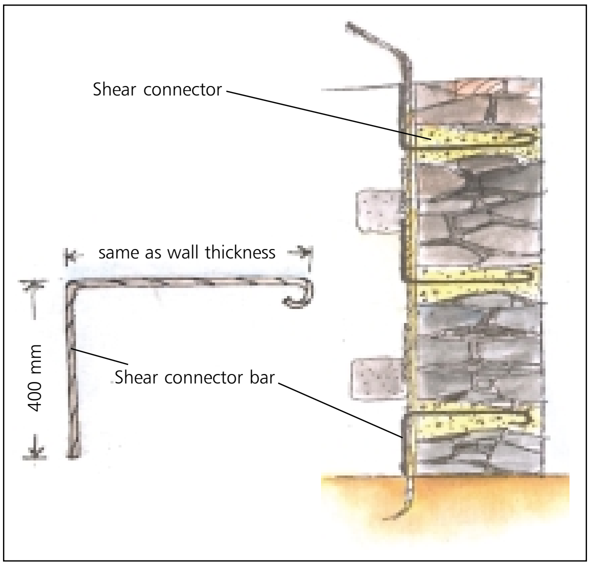
Breaking flooring and digging hole for vertical bar anchor

4. Remove the plaster from the marked area and expose the walling material. Rake all the mortar joints to the depth of 12 mm (½"). Clean the surface with a wire brush.
5. Remove flooring within 300 mm x 300 mm patch at the corner and excavate to 450 mm depth.
6. Make holes for installing shear connectors in both walls, starting on one wall at 150 mm (6") from the floor, with successive holes at approximately every 600 mm (2') but in alternate walls, and the last hole 150 mm below the ceiling level or 150 mm below eave level. Clean all the holes with wire brush to remove loose material.



Placing of vertical bar in the corner along with shear connectors

7. Place appropriate diameter bar in the floor excavation with the lower 150 mm (6") bent in 'L' shape. In a structure with CGI roof, the top end can be connected to one of the principal elements of the attic floor or the roof. In case of an RC slab roof, the top end can be bent into 'L' shape for connecting to the slab reinforcement. The rod will pass through each intermediate floor.
8. Place appropriately shaped 8 mm TOR bar in the holes made for shear connectors and connect them to the vertical bar making sure that the vertical bar is 35 to 50 mm (½" to 2") from each wall.

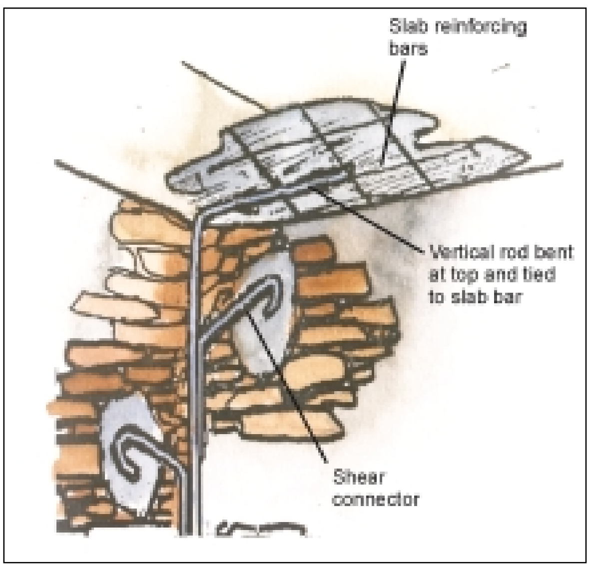


Shear connector & vertical rod details

9. With vertical bar plumb and at right distance from the walls pour concrete in 1:2:4 proportion in the hole excavated in the floor, with continuous rodding, to completely encase the bottom of the steel rod in concrete.
10. Clean all the shear connector holes by splashing water and wetting the surface of the holes thoroughly. Fill up the holes with non-shrink cement cum polymer grout. Make sure that the grout completely encases the shear connector bar.
11. Once all the shear connectors are grouted, clean the exposed surfaces of the wall with wire brush and water.


Encasing vertical rod in concrete

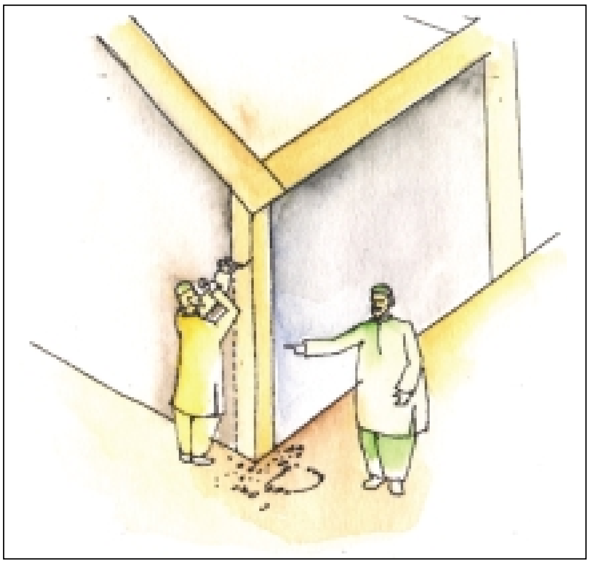
12. Install centering for concreting around the vertical bar. This can be done with GI sheet or timber plank. The concreting must be done in stages with the height of each new stage not exceeding 900 mm (3'). Pour 1:1½:3 micro-concrete into the form work, with continuous rodding to prevent honeycombing. Once the concrete is set, move the formwork upwards and continue concreting. Encase the entire length of the vertical bar in this manner. The bar must have the minimum concrete cover of 15 mm.



Connecting top bent end of vertical rod to slab reinforcement

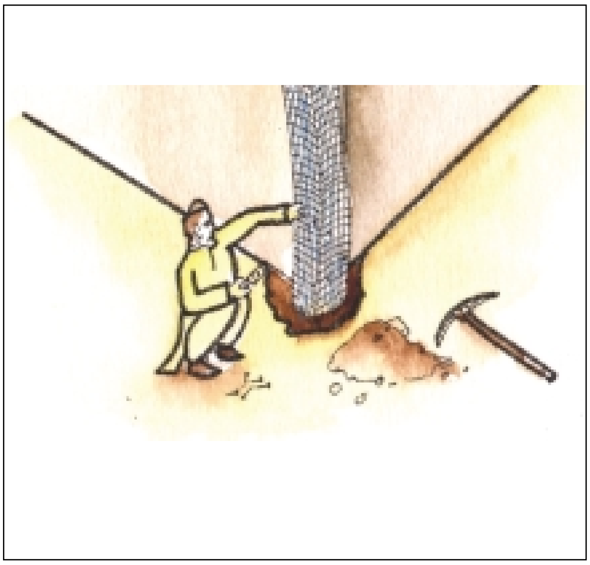
13. Where the roof is of RC slab, in the vicinity of the vertical bar, break the bottom concrete cover to expose the slab reinforcing bars. Connect the top bent portion of the vertical bar to the exposed bars of the slab using binding wires providing a minimum of 300 mm (12") overlap. Wet the exposed surface of the slab and then apply neat cement slurry. Finally apply cement mortar in 1:4 proportions and finish the joint to match the surrounding area.
14. Cure all concrete work for 15 days.

How to Install Vertical Belt with Welded Wire Mesh at Wall Junctions



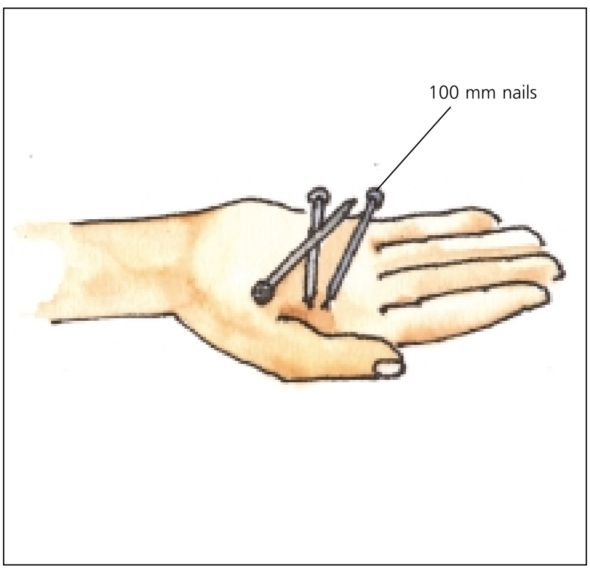
Removing plaster for vertical belt installation

1. Identify the corners where flat configuration belts are to be installed and where 'L' configuration belts are to be installed.
2. Mark the belt alignment on the wall using string and plumb-bob.
3. Using electric grinder if available, cut the plaster along the limits of the belt to restrict the plaster removal.
4. Remove the plaster from the marked area and expose the walling material.



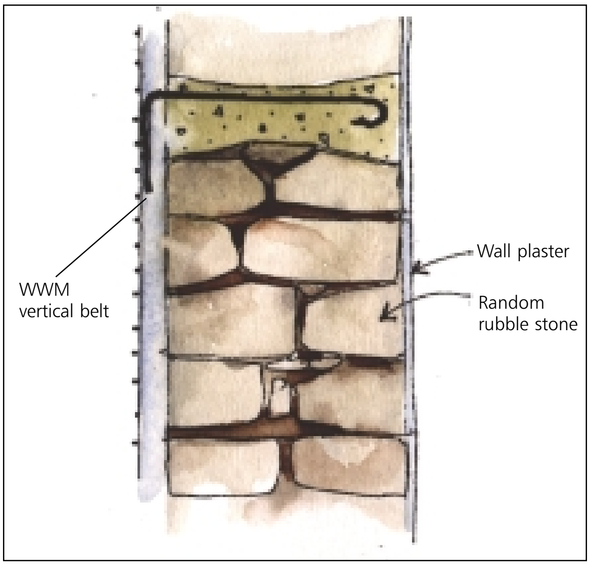
Anchoring vertical belt 300 mm below plinth level

5. The belt will start from 300 mm below plinth level and continue up to the top of wall at roof level.
6. Rake all the mortar joints to the depth of 12 mm (½") by hand or by electric grinder. Clean the surface with a wire brush.
7. Prepare the mesh as per required length and attach it with binding wires to the pre-cut 6 mm bars that have been bent as required.



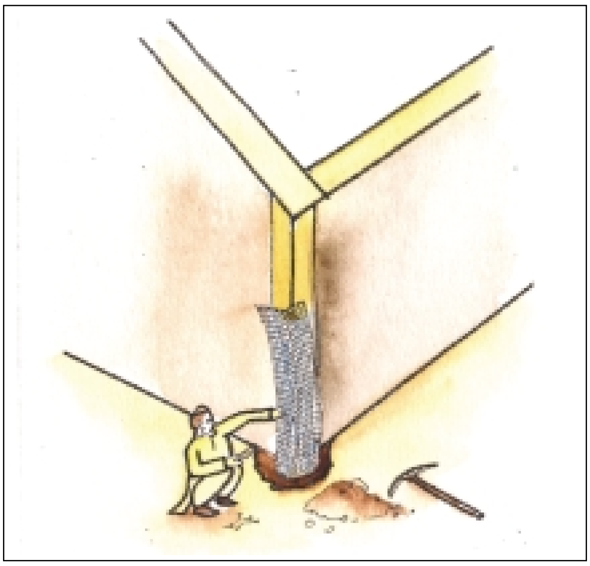
Using nails for anchoring vertical belt to wall

8. Install WWM where the area of the wall has been cleaned. Use wire nails 100 mm - 150 mm (4"-6") in length, spaced in staggered fashion at intervals of about 300 mm (12"), in two lines to fix the mesh to the wall. Nails must be driven into the mortar joints. Provide spacers 15 mm (5/8") thick of any suitable material between the wall surface and the mesh.

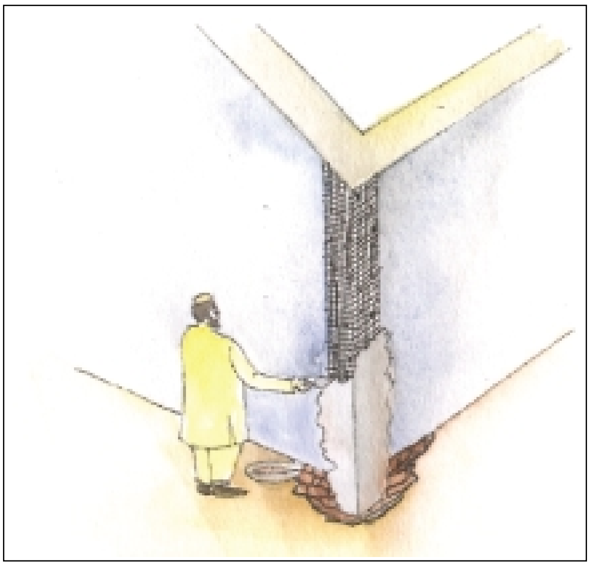


Anchoring WWM to random rubble wall with shear connector

9. In case of rubble walls, use 100 mm long square-headed nails at 300 mm spacing for installation. In addition, use cast in situ RC shear connectors with 'L' shaped dowel bar for greater reliability. Shear connectors are to be installed starting at 150 mm (6") above floor level with a spacing of 600 mm (2'). Successive connectors are to be placed on different walls in the corner. Once the concrete hardens, attach WWM to it with binding wire. Follow the instructions for installing the mesh as described on the previous page.


Anchoring vertical WWM to wall with nails

10. Ensure continuity of WWM and bars through overlap joints. The minimum overlap should be 300 mm (12").


Plastering vertical WWM belt using cement plaster

11. Splash the exposed wall surface with water to remove all dust as well as to wet it properly.
12. While still wet, apply neat cement slurry followed by a first coat of cement-sand (1:3) plaster of 12 mm (1/2") thickness. After 1 to 2 hours, apply second layer of plaster with the same mix and with enough thickness to provide 16 mm (5/8") cover over the reinforcement.
13. Cure the plaster for 15 days.

Weaknesses in Masonry Walls: Diagonal Cracking at Openings

Encase Openings with Seismic Belt: This Will help Prevent Such Diagonal Cracks.


Diagonal cracking; pier width too small


Severe diagonal cracking; windows too close to corner


Diagonal cracking in brick wall


Diagonal cracking in RR wall

How Does the Encasement of Openings Work

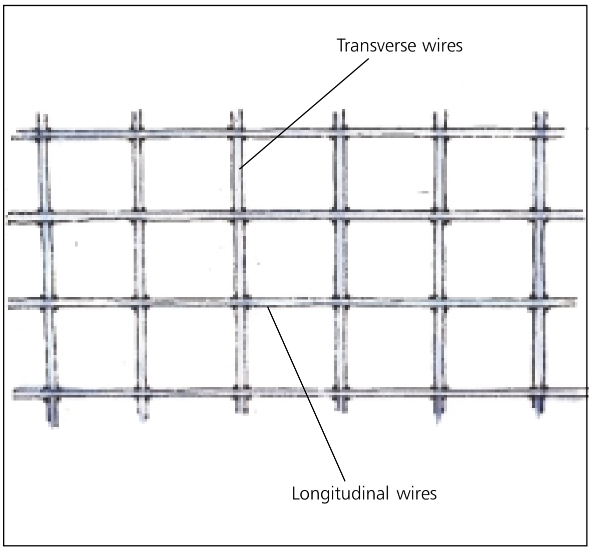
a. It strengthens the boundary around the opening, especially at the corners where concentration of tensile stresses occurs. Encasement helps resist the tearing action that occurs at opening corners. It is similar to stitching extra strips of cloth continuously around the edge of an opening.

b. When the gap between two openings is very small the wall in that gap behaves like a pier. This pier has very weak resistance to shearing and bending, but wrapping the pier in a seismic belt greatly strengthens it against these forces.

The encasement belt must be uninterrupted all around the opening and as close to its boundary as nailing it into the masonry permits.

Specification of Belt

Galvanized 10 gauge mesh with 10 wires spaced at 25 mm with Welded Wire Mesh width of 250 mm and plastered belt width of 280 mm. Alternatively, 13 gauge mesh with 6 wires spaced at 50 mm and 2-6 mm diameter for ease of handling. Reinforcing bars alone with an equivalent area may be used along with chicken wire mesh (CWM) if the right WWM is not available. Alternatively 13 gauge mesh with 6 wires spaced at 50 mm and 2-6 mm diameter rods too may be used.



Galvanized Welded Wire Mesh (WWM)

Installing WWM around door opening

Installing WWM around window opening

Completed encasement belt around window

How to Install Encasement Belt Around Opening

1. Demarcate 280 mm wide belt around the openings.
2. Since the lintel belt is installed just above the openings, the encasement belt is required only underneath and on the sides of the openings and under the openings like windows and ventilators.
3. The procedure is exactly same as that used for the horizontal and vertical seismic belt.
4. Belts on all sides of encasement must overlap at the corners. The belts on top sides must overlap with the lintel belt.
5. If the spacing between two openings is less than 560 mm, (22") the vertical portions of the encasement for both openings will merge with each other.

6.2 Retrofitting of Existing *Dhajji* Walls

Weakness in *Dhajji* Wall: Out-of-Plane Deformation due to Absence of Adequate Confinement to the in-Fill

The out-of-plane deformation results in damage to in-fill such as popping of plaster, horizontal and vertical cracking, and chunks of in-fill material falling out. Note that this only has a marginal impact on the structural safety of the walls.

Minor damage to Dhajji *wall - Cracks in in-fill*

Chunks of plaster popping off exposing lack of horizontal bracing and loose infill masonry

Small chunks of in-fill material falling out - the wall remains structurally safe

More chunks of in-fill material falling out - resulting in adverse affect to structural safety of the wall

Provide Confinement to In-Fill with Chicken Wire Mesh

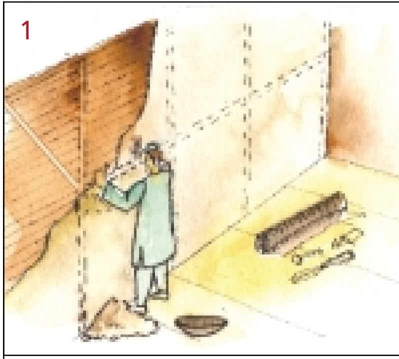
Chicken wire mesh nailed to all the timber elements in the wall on both faces will reduce lateral deformation in the in-fill and thus reduce the damage.

While retrofitting the *Dhajji* Wall assess the condition of the timber elements for degradation due to rotting or insect infestation. If any element is found to have degraded then replace it following the best practice of construction and carpentry.

How to Install Chicken Wire Mesh

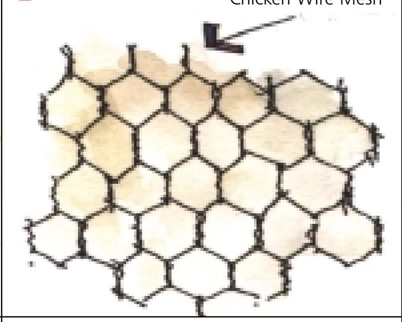
Horizontal & vertical cracking

1



Removing plaster

2



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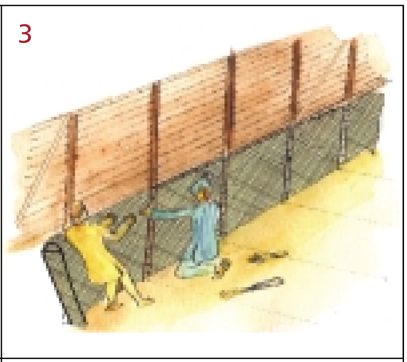
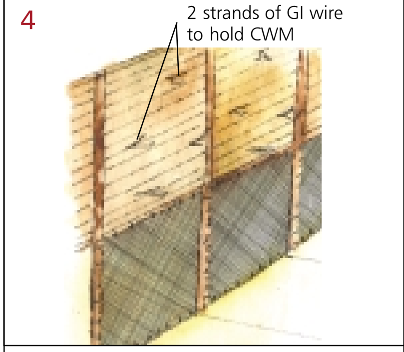


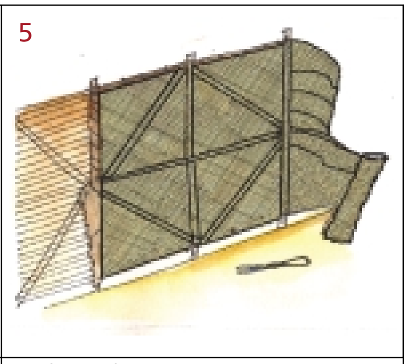
Stretching CWM while installing it

4



Installed chicken wire mesh

5



In-fill confined with chicken wire mesh

1. If the wall is plastered, remove the plaster to expose all the timber elements and in-fill material.
2. In large panels with in-fill material, insert two strands of 2 mm GI wires through the in-fill at two or more locations away from timber elements with 100 mm of wire sticking out on both faces.
3. Begin installing chicken wire mesh from one corner of wall, ensuring that the mesh is stretched in horizontal and vertical directions.
4. Anchor mesh to all the timber elements with 10 gauge nails 50 to 60 mm (2" to 2.5") long, continuously stretching the mesh to ensure that it is taut all the time.
5. Finish with plaster as desired.

Weaknesses in *Dhajji* Wall: In-Plane Deformation due to Lack of Adequate Bracings and their Poor Connections

This results in damage (a) to in-fill, including popping of plaster and diagonal cracking, and damage (b) to the whole structure such as lateral sway. Adequate bracing is a key factor in the structural safety of *Dhajji* construction.

Add Diagonal Bracings with Better Connections, and Strengthen Connections of Existing Bracings to Vertical Posts

Bracing together with stronger end connections will help resist in-plane forces, reducing damage levels as well as lateral tilt.

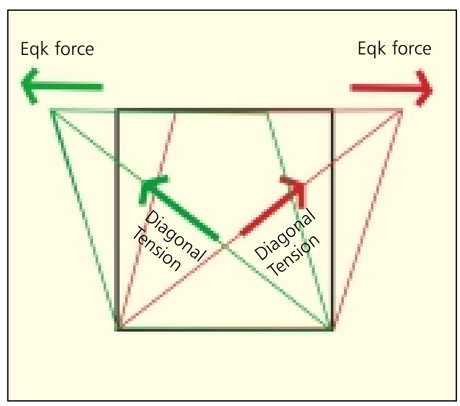
Popping off of plaster

In-plane deformation - tilting of timber frame

Swaying of timber frame with tilting of timber posts

How do Bracings and Better Connections Work

1. Under the effect of lateral forces, the rectangular panels of *Dhajji* walls become parallelograms. This causes tension in the diagonal direction, leading to cracks, popping of plaster and leaning of the structure. If diagonal bracing is installed that resist the tension, this deformation is reduced significantly, thus reducing damage level.
2. Diagonal bracing works if the connections to the vertical posts are sufficiently strong. If a connection fails, the bracing no longer functions. Hence existing connections between the bracings and posts must be strengthened.



Lateral sway causing tension in diagonal direction

How to Install Diagonal Braces in *Dhajji* Wall

Dhajji wall with inadequate bracing & strut system

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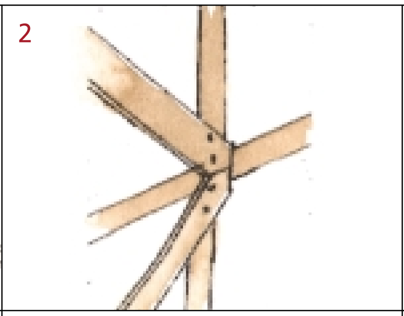
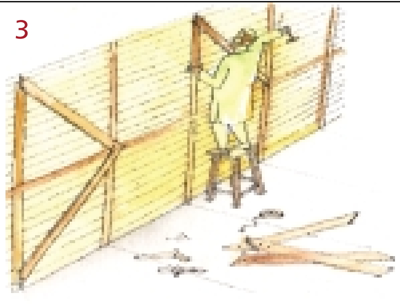
		
Pre-drilling bracings and struts	*Bracings & strut joint detail with min. 2 nails at each end*	*Installing pre-drilled bracings with nails overlapping on posts*

4

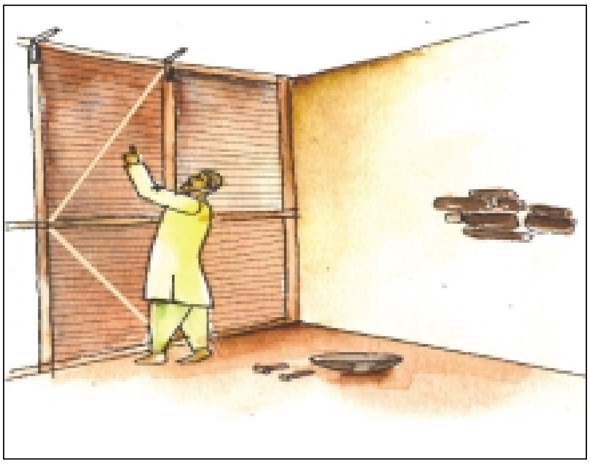
Maintaining continuity of bracings from one to another, and top to bottom of wall

1. If the wall is plastered, remove plaster to expose all the timber elements to assess the need for retrofitting.
2. Demarcate wall panels bound by horizontal (beams and struts) and vertical timber elements (posts) of approximately 0.8 m to 1 m dimension. Smaller panels may be skipped safely.
3. Install diagonal bracings consisting of 20 mm x 100 mm planks between two diagonally opposite corners of the selected panels. Select one of the two options for this. Option 1 - Remove the infill masonry and install the bracing within the timber frame as is commonly done in the new wall, and reinstall the infill OR Option 2 - Install the bracings on the wall face without removing the infill.
4. Use a minimum of two 10 gauge nails 60 to 75 mm (2.5" to 3") long at each end of the brace. Pre-drill braces to prevent splitting at the ends. Pre-drilling pilot holes in existing timber in the wall is also recommended. To prevent splitting. If the wood is old it can be dry, and hence, hard. Pre drilling in struts is also recommended.
5. If the bracing is installed in a location that will expose it to the weather on a long-term basis, it should be made of a good quality hard wood. If it is not of good quality, it can be painted for protection.
6. In every wall, provide bracings in alternate vertical bays moving from top to bottom preferably running in opposite directions.

Note: Nailing additional braces in front of Dhajji *wall should only be applied where it is not possible to add horizontal and diagonal braces through wood joining inside the panel*

Weakness in *Dhajji* Wall: Inadequate Connection of Wall with Floor and Ceiling, and Lack of Positive Connection to Adjacent Masonry Walls

This results in damage to or the collapse of (a) *Dhajji* wall and (b) masonry wall.



Anchoring Dhajji *wall to roof deck*

Strengthen Connection Between *Dhajji* Wall and the Floor and Roof

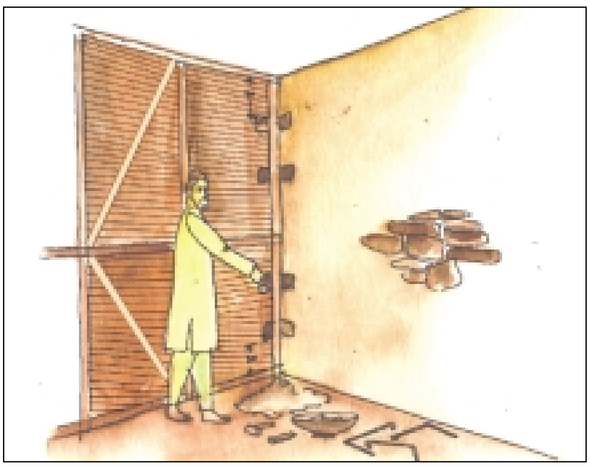
This will result in a better support to the wall, thus reducing its movement and potential for damage in an earthquake.

How to Anchor *Dhajji* Wall to Timber Floor (lower level) and Ceiling

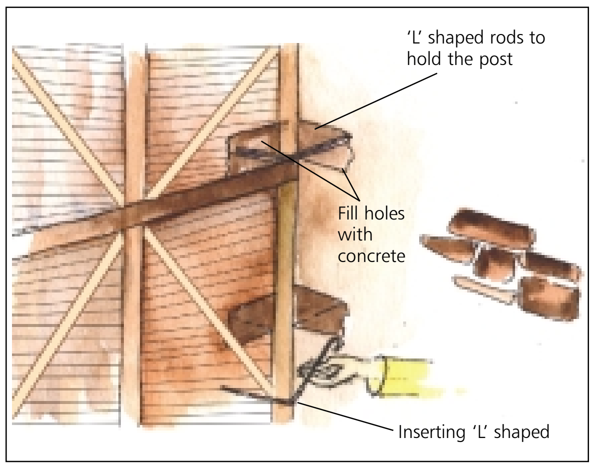
Install 'L' shaped brackets made of MS flat 30 mm x 3 mm with 10-gauge nails 75 to 90 mm long to connect the top chord of Dhajji wall to the floor joists.

Introduce Positive Connection Between *Dhajji* Wall and the Adjacent Masonry Wall

This results in a better support to *Dhajji* and masonry walls, thus restraining them and reducing damage.



Making holes for anchors in adjacent walls



Anchoring Dhajji *wall to masonry wall with ''L' shaped rods*

How to Connect *Dhajji* Wall to Adjacent Masonry Wall

1. Make holes in masonry walls similar to those for shear connectors adjacent to the junction of *Dhajji* wall and masonry wall.
2. The lowest hole should be approximately 300 mm (1′) from the floor and the topmost hole should be approximately 300 mm (2′) from the ceiling. Make additional holes equally spaced no more than 600 mm apart.
3. Each hole should be cast just like a shear connector.
4. The holes should be positioned in such a manner that from each hole one rod projects out along one face of *Dhajji* wall and the second rod projects out along the other face.
5. Each reinforcing rod should be so oriented that its bent end is anchored in the cavity made in the *Dhajji* wall and the hooked end is in the masonry wall.
6. Fill the cavity in *Dhajji* wall as well as in the masonry wall with concrete and cure for ten days.

6.3 Retrofitting of Existing Flat Floors / Roofs

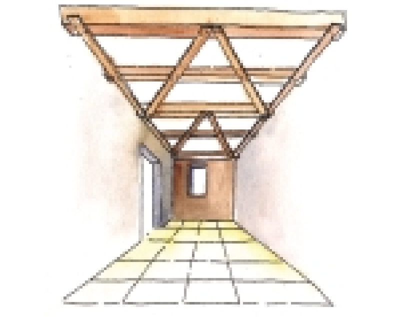
Weakness in Flat Floor/Roof: In-Plane Flexibility Leading to Significant Deformation and Breakage of Timber Deck under Lateral Seismic Loads

Install Diagonal Braces and Struts in Timber Floor/Roof Deck

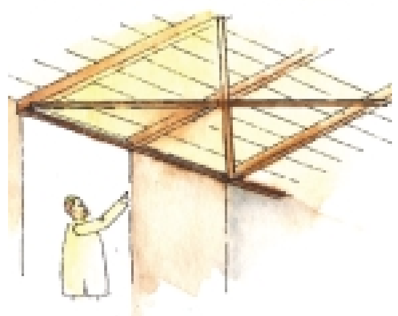
When the deck deforms from a rectangular shape, its diagonals lengthen. Diagonal braces along with struts, if connected well on the underside of the deck, greatly reduce the in-plane deformation of the deck and thus significantly reduce the lengthening.

Damaged roof elements

Pre-driling bracings and struts



Floor deck timber bracings - 'K' arrangement



Floor deck timber bracings - 'X' arrangement

How to Install Timber Struts and Braces under Flat Deck

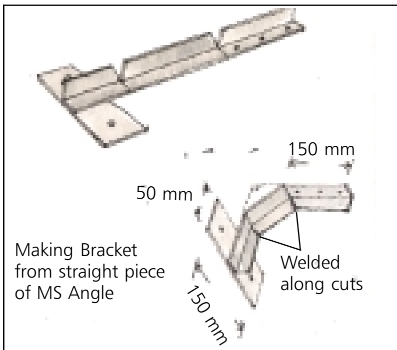
1. The bracings and struts can be installed in a variety of arrangements as shown.
2. Install a 100 mm x 25 mm (4" x 1") strut (plank) on the underside of the floor beams adjacent to a long wall. Install an additional strut parallel to this on opposite wall. Pre-drill these planks to prevent splitting from the holes at the ends. Also pre-drill pilot holes in the floor beams, if possible, to facilitate nail driving. Use a minimum of 2 nails at each end of the beam.
3. Install diagonal bracings starting from one end of a strut to the far end of the opposite strut. The angle between the brace and the strut should be as close to 45° as possible and also such that full sets of bracings are accommodated.
4. Install more sets of bracings starting from the end points of the bracings already installed to cover more of the deck area.
5. Installation of bracings can also be done in a manner similar to that of the planks. If it is difficult to accommodate two nails at each end, 3 mm thick steel gusset plates may be used with bolts.

Weakness in Pitched CGI Roof Supported on Masonry Walls: When Roof and Walls are not Connected to Each other, Walls are Unsupported at the Top and Hence More Vulnerable

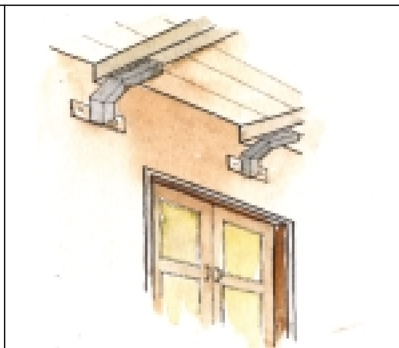
Anchor Roof/Floor deck to Masonry Walls

When roof deck with diagonal bracings is anchored to masonry walls, it holds the walls together and reduces their movement, thus reduces likely damage.

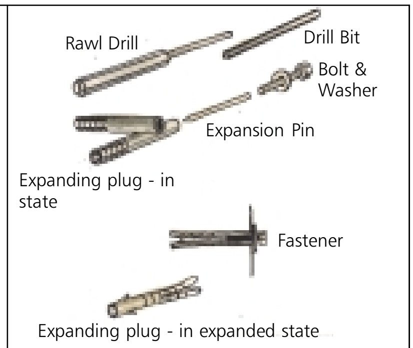
Wall damaged due to in-adequate bonding between brick masonry walls and roof deck



Roof deck to brick wall anchor



Roof deck anchored to brick wall



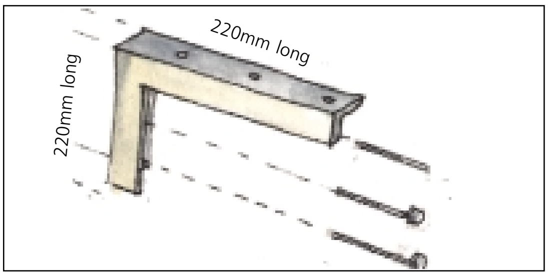
Fasteners for anchoring on to brick masonry wall

How to Anchor Roof/Floor Deck to Brick Masonry Walls

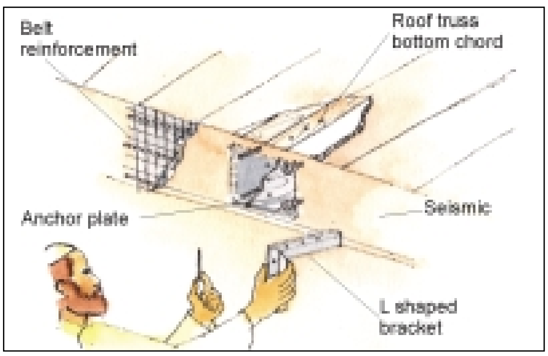
1. Use brackets made from MS steel angle (50 mm x 50 mm x 3 mm) with an MS plate (150 mm x 150 mm x 3 mm) with two holes, welded to one end of the bracket.
2. Identify principal beams that must be anchored to wall.
3. Using 15 mm diameter bit, drill two through holes at suitable locations in the walls at each identified beam location.
4. Install brackets on the wall using two bolts of 12 mm diameter.
5. In the case of through holes, place an MS bearing plate (75 mm x 75 mm x 3 mm) on the other face of the wall before installing nut on the bolt.
6. Connect bracket to the underside of the wood beams with 10 gauge nails of 100 mm length driven into the pre-drilled holes.
7. In the case of a 350 mm (14”) thick wall, make holes 250 mm (10”) deep and use polymer grout or mechanical anchors to anchor the bolts.

How to Anchor Roof/Floor Deck to Random Rubble Walls

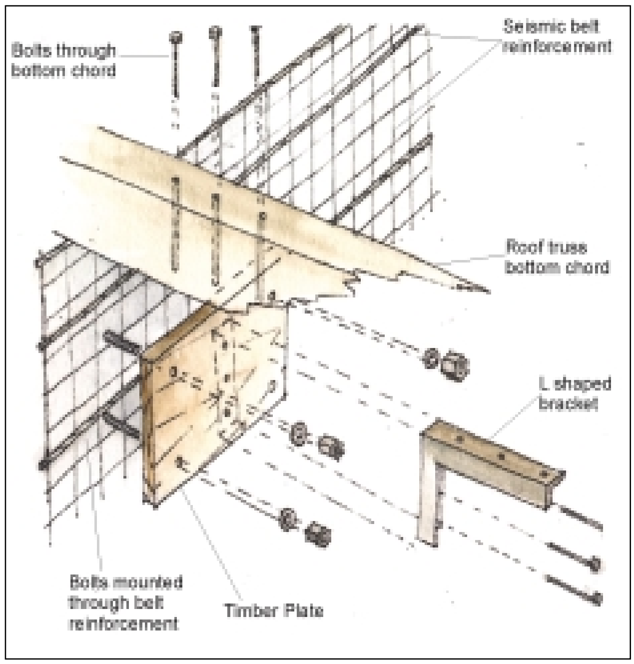
Damaged RR walls due to in-adequate bonding between roof and walls



MS bracket & bolts assembly



Installing bracket on timber plate mounted on seismic belt



Bracket assembly installation blow up diagram

1. Use 220 mm x 220 mm 'L' shaped brackets made from MS steel angles (50 mm x 50 mm x 3 mm) with three 15 mm diameter holes in each leg.
2. Identify bottom chords of trusses that must be anchored to the wall.
3. Prepare a 35 mm x 250 mm x 450 mm wooden anchor plate with four 15 mm diameter holes in the corners and 3-15 mm diameter holes for the bracket.
4. Connect bracket to the plate with 3-12 mm diameter bolts.
5. Under the location of each truss on the wall install the plate with 4-12 mm diameter bolts which are already installed through the WWM of the seismic belt or on the wall.
6. Connect bracket to the underside of bottom chord of the truss using 3-12 mm diameter bolts placed through thebottom chord. Alternatively, use three 8 gauge 100 mm to 150 mm nails driven into the pre-drilled pilot holes.
7. Instead of individual wood plates at each truss locations, a full-length 30 mm x 250 mm plank may be installed on the wall with 12 mm diameter bolts through the wall.

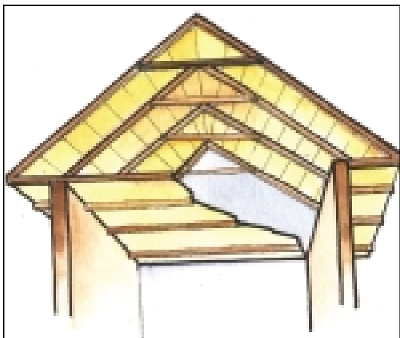
6.4 Retrofitting of Existing CGI Roofs

Weakness in Sloping CGI Roof: Out-of-Plane Flexibility leads to Significant Deformation of Roof Under Lateral Seismic Loads, Resulting in Damage

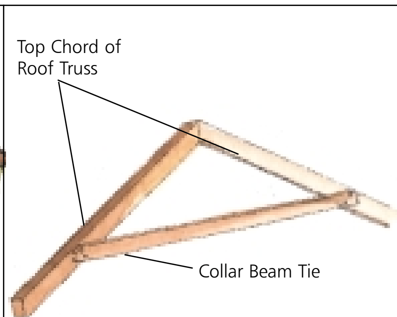
Install Principal Rafter Collar Beam or Horizontal Tie

This tie will help restrain the principal rafters in a horizontal direction, thus reducing the out-of-plane deformation of the roof. This effectively reduces the horizontal thrust from rafter to the attic floor deck.

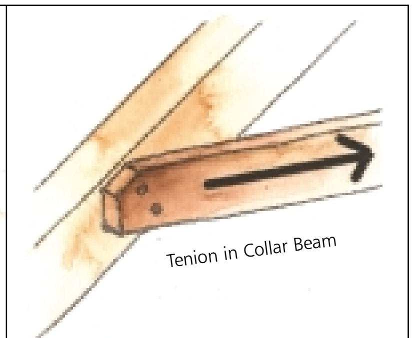
Roof damaged due to inadequate tying



Roof retrofitted with tying by collar beams



Roof truss with Collar beam



Arrangement of bolts with respect to tensile force

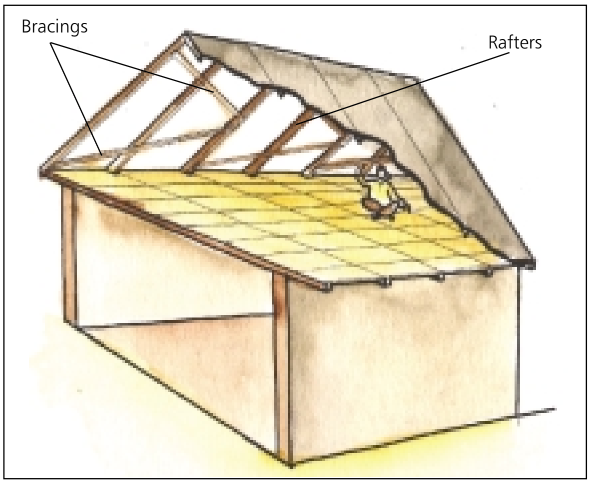
How to Install Collar Beam/Horizontal Tie

1. Mark installation points on the principal rafters at approximately 2/3 height of the roof rise on both sides of the ridge. Ensure proper level using water tube.
2. Prepare collar beam from 35 mm x 100 mm plank. Pre-drill the plank to prevent splitting at ends. The holes should be so aligned that they are not in one line with the length of the collar beam. To avoid damage when nailing the wood, which may be dry and hard, pre-drill pilot holes in the rafters also.
3. Install collar beam plank stretching from one rafter to the opposite rafter.
4. Use a minimum of 2-10 g 75 mm nails or 2- 5 mm diameter bolts at each end to fix plank to the principal rafter.

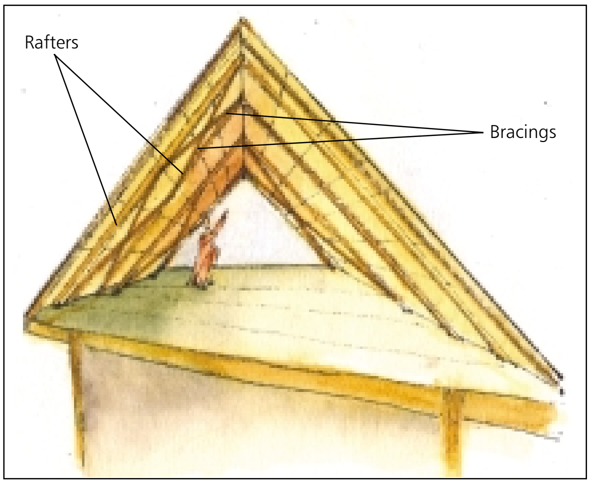
Install Diagonal Bracings

Diagonal bracings installed on the underside of the top chords of trusses or the principal rafterswill prevent the in-plane distortion of roof in the event of seismic forces parallel to the ridge.

Roof damage due to inadequate in-plane strength



Roof retrofitted with in-plane bracings - 'K' Arrangement



Roof retrofitted with in-plane bracings - 'X' Arrangement

How to Install Diagonal Bracings in CGI Roof

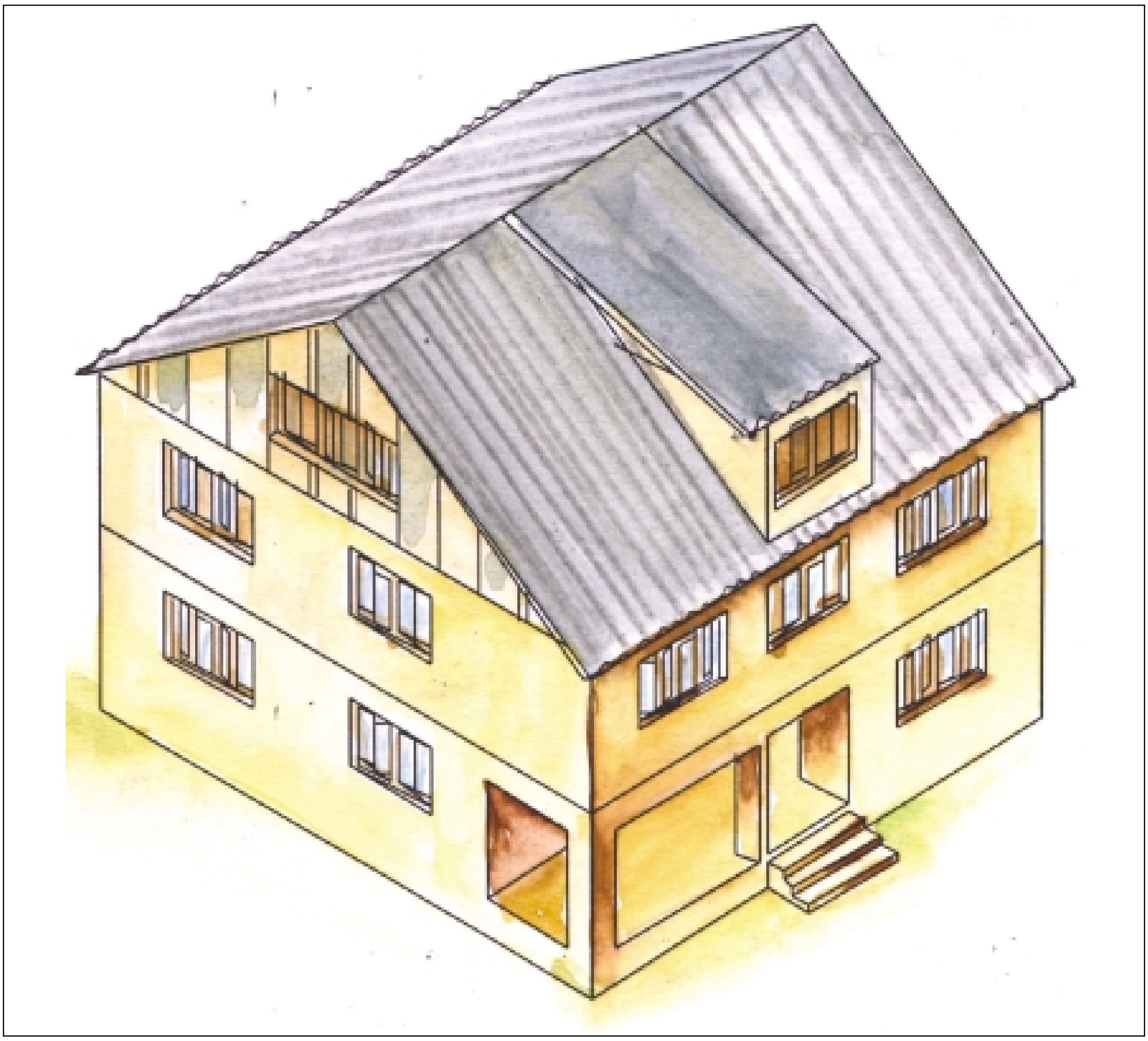
1. Bracings can be installed in a variety of arrangements as shown in the diagram, depending upon available timber length. Continuity from ridge to eave level must be maintained.
2. The angle between the brace and top chord/rafter should be as close to 45° as possible for optimal effectiveness.
3. Bracing should be of 100 mm x 25 mm (4" x 1") or heavier planks. Pre-drill the planks to prevent splitting from the holes at the ends. Also pre-drill the top chord/principal rafters to minimize the likelihood of splitting because of their age and dryness. Use a minimum of two nails at each end.
4. Install one or two more sets of bracings with similar arrangement between other sets of rafters, maintaining symmetry. Bracings must be installed in a symmetrical fashion on either side of the ridge.
5. If the space is not adequate for two nails at each end, joints can be made using a 3 mm gusset plate.

Chapter 7 Seismic Retrofitting: Step by Step

Knowing how to carry out a particular retrofitting measure is not enough. The decision-making for each step, and coordination of various steps in relation to each other, are critical to successful retrofitting of a structure.

Typical House of Rural Kashmir

Houses generally have two storeys. The walls in such houses are made of brick in cement mortar or random rubble masonry. Roofing is generally CGI sheeting supported on timber understructure. The intermediate floor and attic floor are made of timber joists and beams with planks on top of them.



Step 1: Planning for Retrofitting

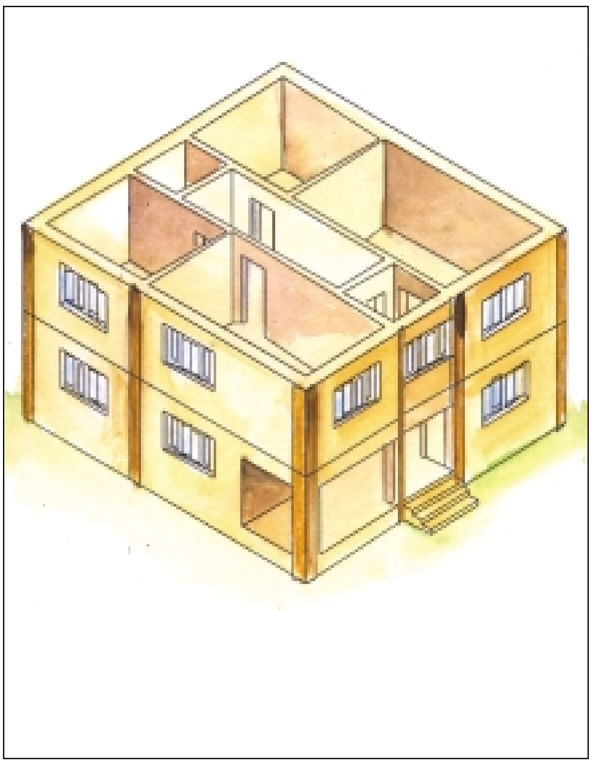
- If the house is damaged, restore it to pre-earthquake undamaged condition.
- Assess vulnerability of the structure as described in Vulnerability Assessment (Chapter 4).
- Assess one room at a time to decide what needs to be done.
- Develop retrofitting scheme for the whole building in order to ensure coordination among various retrofitting measures. Obtain technical information from this manual and additional information from *Guidelines for Kashmir* published by Government of India.
- Prepare drawings necessary for efficient and exact execution of retrofitting and prepare material quantity estimate as well as cost estimate of each item.
- Assign priority to the retrofitting measures to be implemented. Execute the measures based on the availability of funds and time. It is not necessary to execute all the measures at the same time.

Step 2: Installation of Horizontal Seismic Belt

- Plan for all the belts, including those for the encasement of openings.
- Identify walls which require belts on both wall faces and those, which require a belt on one face only.
- Plan the alignment of belts to ensure proper connection between all the belts. This is especially important when some walls have belts on one face and some on both faces. No belt may terminate without a connection to either the other end of the same belt or to some other belt. If a belt terminating on one wall is to be connected to a belt on a non-contiguous face of another wall, dowel bars will be required for linking the two.
- Points of tie-rods and their anchoring must be determined, and the required provision for their installation during the installation of the belt must be made.
- When it is possible to install a belt on only three walls, a tie rod must be installed on the fourth wall to ensure continuity.
- In the case of openings, if the space between two openings is less than the encasement belt width, then both belts will merge with each other.
- In case of obstructions, part of the belt may be raised through a sloping transition while maintaining adequate overlap.

Step 3: Installation of Vertical Reinforcing Bar at Wall Junctions

- Identify all potential locations for the installation of vertical bars.
- In the case of "T" wall junctions, the bar may be placed on one side of the "T" or on both sides, as desired.
- With a two-storey (or more)-storey building, try to ensure continuity of the bar from the bottom storey to top storey. If this is not possible, explore alternate locations for the bar.
- While installing the shear connectors, ensure a common shear connector at the crossing of the vertical bar and the seismic belt. This will ensure a connection between the two and also save costs by reducing the number of shear connectors.
- In case of obstruction by stepped footing, bend the bar as required for correct positioning.
- In each room, follow installation of seismic belt with the installation of vertical reinforcement.

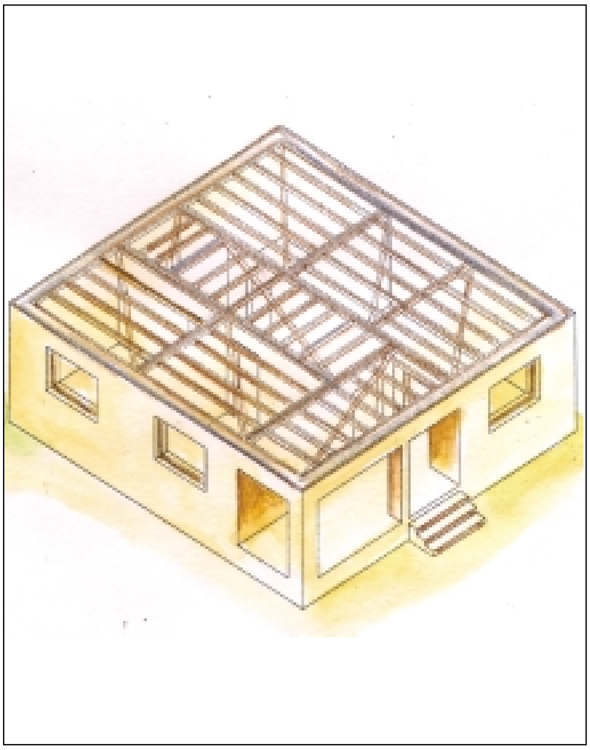


Step 3 (alternate): Installation of Vertical Belt with Weld Wire Mesh as an Alternate to Single Vertical Bar at Wall Junctions

- In the event that it is not possible to work inside a room, the vertical reinforcement may be provided with WWM belt on the outer face of the wall.
- Continuity of the vertical reinforcement must be ensured from bottom to top, be it entirely in the form of a WWM belt or using both WWM and a single bar.
- The overlap between the reinforcement of seismic belts and the vertical belt with WWM must be ensured through tying and dowelling.
- In the case of brick masonry walls, simple nailing may be adequate for anchoring of the belt to the wall. With random rubble masonry, nailing may also have to be used since shear connectors can not be installed adjacent to exterior wall corners.

Step 4: Installation of Cast in Situ Reinforced Concrete Bond Elements in Random Rubble Walls

- Before marking the locations for installation, decide the number of elements required. Identify cast in situ RC shear connectors that will be installed for vertical reinforcement, seismic belt and opening encasement. Deduct these from the required number.
- Review the wall from both faces before finalizing the locations, to prevent conflict with wall junctions, built- in cupboards, shelving etc.
- Exercise extreme care not to weaken the wall while making holes.
- Finish one wall at a time at each storey, starting from bottom storey.
- On the exterior face it may be best to finish the elements to enhance their visibility.
- Bond elements may be installed in thick brick walls as well.

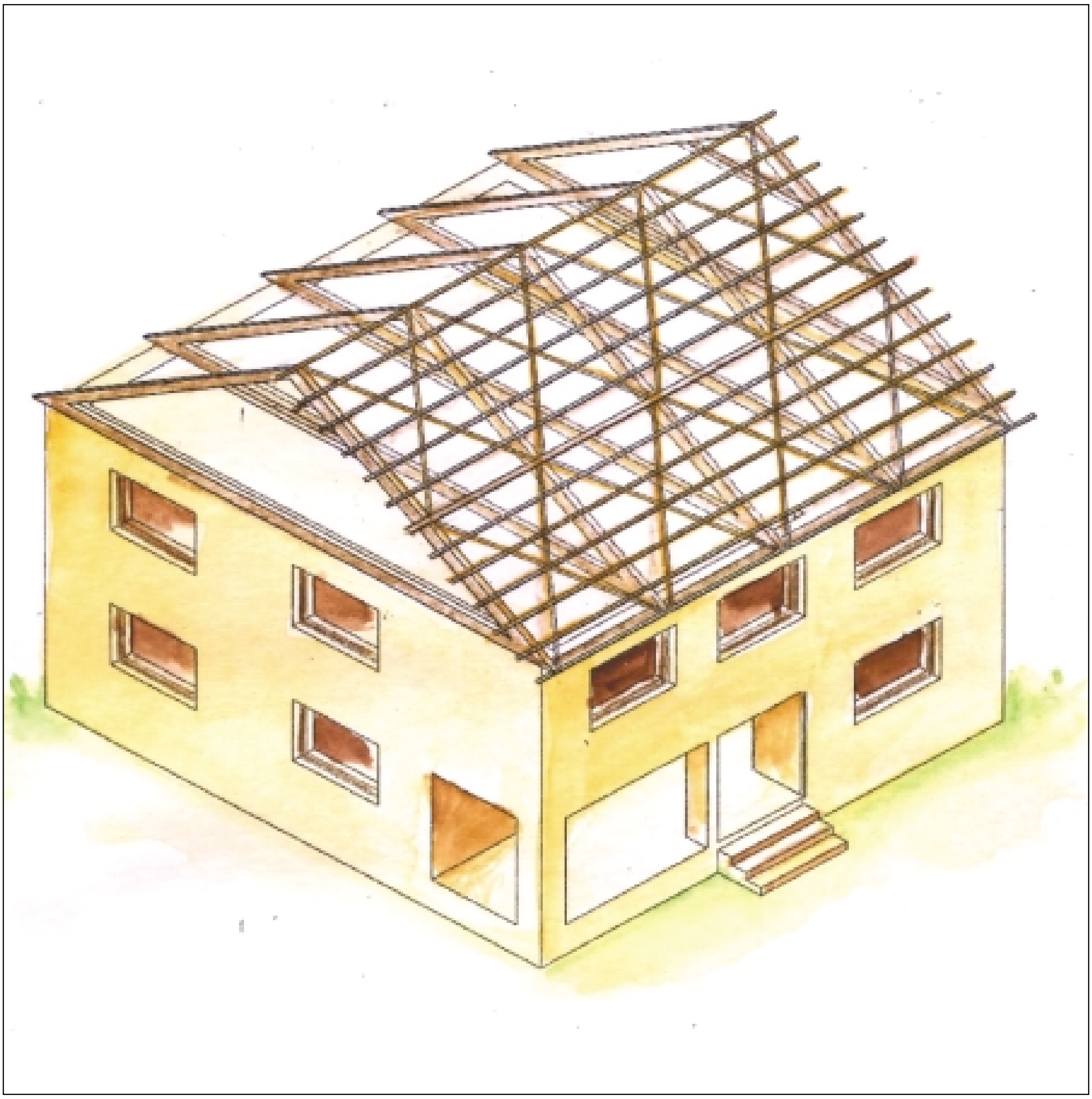


Step 5: Anchoring of Floor to Walls

- Anchoring of the floor deck should be done at the bottom chord of trusses as well as other important floor beams. Ascertain that there is adequate clearance for the required working space in the attic before beginning.

Step 6: Additional Nailing in Floor Planks and Adding In-Plane Bracing and Struts to Underside of Wooden Floor.

- If any planks are rotten, they should be replaced before installing additional nails. Pre-drilling in planks (new and old) and making pilot holes in joists will help reduce the splitting.
- The arrangement of struts and bracings should be such that the angle between bracings and joists is within the range of 35 to 55 degrees.
- Bracings and struts should be nailed to every joist that they cross. A minimum of two nails should be applied at each point.
- Continuity of bracings is desired within a room while moving from one end of the floor to the other in both directions.



Step 7: Installing Collar Beam Ties across Top Chords of Roof Truss /Principal Rafters

- After identifying, pre-drill the roof truss top chords/rafters, and collar beams at appropriate spots.
- Ensure enough vertical clearance under the collar beams to permit the use of floor space.

Step 8: Installing Diagonal in-Plane Bracings on Underside of Top Chords of Roof Truss/Principal Rafters

- To decide the layout of bracings, align them at an angle of 35° to 55° degrees with the ridge of the roof.
- Ensure continuity of bracings from ridge to eave.
- The arrangement should take into consideration the length of timber easily available.
- The arrangement should be symmetrical with respect to the ridge.
- Upon finalizing the arrangement and points of installation, pre-drill at all points before installing the bracings.

Chapter 8 | Case Studies

Case studies are the best way to learn the practical aspects of the retrofitting process from the experience of the others. They eliminate the need for reinvention, and a further benefit is that they can help build confidence in prevailing building systems.

8.1 Introduction

Case studies are a useful element in any manual. They present real-life problems that were tackled using the know-how given in the manual. Case studies thus help to show how the textbook knowledge can be usefully applied in real life action.

Retrofitting buildings for improved performance in earthquakes is a relatively new concept in our country, although in California simple retrofitting measures such as anchoring of roof parapets were made obligatory by law over half a century ago. Further – more complex – retrofitting applications have been added over the past few decades, which are based on sound engineering analysis.

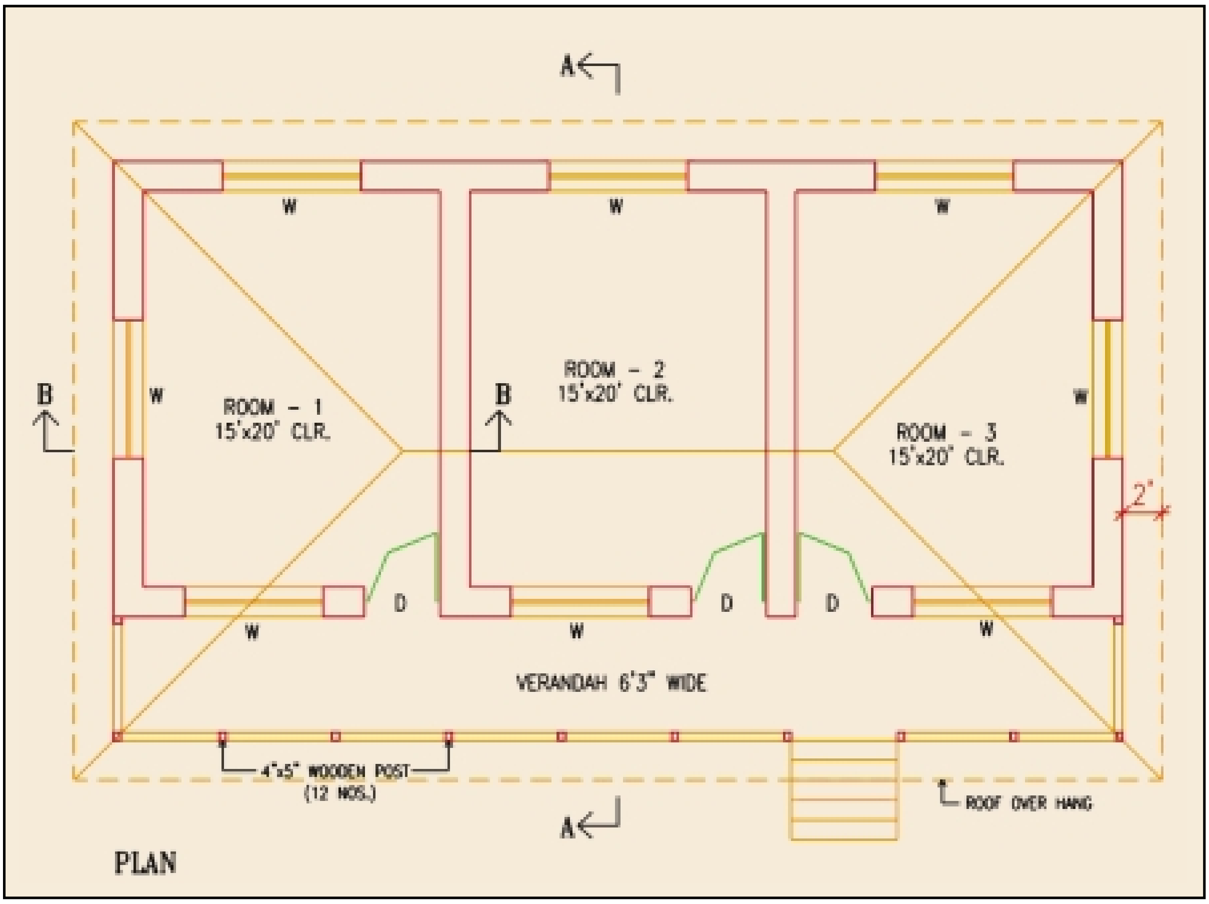
In India, although some work was done on retrofitting as far back as the late 1960s in the aftermath of the Koyna earthquake, this option received official recognition only during the post-Latur earthquake rehabilitation programme. More recently, the Kutchch (Gujarat) earthquake of 2001 brought much-needed visibility to the concept of retrofitting. In spite of all this, the extent of actual application of retrofitting remains limited. A large number of structures that can easily be retrofitted are still being demolished and replaced, or continue to remain in use in a highly vulnerable state.

The purpose of presenting case studies in this manual is to share the learning from cases that are relevant to the present-day scenario of high-level seismic risk in the State of Jammu and Kashmir. These studies will help the reader develop an understanding of the practical aspects of retrofitting and of the retrofitting scheme for the building as a whole unit, rather than just the individual measures described in the preceding chapters. The specific details that have emerged from these individual cases can help eliminate the need for reinventing solutions. These case studies will also help to establish good practices in this emerging field and build readers' confidence in these new concepts.

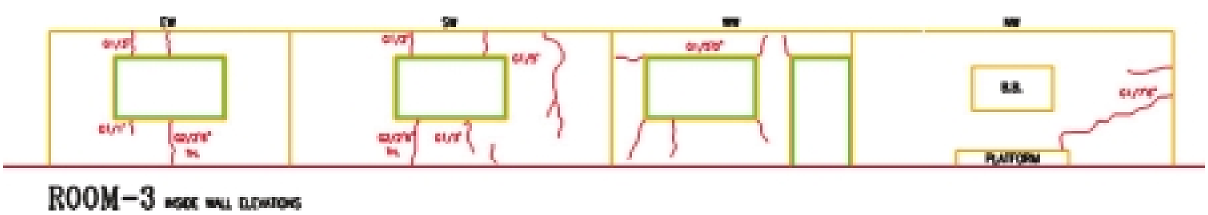
The case studies presented here include two public buildings. Both are typical Kashmiri buildings, one of them rural and the other more urban.

8.2 Sultan Daki High School, Uri Block, Dist. Baramula, Kashmir - A Rural Example

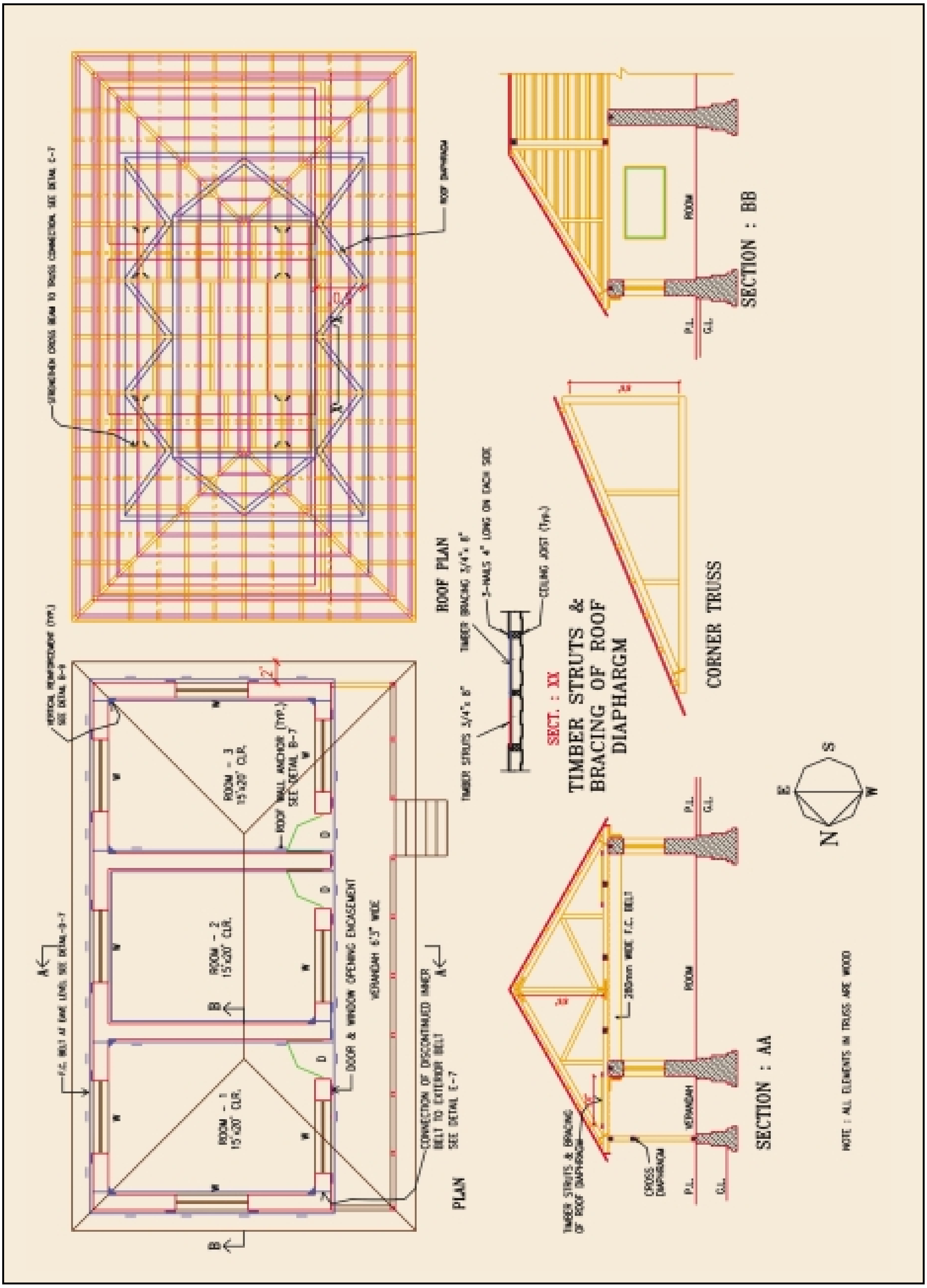
Drawings for the Restoration and Refrofitting



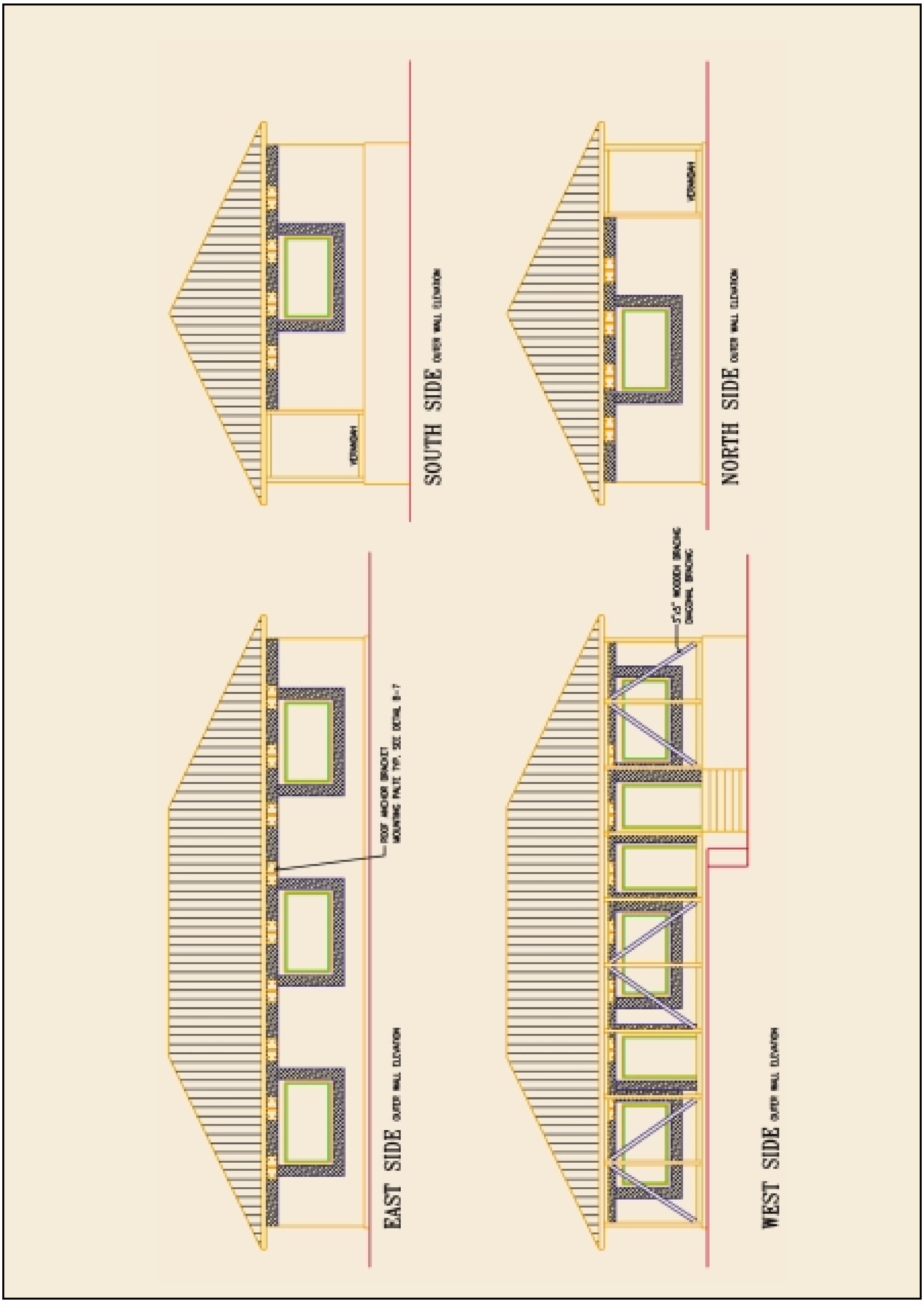
One of the six buildings in the school had some earthquake damage up to G3. It is a typical school building of the area with CGI sheet roof supported on stone masonry walls. The large-scale casualties among school children in Pakistani Kashmir clearly points to the need for vulnerability reduction in these structures. In addition, the building system is no different from the typical houses of the area, so the lessons learnt in this case are also relevant to houses. The building has three rooms in a line with a verandah in front and a roof supported on wood posts. The roof is of CGI sheets with timber under-structure. The entire building has an attic floor which keeps the winter cold out. Similar to other buildings in the area the openings are large with small piers in between on front wall.



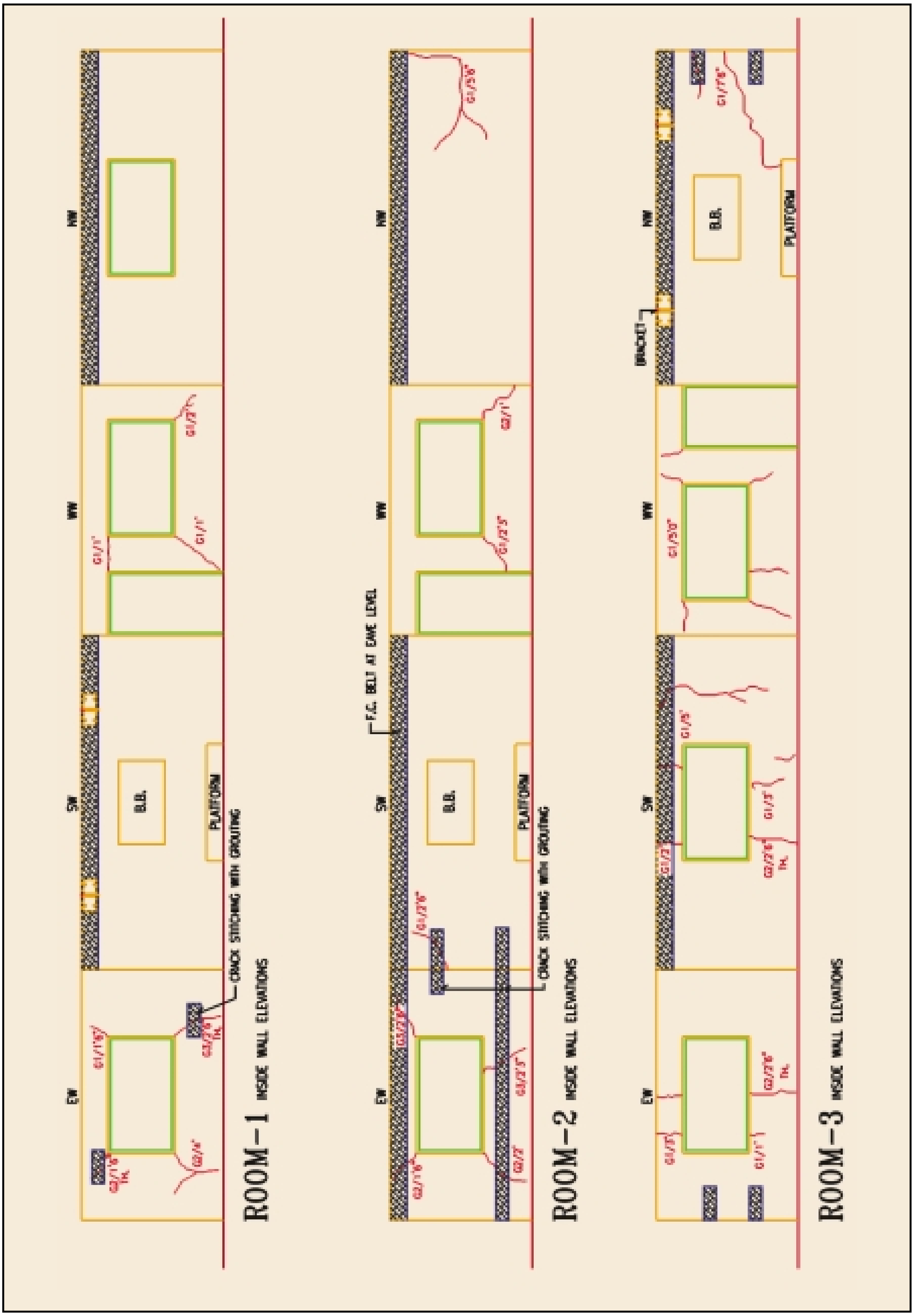
The building was documented room by room and wall by wall. All the damages were put on paper in the form of "fold-outs" to understand the need for restoration and to develop the retrofitting scheme for the whole building.



Necessary drawings for efficient and exact execution of retrofitting were prepared along with material quantity estimate as well as cost estimate of each item. Roof structure was studied in detail and suitable measures were evolved along with required details.

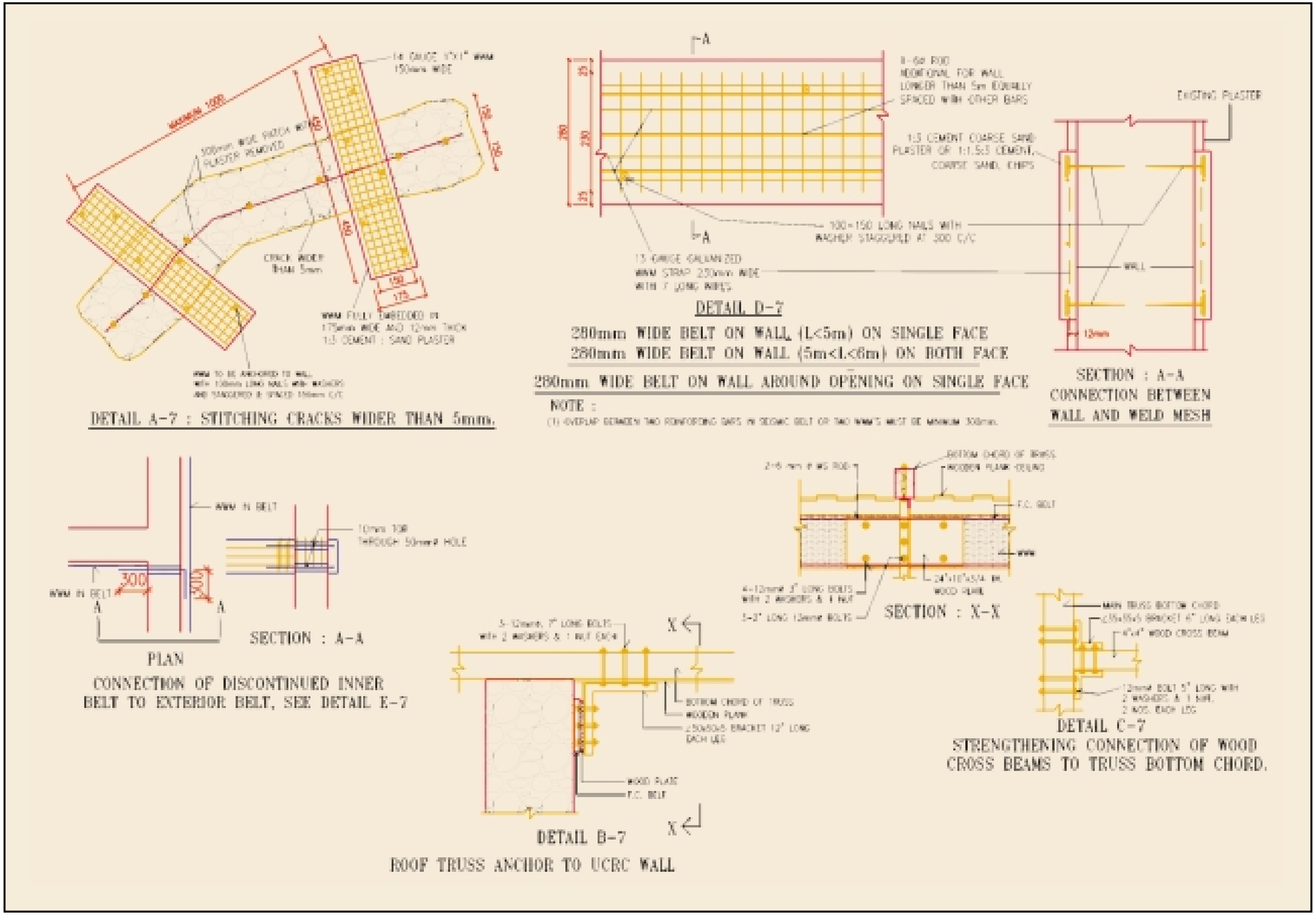


Drawings was prepared for installation of all the Horizontal Seismic Belts including those for the encasement of openings. Walls with belts on both faces and those with belt on only one face were identified in plan view. Because of the narrow piers, merging of the encasement reinforcement was necessary.

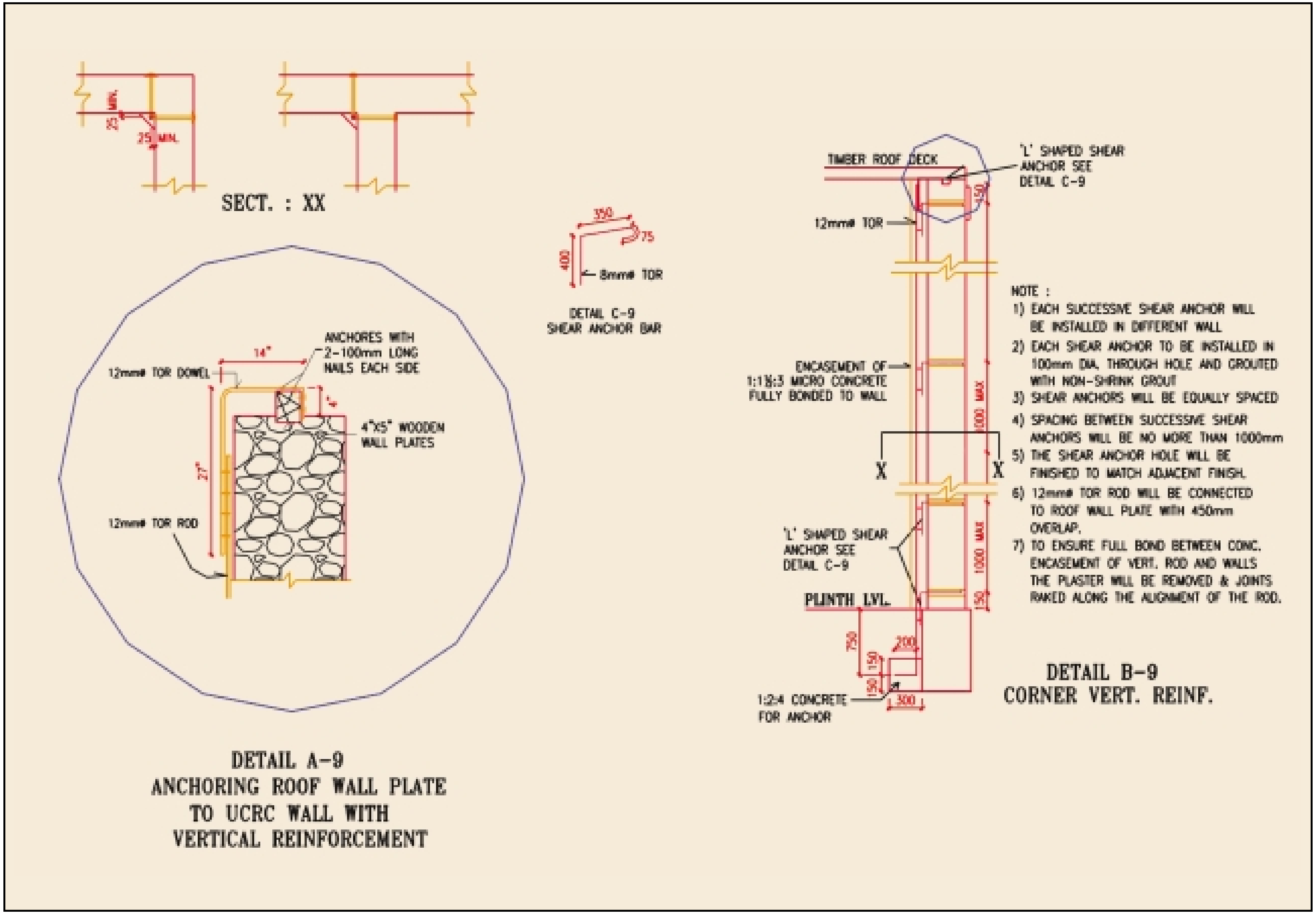


Measures required for the restoration of the damaged portions were shown on the fold-outs to enable the site supervisor to relate the corrective actions to the existing situation.

All the details were worked out adhering to good engineering practice in order to ensure coordination among various retrofitting measures including their interfaces.

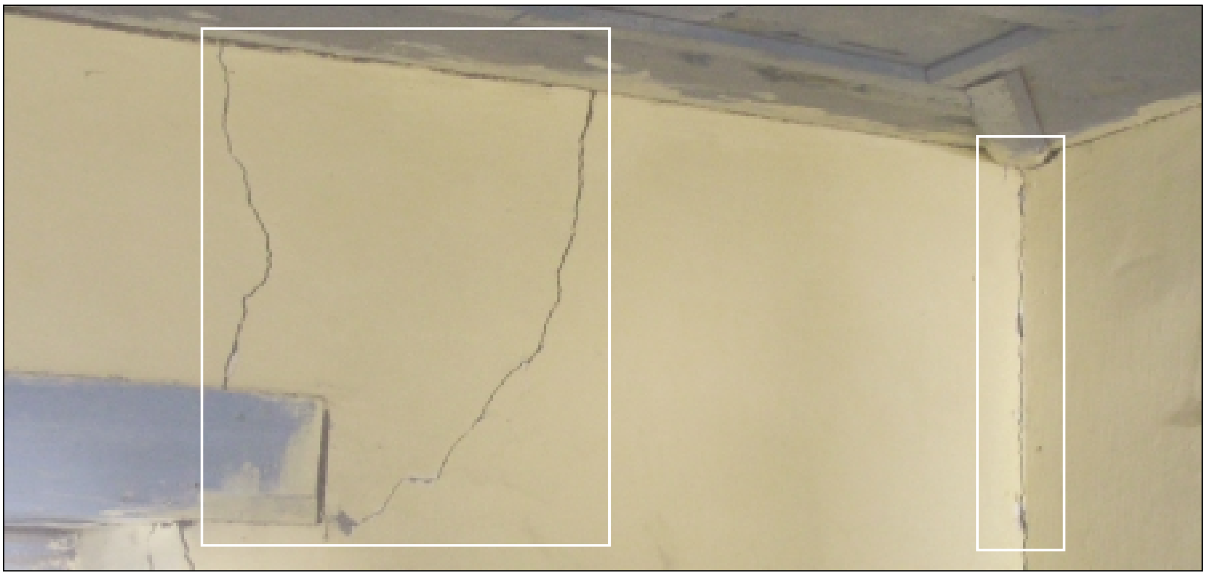


All the details were worked out adhering to good engineering practice in order to ensure coordination among various retrofitting measures including their interfaces.



Pictures of Restroation & Retrofitting of the School Building

Existing 3 room school building before retrofitting



Typical cracking in corners and at corners of opening such as windows

Bond elements yet to be completed in RR wall

Grouting no-shrink grout in crack with hand pump

Corner crack splicing with WWM

Installing Seismic Belt at Eave Level and Around the Opening


Preparing WWM with 6 mm rebars


Installing WW mesh from aroll


Tying encasement reinforcement toshear connector dowel


Installing belt reinforcement

After Deciding the Alignment of the Seismic Belt Details were Evolved to Ensure its Continuity at Every Point in its Alignment


Inserting dowel for belt to belt connection at corner


Belt continuity at corner behind wood post obstruction


Installing 'L' shaped dowel at corner to ensure continuity


Applying cement-sand plaster

Installing vertical reinforcement in the corner

Vertical reinforcement concreting formwork

Anchoring vertical bar over wall-plate at attic deck

Installing bolts and brackets for roof-wall connection

Retrofitted building with belts, roof anchoring and diagonal timber bracings

8.3 Sub-District Hospital at Kupawada town, Dist. Kupwada, Kashmir - An Urban Example

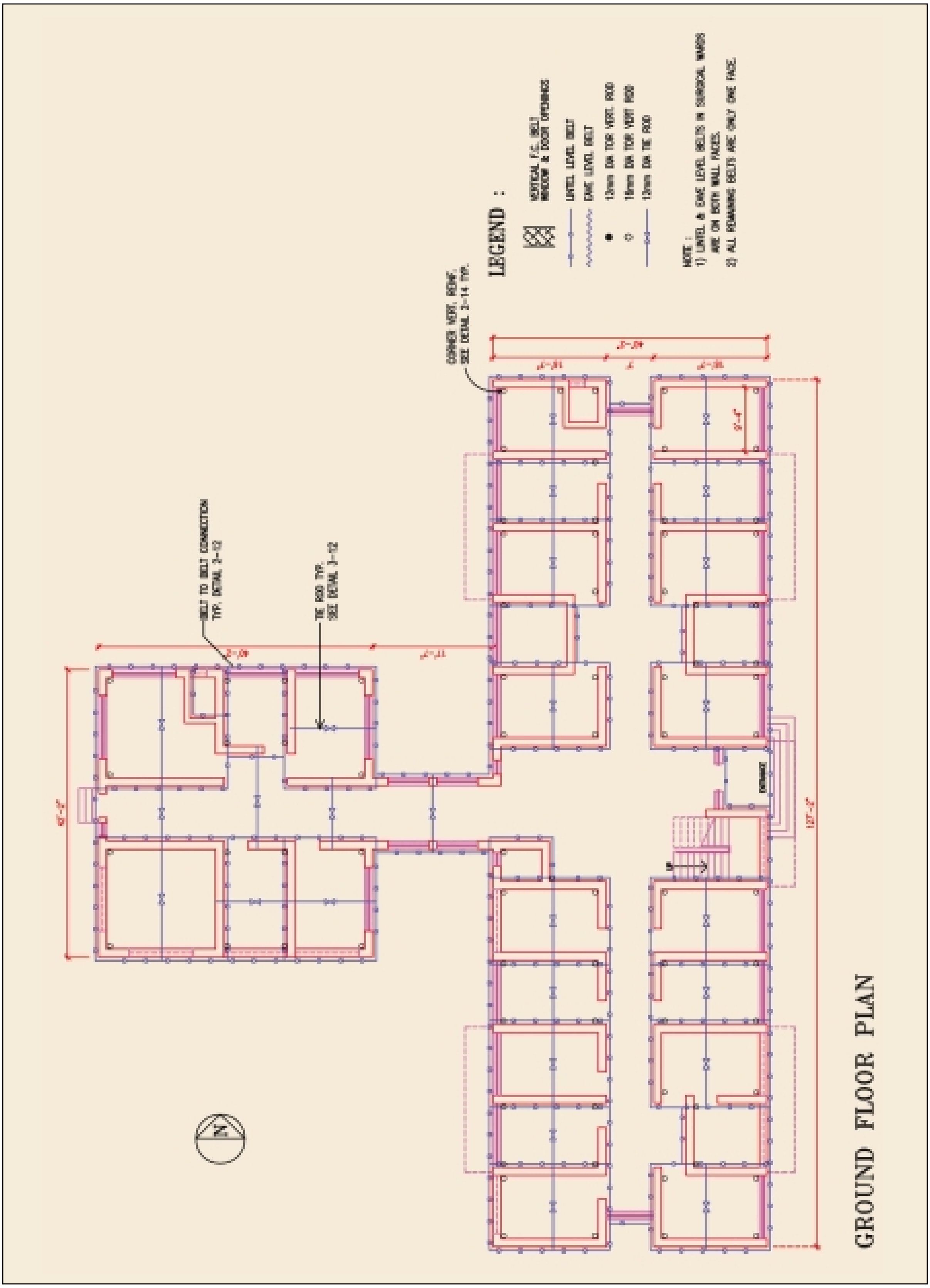
Existing building - large numbers of window openings in walls make it vulnerable

Existing building - exceptionally high walls make it vulnerable

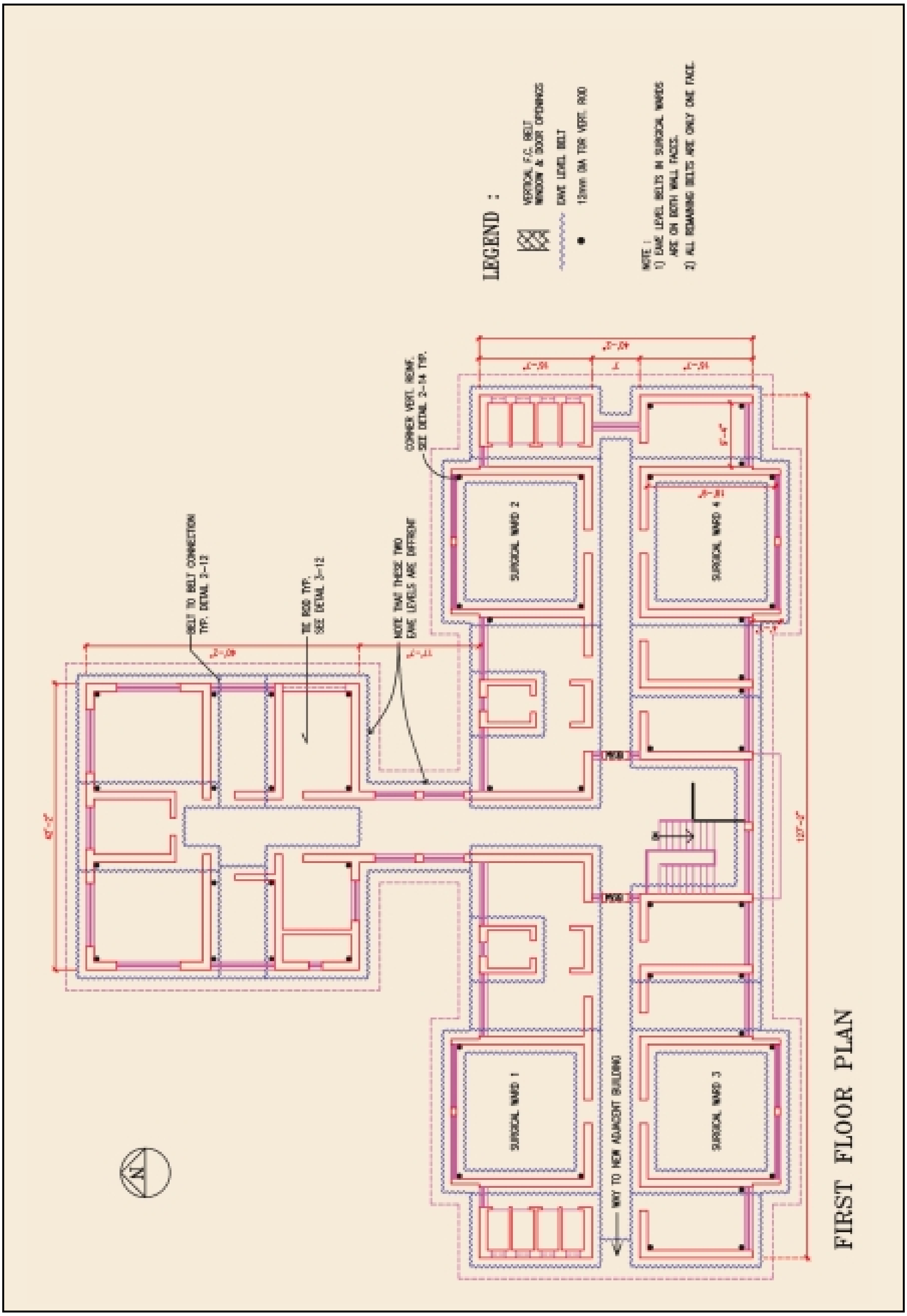
This is a landmark facility since it caters to a very large area in the absence of any other hospital. It is a large two-storey brick masonry building with RC intermediate floor and CGI roofing on a timber understructure. The hospital is a Category E building (high importance) which must withstand an Intensity IX earthquake without collapsing or severe damage so as to remain functional. In the recent earthquake, the building was damaged up to G2 in a few locations. Although the masonry is of good quality and RC bands were installed at lintel level during construction, the vulnerability caused by factors like the large openings, lack of roof-to-wall anchoring, absence of vertical reinforcement, extra-high walls in the operating theatre, etc. were to be reduced significantly. The functioning hospital also posed a problem of minimizing disturbance to the patients or of disruption of other activities. The operating theaters are used every day, so it was not possible to do any work inside them because of the risk of causing infection. Retrofitting measures therefore had to be adapted so that they could be handled from the outside.

The building was studied and documented with focus on its vulnerability to assess the need for restoration and to develop the retrofitting scheme

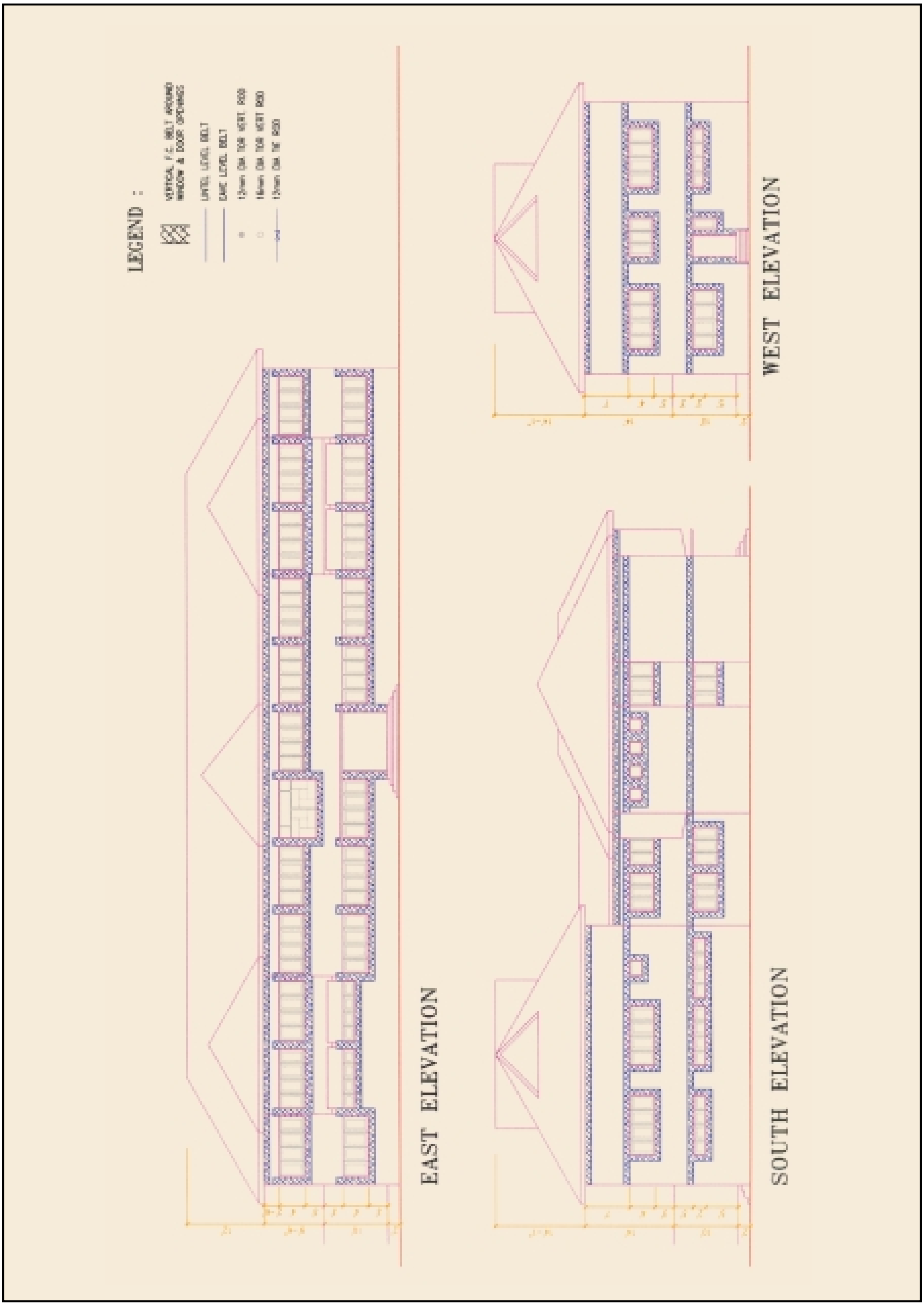
Drawings for Restoration and Retrofitting



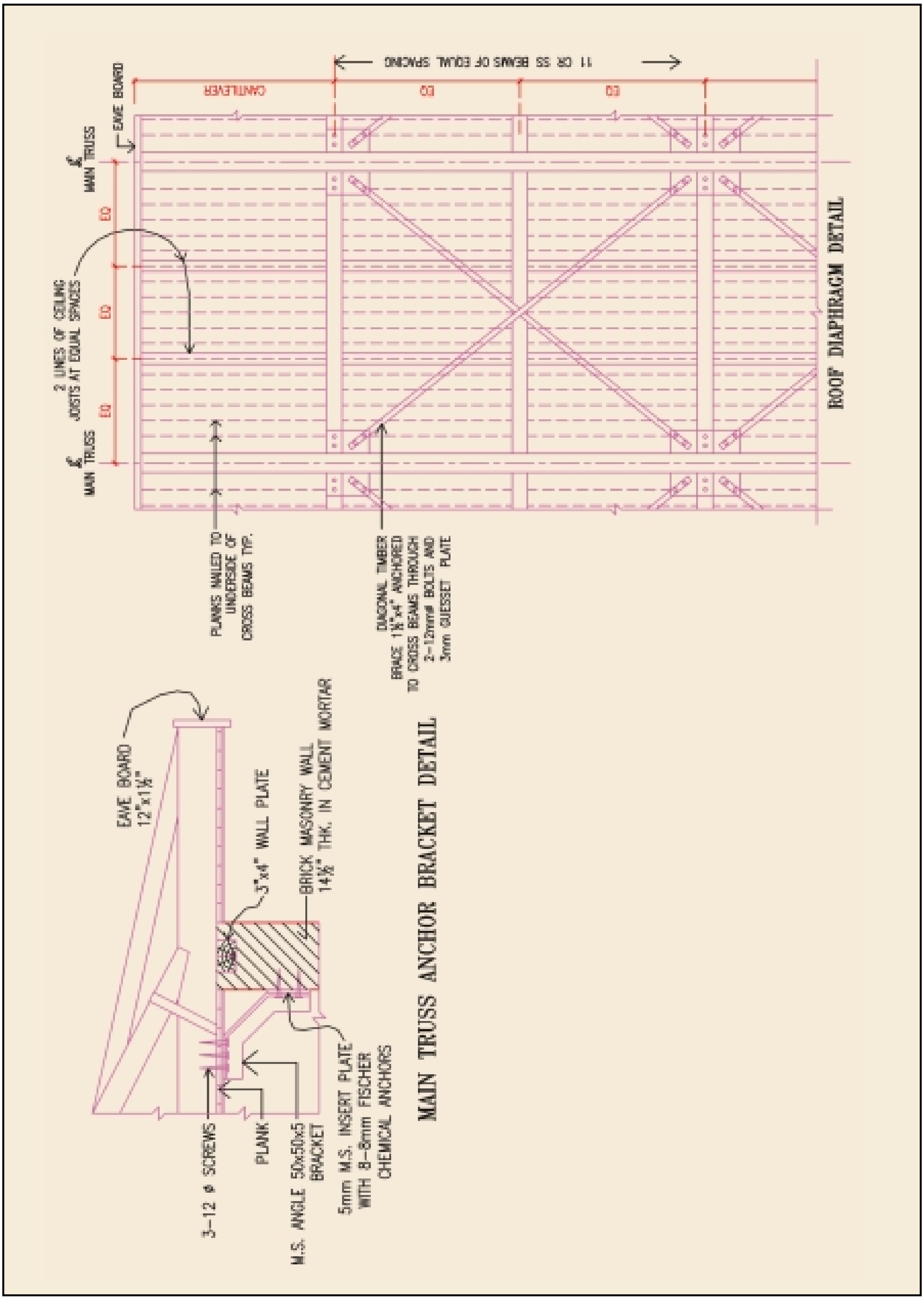
Necessary drawings for efficient and exact execution of retrofitting were prepared along withestimates for material quantity and cost of each item. Alignment of belt was finalized, and basedon that the Tie Rod locations were identified.



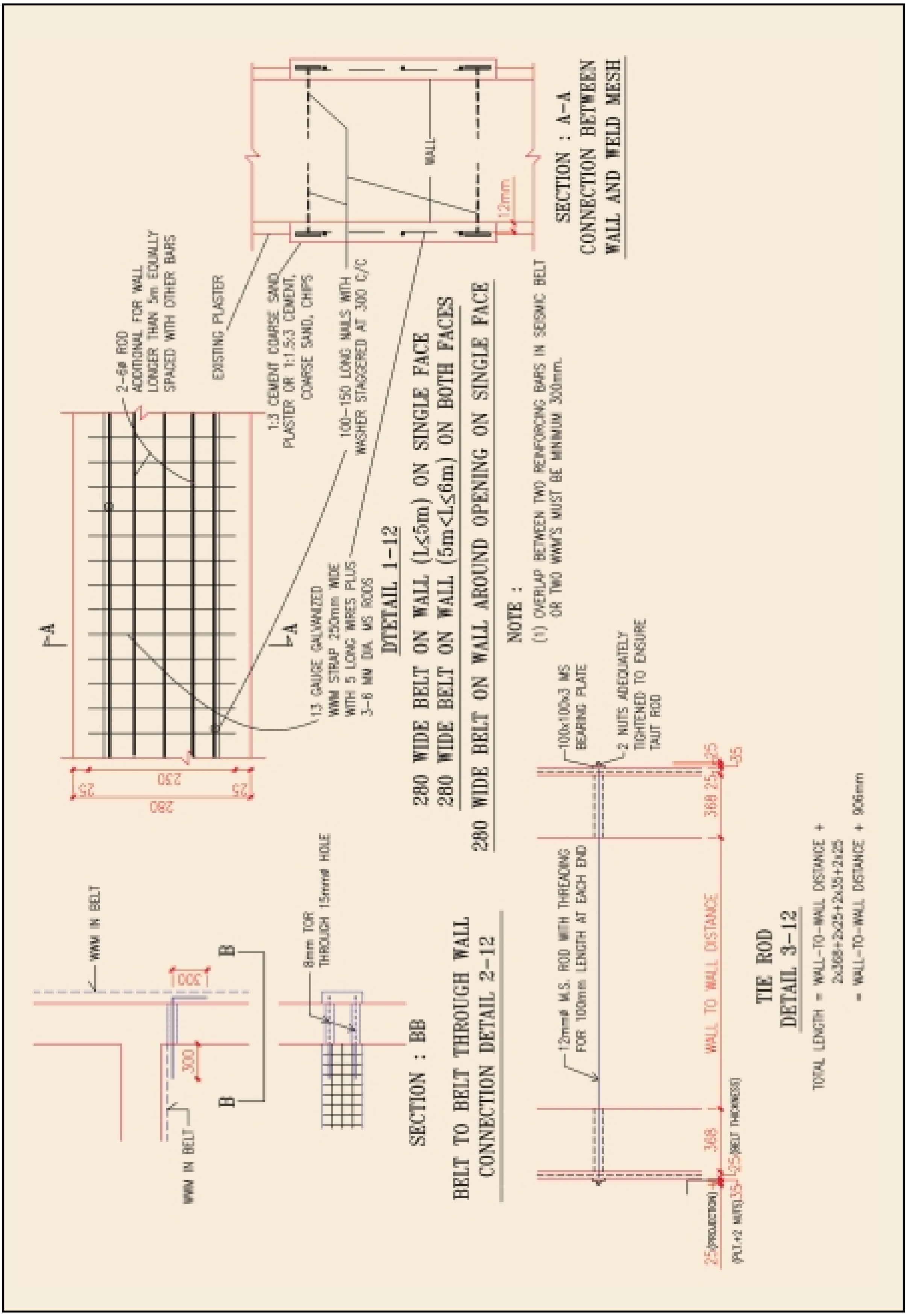
Locations for vertical rods as well as vertical Seismic Belts were shown on the drawings to ensure coordination between the lower and upper storeys.



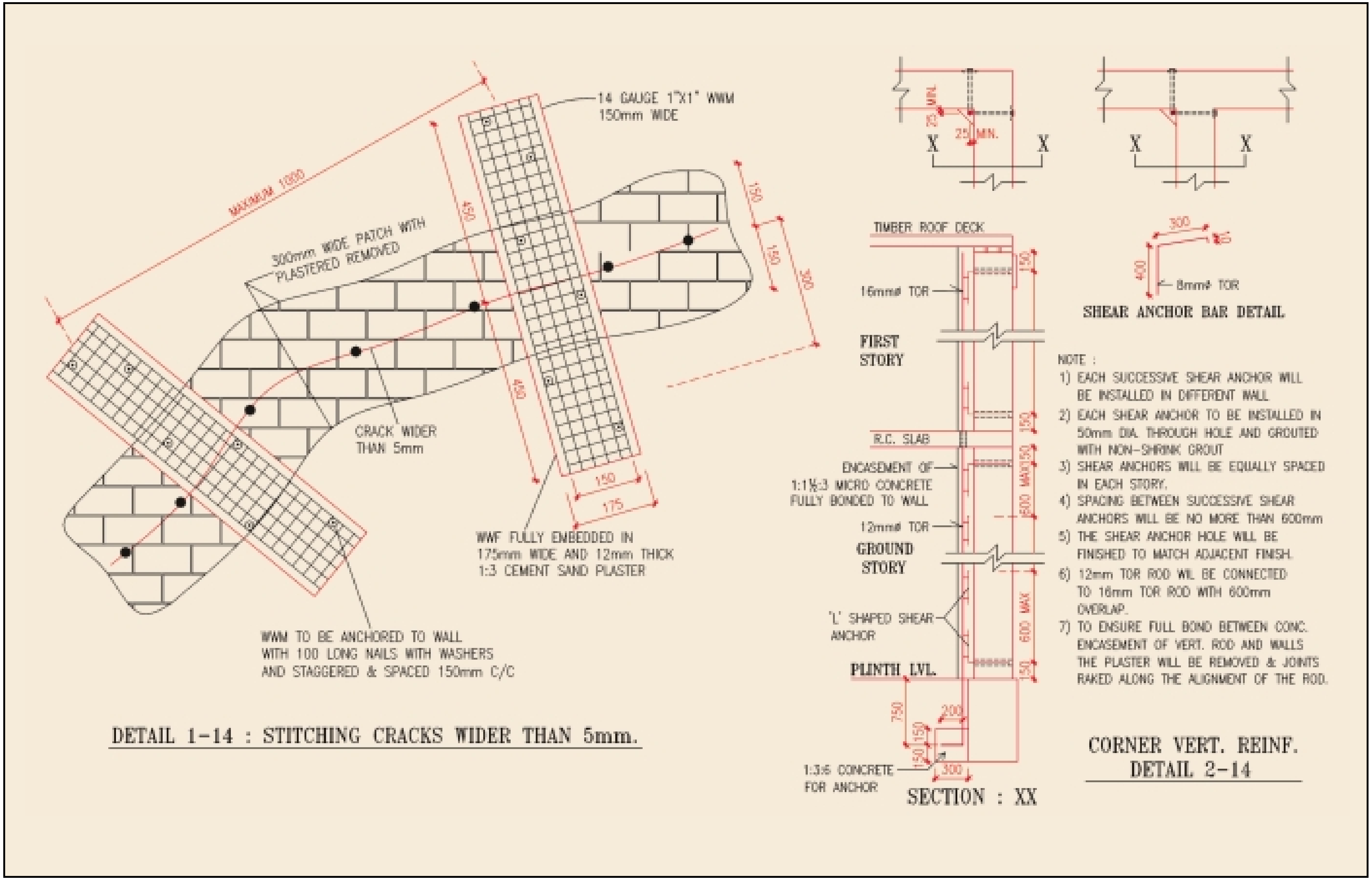
Drawings were prepared for installation of all the Horizontal Seismic Belts including those for the encasement of openings. On all the wall belts were provided on one face except four wards where belts were provided on both faces.



Roof structure was studied in detail and suitable measures were evolved along with required details. A special bracket design was evolved to anchor the floor deck to the walls. Additional measures for improving the Diaphragm Action were also evolved.



All the details were worked out adhering to good engineering practice in order to ensure coordination among various retrofitting measures including their interfaces.


MAXIMUM 1000
14 GAUGE 1"X1" WWM
150mm WIDE
300mm WIDE PATCH WITH
PLASTERED REMOVED
450
450
150
150
300
CRACK WIDER
THAN 5mm
150
175
WWF FULLY EMBEDDED IN
175mm WIDE AND 12mm THICK
1:3 CEMENT SAND PLASTER
WWM TO BE ANCHORED TO WALL
WITH 100 LONG NAILS WITH WASHERS
AND STAGGERED & SPACED 150mm C/C
DETAIL 1-14 : STITCHING CRACKS WIDER THAN 5mm.
25 MIN.
25 MIN.
X
X
X
X
TIMBER ROOF DECK
16mmø TOR
FIRST
STORY
R.C. SLAB
ENCASEMENT OF
1:1½:3 MICRO CONCRETE
FULLY BONDED TO WALL
12mmø TOR
GROUND
STORY
'L' SHAPED SHEAR
ANCHOR
PLINTH LVL.
750
200
150
150
300
1:3:6 CONCRETE
FOR ANCHOR
SECTION : XX
150
150
150
600 MAX
600 MAX
150
300
60
400
8mmø TOR
SHEAR ANCHOR BAR DETAIL
NOTE :
1) EACH SUCCESSIVE SHEAR ANCHOR WILL BE INSTALLED IN DIFFERENT WALL
2) EACH SHEAR ANCHOR TO BE INSTALLED IN 50mm DIA. THROUGH HOLE AND GROUTED WITH NON-SHRINK GROUT
3) SHEAR ANCHORS WILL BE EQUALLY SPACED IN EACH STORY.
4) SPACING BETWEEN SUCCESSIVE SHEAR ANCHORS WILL BE NO MORE THAN 600mm
5) THE SHEAR ANCHOR HOLE WILL BE FINISHED TO MATCH ADJACENT FINISH.
6) 12mm TOR ROD WIL BE CONNECTED TO 16mm TOR ROD WITH 600mm OVERLAP.
7) TO ENSURE FULL BOND BETWEEN CONC. ENCASEMENT OF VERT. ROD AND WALLS THE PLASTER WILL BE REMOVED & JOINTS RAKED ALONG THE ALIGNMENT OF THE ROD.
CORNER VERT. REINF.
DETAIL 2-14

Pictures of Restroation & Retrofitting of Hospital Building

Civil hospital at Kupwada before retrofitting

Damage: Pier failure

Typical damage at opening

Installing vertical reinforcement at inside corners

MS brackets for anchoring roof deck to wall

Anchoring roof wall plate corner with vertical rebar

In-plane bracing & struts on attic floor

Anchoring Roof truss to wall with 'U' clamp

Encasing Openings all Around with Seismic Belt


Preparing WWM for belt


Raking mortar joints with power grinder


Installing WWM with bars to walls


Raking mortar joints with power grinder


Installing WWM with bars on the walls


Installing WWM with bars on the walls


Installing WWM with bars to walls


Ensuring continuity of belt reinforcement using dowels

Encasement of windows

Eave-level belt and opening encasement

Retrofitting work in progress

Retrofitting work in progress

Retrofitting work in progress

Retrofitted Hospital

Retrofitted Hospital

Chapter 9 Good Construction Practices

Mistakes are commonly made which may appear simple and insignificant, but which make a structure vulnerable to seismic forces. These mistakes are usually committed due to ignorance or laxity. Following good construction practice means adhering to basic rules, ensuring quality and not taking short cuts. This goes a long way towards reducing a structure's vulnerability.

Common Precautions to be exercised, Based on Mistakes Observed at Sites

Basic Rules for Planning an Earthquake-Resistant House

1. When selecting a site on the sloping hill side for a building, a site adjacent to a stable slope should be chosen.
2. Any site near a hillside that is liable to slides during an earthquake should be avoided.
3. A site subject to the risk of rock falls should be avoided.
4. On a sloping site it is preferred to place several individual blocks independently on stepped terraces rather than placing the whole structure along a slope with footings at different heights.
5. Locating a structure on very loose sands or sensitive clays must be avoided.
6. Locating a structure on hard soil and rocky ground is preferred.
7. Constructing a number of smaller buildings is better than constructing one very large building.
8. In an earthquake a building with a square or round plan is safer than that with a rectangular plan.
9. If a rectangular plan is used, the length of the building should not be more than three times the width of the building.
10. A building plan symmetrical about both axes is better than an asymmetrical plan. 'L', 'T', 'C' and 'H' shaped plans are to be avoided.
11. If a projection of a room from the main structure is required, the length of the projecting wall must be limited to 15% of the overall length of the structure in that direction.
12. Symmetry is desirable in the placing of door and window openings.
13. Simplicity is the best approach for building design. Ornamentations involving large cornices, vertical or horizontal cantilever projections, facia stones and the like must be avoided.
14. A four-sided pitched roof is better than a two-sided pitched roof.
15. The height of the parapet walls in the terrace or balcony must be limited to three times the thickness of the parapet wall. It is better to build a lower masonry wall and provide an iron railing above.

During restoration pay attention to the following Principles of good practice;

The Making and Use of Mortars

1. Mix all dry ingredients of concrete and mortar thoroughly before adding water.
2. Do not use very fine sand in cement concrete.
3. Mud for mud mortar must be of good quality clayey soil. It must be kept wet at least for three days and must be thoroughly mixed every day before using it for mortar.

The Construction of Masonry Walls

1. Use only one type of mortar in the construction of the wall.
2. Wet the masonry units, including brick, stone, concrete block, etc. thoroughly in drums or tanks just before placing them on wall, so that they do not suck the water out of cement mortar. Reduction of water content in the mortar means weaker mortar.
3. In order to ensure good bond with the next course, on completing a masonry course its top surface must be clean with no mortar spread over it unless masonry units are going to be placed immediately on top of it. Hardened mortar weakens the joint with the next course or the band that will be placed above it.
4. Keep all vertical joints in the masonry wide enough so that the finger can be inserted in them and fill them properly with mortar.
5. Use tube level in every third or fourth course while use string in every course to maintain level and alignment, and for ensuring uniform thickness of mortar.
6. Use plumb-bob frequently during construction to ensure that the walls are vertical.

7. Brick or stone masonry column of single-storey height must have at least one 12 mm TOR rod that is adequately anchored in the base of foundation and to the roof at the top.
8. Doors and window openings must not be located at the room corners.
9. Provide the lintel level of all the openings at the same height.
10. The total width of all the doors and windows in a wall must not exceed 40% of the length of that wall.
11. Strictly adhere to the following Random Rubble masonry rules:
    a. Place each stone flat on its broader face.
    b. Place the stone in the wall such that its length goes into the thickness of the wall, resulting in the interlocking of inside and outside wythes.
    c. Provide at least one through stone in every 0.8 sq m (8 sq ft) of wall.
    d. Place long stone at the corner of each course, with length of the stone placed parallel to the length of that wall.
    e. Do not leave voids in masonry. Fill all voids in masonry using small chips of stone with minimum possible use of mortar.
    f. Never use rounded stones for masonry. Stones must be angular. It is not necessary to dress the stones fully like in Ashlar masonry.

The Construction of Floors and Roofs

1. Use a minimum of two nails for a proper wood-to-wood joint and always pre-drill all the timber before nailing.
2. Anchor RC slab to masonry wall by properly connecting the vertical reinforcement in the wall to that in the slab.
3. Use 6 mm MS or 8 mm TOR rod dowels suitably located and anchored in eave-level RC band and projecting up adequately, to anchor roof deck elements including truss bottom chords, beams and joists.

Dealing with Timber Elements

1. Adhere to good practice in wood construction using proper joinery.
2. When using nails or screws make sure that
    a. Holes are pre-drilled to minimize splitting of wood.
    b. Screws are never driven by hammer.

The Construction of *Dhajji* Walls

1. Top and bottom wall plates should be anchored to the RC band at top and bottom of the wall respectively, using MS brackets or 8 mm TOR rod dowels.
2. All connections between the vertical posts and the top and bottom wall plates should be made using metal strap and nails. The end posts adjacent to the masonry walls must be anchored to walls using 8 mm TOR dowels.
3. Horizontal struts must be installed at a vertical spacing not of 1 m between consecutive posts.
4. Diagonal bracings must be installed in every vertical bay between consecutive posts maintaining continuity from top of the wall to the base.
5. All connections of horizontal struts and bracings to vertical posts must be made using good carpentry practice in the joinery, but may be supported by wooden blocks no less than 50 mm thick to reduce splitting.
6. Where possible, the wooden blocks are to be attached first to the posts, followed by attachment of bracing and strut to the block.
7. When attaching the wooden block to the post, pre-drill the blocks in order to prevent splitting.
8. Chicken Wire Mesh may be installed on both faces of the wall to ensure confinement of the filler material. It must be well stretched to be effective in tension.

During Retrofitting Pay Attention to the Following Principles of Good Practice

Seismic Belt and Vertical Reinforcement

1. Study the possible alignment of full seismic belt before its installation to avoid unexpected obstructions later.
2. Use tube level to mark out the seismic belt alignment before plaster removal for better aesthetics.
3. Use electric grinder to make a groove along the top and bottom of belt alignment in order to minimize damage to plaster during its removal and to reduce cost.
4. Rake all joints adequately and clean the wall surface with wire brush within the limits of the belt and in vicinity of vertical reinforcement to ensure a good bond with the wall.
5. Ensure total embedment of WWM belt in cement mortar by keeping a 1/2" gap between exposed wall surface and WWM with the use of spacers, so that the mortar reaches behind the mesh.
6. Ensure adequate concrete cover on vertical reinforcement by ensuring a gap of 1½ to 2" between the rod and the wall.
7. Use wire nails for anchoring WWM in brick or concrete block walls, and use square headed nails in case of rubble wall. Remove and relocate loose nails to ensure that they are secure.
8. Concrete for vertical reinforcement must contain aggregates no larger than 1/2".
9. WWM must be galvanized for all applications on exterior wall
10. No end of WWM should be left unattached to other WWM: it should be attached either directly through overlap or indirectly through the use of overlapping dowel bars.

Shear Connectors and Bond Elements

1. Make dumbbell-shaped holes for shear connector and bond element, with the core just wide enough to permit insertion of the 8 mm TOR rod with hooked ends, in order to ensure its effectiveness in holding the wythes together and to reduce mortar consumption.
2. Prior to concreting, remove all loose material from holes and clean it with water.
3. In the case of rubble masonry walls, use aggregates no bigger than 1/4" in concrete. In the case of brick masonry walls, use only coarse sand in mortar.
4. Reinforcing bars must be fully encased in concrete.

Roof and Floor

1. With "in-plane" bracings made of wood, use at least two bolts at each end. If made of multiple strands of GI wires, use carpenter's hammer to pull each wire tight while installing, followed by twisting all the wires together in one direction for pre-tensioning.
2. For timber-to-timber connections use a minimum of two nails or screws for each joint. Pre-drilling is a must to prevent cracking of wood.
3. Secure the roof structure properly to the walls using MS angle brackets and bolts.

Dhajji Walls

1. All panels must have diagonal bracings to ensure continuity moving from the top to the bottom of wall.
2. Pre-drilling is a must to prevent splitting of wood.
3. Connections must be established between *Dhajji* wall and adjacent masonry walls.
4. Chicken Wire Mesh may be installed on both faces of the wall to ensure confinement of the filler material. It must be well stretched to be effective in tension.

Appendices

The information given in the following pages can be used to help calculate the quantity of materials required and the cost of the work to be carried out. The government's condensed guidelines provide useful quantitative information on various items that can be used for the retrofitting of different types of buildings.

Materials Quantity Estimate

Sr. No.	Description of Items	Unit	Labour Rate	Materials Rate	Total Rate
	Restoration & Retrofitting Work				
1	Cast in-situ concrete Bond Element in 350 mm thick wall with 8 mm TOR rod and infill of concrete 1:2:4	No.	33.0	18.1	51.1
2	Cast in-situ concrete Bond Element in 450 mm thick wall with 8 mm TOR rod and infill of concrete 1:2:4	No.	38.0	22.8	60.8
3	Cast in-situ concrete Shear Connector for Seismic Belt in 350 mm thick wall with 8 mm TOR rod and infill of concrete 1:2:4	No.	33.0	19.9	52.9
4	Cast in-situ concrete Shear Connector for Seismic Belt in 450 mm thick wall with 8 mm TOR rod and infill of concrete 1:2:4	No.	38.0	24.6	62.6
5	Cast in-situ concrete Shear Connector for Vertical Rod in 350 mm thick wall with 8 mm TOR rod and infill of concrete 1:2:4	No.	35.0	23.5	58.5
6	Cast in-situ concrete Shear Connector for Vertical Bar in 450 mm thick wall with 8 mm TOR rod and infill of concrete 1:2:4	No.	40.5	23.5	64.0
7	Vertical bar foundation anchor 750x300x300 mm filled with 1:3:6 concrete	No.	81.0	281.5	362.5
8	Vertical bar at corners 12 mm dia TOR encased in 4"x4" triangle of 1:½":3 micro concrete	R.mt.	60.0	69.2	129.2
9	Vertical bar at corners 16mm dia TOR encased in 4"x4" triangle of 1:½":3 micro concrete	R.mt.	60.0	104.5	164.5
10	Vertical Seismic Belt 400 mm wide from foundation to top of wall, including bottom anchor, made with WWM having 14 - 13 gauge galvanized wires in longitudinal direction and cross wires at 50 mm spacing plus 2-6 mm dia MS and 1-12 mm TOR bars.	R.mt.	125.6	290.0	415.6
11	Vertical Seismic Belt 400 mm wide from intermediate floor to roof made with WWM having 14 - 13 gauge galvanized wires in longitudinal direction and cross wires at 50 mm spacing plus 2-6 mm dia MS bars.	R.mt.	122.6	232.3	354.8
12	12 mm MS Tie Rod for 1 m span (0.45 th. wall) threaded at both ends with 2 nuts and 100x100x5 mm MS bearing plate at each end.	R.mt.	51.3	182.5	233.8
13	G1 Crack Sealing with 1:2 cement sand mortar	R.mt.	1.9	5.9	7.9
14	G3 Crack Grouting with cement sand (1:2) mortar using appropriate grouting plasticizer	C.mt.	1,416.0	4,884.6	6,300.6

Note: All rates are based on 2006 June local rates for Uri area by road side site only. They are purely indicative only and should not be taken as standard.

Restoration & Retrofitting Work

Sr. No.	Description of Items	Unit	Labour Rate	Materials Rate	Total Rate
14a	G3 Crack Grouting in 350 mm thick brick wall with 30% cavity in crack	R.mt.	2.8	9.5	12.3
15	G3 Crack Grouting in 450 mm thick UCRC wall with 150% cavity in crack	R.mt.	17.0	58.6	75.6
16	Connection between belts using 2-10 mm TOR dowels through the 350mm wall with cavity grouted with 1:2:4 concrete	No.	66.0	69.3	135.3
17	Connection between belts using 2-10 mm TOR dowels through the 450 mm wall with cavity grouted with 1:2:4 concrete	No.	76.0	90.6	166.6
18	Timber attic floor to UCR wall anchor made of MS Angle 50x50x3 mm mounted on 600x250x35 mm wooden plate with 3-12 mm dia.bolts and connected to floor joist with 3-12 mm dia. bolts, with plate mounted on the Seismic Belt with 4-12 mm dia. bolts at its corners.	No.	167.1	216.2	383.4
19	Timber attic floor to brick wall anchor made of MS Angle 50x50x3 mounted on MS plate 150x150x3 with full length welding along both edged, connected to floor joist with 3-12 mm dia. bolts and connected to wall with 2-12 mm dia. studs that are anchored in to 15 mm holes and grouted with polyester/epoxy grout.	No.	167.1	312.7	479.8
20	Horizontal Seismic Belt 280 mm wide for length of wall < 5 m and also for opening encasement with 250 mm WWM having 10 - 13 gauge wires at 25 mm spacing and cross spacing of 75 mm plus 2-6 mm dia MS bars	R.mt.	66.0	149.4	215.4
21	Horizontal Seismic Belt 280 mm wide for length of wall length of 5 to 6 mt. with 250 mm WWM having 10 - 13 gauge wires at 25 mm spacing and cross spacing of 75 mm plus 4-6 mm dia MS bars	R.mt.	72.7	165.7	238.3
22	Horizontal Seismic Belt 280 mm wide for length of wall length of 6 to 7 m with 250 mm WWM having 10 - 13 gauge wires at 25 mm spacing and cross spacing of 75 mm plus 5-6 mm dia MS bars	R.mt.	76.6	173.8	250.4
23	5"x3" Wooden Bracing between vertical posts in varandah	No.	135.0	261.1	396.1
24	Wooden Bracing & Struts on upper side of wooden attic floor (approx)	Rmt	33.8	26.8	60.5
25	Horizontal Seismic Belt 280 mm wide for length of wall < 5 mt with 250 mm WWM having 10 - 13 gauge wires at 25 mm spacing and cross spacing of 75mm for crack stitching	Rmt	66.0	133.2	199.2

Note: All rates are indicative only and should not be taken as standard and are based on 2006 June local rates for Uri area by road side site only.

Material Quantities for Repair & Retrofitting Items

Sr. No.	Description	Quantity	Unit	Rate (Rs)	Amount (Rs)	Item Quantity	Item Unit
1	Cast in-situ concrete Bond Element in 350 mm thick wall					1	ea.
	Steel - 8 mm TOR	0.18	kg	30.40	5.40		
	Cement	0.86	kg	6.14	5.31		
	Sand	0.00	cm	1,058.70	1.26		
	Aggregates	0.00	cm	1,293.97	3.09		
2	Cast in-situ concrete Bond Element in 450 mm thick wall					1	ea.
	Steel - 8 mm TOR	0.22	kg	30.40	6.61		
	Cement	1.11	kg	6.14	6.83		
	Sand	0.00	cm	1,058.70	1.62		
	Aggregates	0.00	cm	1,293.97	3.97		
3	Cast in-situ concrete Shear Connector for Seismic Belt in 350 mm thick wall					1	ea.
	Steel - 8 mm TOR	0.23	kg	30.40	6.91		
	Cement	0.86	kg	6.14	5.31		
	Sand	0.00	cm	1,058.70	1.26		
	Aggregates	0.00	cm	1,293.97	3.09		
4	Cast in-situ concrete Shear Connector for Seismic Belt in 450 mm thick wall					1	ea.
	Steel - 8 mm TOR	0.27	kg	30.40	8.11		
	Cement	1.11	kg	6.14	6.83		
	Sand	0.00	cm	1,058.70	1.62		
	Aggregates	0.00	cm	1,293.97	3.97		
5	Cast in-situ concrete Shear Connector for Vertical Rod in 350 mm thick wall					1	ea.
	Steel - 8 mm TOR	0.33	kg	30.40	9.91		
	Cement	0.86	kg	6.14	5.31		
	Sand	0.00	cm	1,058.70	1.26		
	Aggregates	0.00	cm	1,293.97	3.09		
6	Cast in-situ concrete Shear Connector for Vertical Bar in 450 mm thick wall					1	ea.
	Steel - 8 mm TOR	0.33	kg	30.40	9.91		
	Cement	0.86	kg	6.14	5.31		
	Sand	0.00	cm	1,058.70	1.26		
	Aggregates	0.00	cm	1,293.97	3.09		

Note: All rates are indicative only and should not be taken as standard and are based on 2006 June local rates for Uri area by road side site only.

Material Quantities for Repair & Retrofitting Items

Sr. No.	Description	Quantity	Unit	Rate (Rs)	Amount (Rs)	Item Quantity	Item Unit
7	Vertical bar foundation anchor 750x 300x300 mm filled with 1:3:6 concrete					1	ea.
	12 mm TOR steel	1.02	kg	30.40	31.08		
	Cement	14.87	kg	6.14	91.30		
	Sand	0.03	cm	1,058.70	32.59		
	Aggregates	0.06	cm	1,293.97	79.66		
8	Vertical bar at corners 12mm dia TOR encased in micro concrete					1	rmt.
	12 mm TOR steel	1.24	kg	30.40	37.83		
	Cement	2.00	kg	6.14	12.30		
	Sand	0.00	cm	1,058.70	2.19		
	Aggregates	0.00	cm	1,293.97	5.36		
9	Vertical bar at corners 16 mm dia TOR encased in micro concrete					1	rmt.
	16 mm TOR steel	2.21	kg	30.40	67.26		
	Cement	2.00	kg	6.14	12.30		
	Sand	0.00	cm	1,058.70	2.19		
	Aggregates	0.00	cm	1,293.97	5.36		
10	Vertical Seismic Belt 400 mm wide from foundation to top of wall, including bottom anchor, made with 13 gauge WWM plus 2-6 mm dia MS and 1-12 mm TOR bars.					1	rmt.
	galvanited WWM g13 50x50 mm	0.46	Smt	215.20	97.92		
	Steel - 6 mm	0.64	kg	30.40	19.59		
	Steel - 12 mm	1.29	kg	30.40	39.18		
	Cement	6.59	kg	6.14	40.49		
	Sand	0.01	cm	1,058.70	14.45		
	Nails	0.67	kg	45.00	30.00		
11	Vertical Seismic Belt 400 mm wide from intermediate floor to roof made with WWM plus 2-6mm dia MS bars.					1	rmt.
	galvanited WWM g13 50x50 mm	0.42	Smt	215.20	90.38		
	Steel - 6 mm	0.60	kg	30.40	18.24		
	Cement	6.59	kg	6.14	40.49		
	Sand	0.01	cm	1,058.70	14.45		
	Nails	0.67	kg	45.00	30.00		

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Material Quantities for Repair & Retrofitting Items

Sr. No.	Description	Quantity	Unit	Rate (Rs)	Amount (Rs)	Item Quantity	Item Unit
12	12 mm MS Tie Rod in 0.45 th. wall with necessary fixtures					1	rmt.
	Steel - 12 mm dia MS	0.89	kg	48.00	42.67		
	Steel - MS Bearing Plates - 2 Ea.	0.47	Kg	48.00	22.61		
	Misc. - Nuts, threading, washers etc.	2.00	Nos.	31.00	62.00		
	Cement	2.22	kg	6.14	13.65		
	Sand	0.00	cm	1,058.70	3.25		
	Aggregates	0.01	cm	1,293.97	7.94		
13	G1 Crack sealing with 1:2 cement Sand mortar					1	rmt.
	Cement	0.65	kg	6.14	4.00		
	Sand	0.00	cm	1,058.70	0.95		
14	G3 Crack Grouting with non-shrink Cement Sand mortar						
	Cement	603.86	kg	6.14	3,707.73		
	Sand	0.83	cm	1,058.70	882.25		
	Grouting Plasticizer	1.81	Litre	275.00	498.19		
14a	G3 Crack grouting in 350 mm thick Brick wall with 30% cavity in crack					1	rmt.
	Cement	0.94	kg	6.14	5.78		
	Sand	0.00	cm	1,058.70	1.38		
	Grouting Plasticizer	0.00	Litre	275.00	0.78		
15	G3 Crack grouting in 450 mm thick UCRC wall with 150% cavity in crack					1	rmt.
	Cement	5.80	kg	6.14	35.59		
	Sand	0.01	cm	1,058.70	8.47		
	Grouting Plasticizer	0.02	Litre	275.00	4.78		
16	Connection between belts using 2-10mm TOR dowels through the 350 mm wall					1	rmt.
	10 mm Steel	1.54	kg	30.40	46.91		
	Cement	0.97	kg	6.14	5.97		
	Sand	0.00	cm	1,058.70	1.42		
	Aggregates	0.00	cm	1,293.97	3.47		

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Material Quantities for Repair & Retrofitting Items

Sr. No.	Description	Quantity	Unit	Rate (Rs)	Amount (Rs)	Item Quantity	Item Unit
17	Connection between belts using 2-10 mm TOR dowels through the 450mm wall					1	ea.
	10 mm steel	1.67	kg	30.40	50.67		
	Cement	2.22	kg	6.14	13.65		
	Sand	0.00	cm	1,058.70	3.25		
	Aggregates	0.01	cm	1,293.97	7.94		
18	Timber attic floor to UCR wall anchor made of MS Angle with all fixtures					1	ea.
	Anchor Brackets - MS Angle 50x50x3 12"x12" with three 13 mm holes in eacharm	1.38	kg	48.00	66.24		
	18"x10"x1.25" wooden plank	0.46	rmt	29.61	13.54		
	10" long 12 mm Dia. Bolt with 2 nos. woshers & 1 nos nut	1.00	kg approx.	60.00	60.00		
	3" long 12 mm Dia. Bolt with 2 nos. woshers & 1 nos nut	0.57	kg approx.	60.00	34.29		
	2" long 12 mm Dia. Bolt with 2 nos. woshers & 1 nos nut	0.38	kg approx.	60.00	22.50		
19	Timber attic floor to brick wall anchor made of MS Angle with all fixtures					1	ea.
	Anchor Brackets - MS Angle 50x50x3 mm 150x600x150mm long with holes in one arm	2.07	kg	48.00	99.36		
	Steel - MS Bearing Plates - 2 Ea.	1.06	kg	48.00	50.87		
	2-12mm dia. studs	0.67	kg approx.	60.00	40.00		
	3-12 mm Dia. 10" long Bolt with 2 nos. woshers & 1 nos nut	1.00	kg approx.	60.00	60.00		
	Hole grout with plasticizer	2.00	Nos.	17.01			
20	Horizontal Seismic belt 280 mm wide for length of wall <5 m & also for opening encasement					1	rmt.
	galvanited WWM gauge 13	0.25	smt.	215.20	80.00		
	Nails	0.45	kg	45.00	40.50		
	6 mm M.S.steel	0.44	kg	30.40	42.15		
	Cement	4.44	kg	6.14	31.96		
	Sand	0.01	cm	1,058.70	2.60		

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Material Quantities for Repair & Retrofitting Items

Sr. No.	Description	Quantity	Unit	Rate (Rs)	Amount (Rs)	Item Quantity	Item Unit
21	Horizontal Seismic belt 280 mm wide for length of wall 5 to 6 mt.					1	rmt.
	Galvanited WWM gauge13	0.25	smt.	215.20	80.00		
	Nails	0.45	kg	45.00	40.50		
	6 mm M.S.steel	0.89	kg	30.40	42.15		
	Cement	4.44	kg	6.14	31.96		
	Sand	0.01	cm	1,058.70	2.60		
22	Horizontal Seismic belt 280 mm widefor length of wall 6 to 7 mt.					1	rmt.
	Galvanited WWM gauge13	0.25	smt.	215.20	80.00		
	Nails	0.45	kg	45.00	40.50		
	6 mm M.S.steel	1.11	kg	30.40	42.15		
	Cement	4.44	kg	6.14	31.96		
	Sand	0.01	cm	1,058.70	2.60		
23	5"x3"x9' 6" wooden bracing connection to post in verandah					1	ea.
	5"x3"x9"6" long wooden member	1.00	Nos.	231.71	231.71		
	5" long nails - 3 at each end	0.15	kg approx.	38.00	5.70		
24	Wooden bracing & strut upper side ofwooden floor (Approx)					1	rmt
	8"x0.75" wooden planks	1.00	rmt	19.78	19.78		
	4" long nails Approx.	0.12	kg approx.	38.00	4.56		
25	Horizontal Seismic belt 280 mm wide for crack stitching					1	rmt.
	Galvanited WWM gauge13	0.25	smt.	215.20	53.80		
	Nails	0.45	kg	45.00	20.25		
	Cement	4.44	kg	6.14	27.25		
	Sand	0.01	cm	1,058.70	9.73		

Note: All rates are indicative only and should not be taken as standard and are based on 2006 June local rates for Uri area by road side site only.

Materials & Labour Rates for Kashmir
(To be used for reference only)

Sr.No.	Items	Rs.	Unit
1	Aggregates	1293.97	cmt
2	Binding wire	50.00	kg
3	Bolts M.S.	60.00	kg
4	Bricks	3.33	no.
5	Carpenter	300.00	day
6	Cement	6.14	kg
7	Galvanited wire	60.00	kg
8	GI WWM	215.20	Smt.
9	Lime	6.00	kg
10	Mason	300.00	day
11	MPT	56.40	Smt.
12	MS plate	48.00	kg
13	MS section	48.00	kg
14	Nails	45.00	kg
15	5" long Nails	38.00	kg
16	Nuts	5.00	kg
17	Planks	54.00	cm
18	Plasticizer	240.00	Lts.
19	Rubble	399.19	cmt
20	Grouting Plasticizer	275.00	Lt.
21	Sand	1058.70	cm
22	Steel	30.40	kg
23	Timber	52935.00	cm
24	Unskilled	150.00	day
25	Water	0.50	Lts.

Note: All rates are indicative only and should not be taken as standard and are based on 2006 June local rates for Uri area by road side site only.

Tools and Equipment List

Equipment and Miscellaneous Items Needed

For Wall Preparation and Making Holes

- ✓ Rotary power drill with adequately long extension cord (if electric power is available), and drill bits of 1" and 2" dia. 12" long
- ✓ Electric grinder for plaster cutting
- ✓ Brick masonry hole-making tool: 1.25" dia. GI pipe 12" and 18" long
- ✓ Wire brush to clean the wall
- ✓ Tool for raking mortar joints

For Anchors and Concreting

- ✓ Bar bending set up (steel preferred to wooden) with rods welded to it
- ✓ Bar bending tool or 2' long 1" dia. And ½" dia. GI or MS pipes
- ✓ 5 kg sludge hammer
- ✓ Different size chisels for cutting steel rods, WWM and concrete, tongs to hold chisel
- ✓ Pliers with wire cutter, binding wire tightening tool
- ✓ Spanners for the wall anchor bolts
- ✓ Sheet metal for form work of corner vertical reinforcement concreting
- ✓ 6" to 4" long square-top nails, 6" to 4" long wire nails, both withwashers longer nails for walls in mud-mortar

For centering

- ✓ Scaffolding including wood poles and plans extending to min. 10' length along one wall and 15' length along another.
- ✓ Ladders (2 to 3 numbers) high enough to reach the upper storylintel level
- ✓ Coir String for scaffolding

For Mortar Mix & Plastering

- ✓ Shovel
- ✓ Pans
- ✓ Sieve for coarse sand
- ✓ Trowel
- ✓ Plastering tool
- ✓ 2"x1" wood batten for forming the lower edge of the ferro-cementseismic belt plaster, minimum 15' long and an aluminium straightedge 6' long.

Miscellaneous

- ✓ Torch
- ✓ Cotton string for marking
- ✓ Chalk / Marker / Charcoal

Materials

- ✓ Water
- ✓ Cement
- ✓ Polymer additives
- ✓ Coarse sand
- ✓ Aggregates (1/4") and (1/2")
- ✓ Adhesive powder or solution for good bond between old and newconcrete
- ✓ Steel rods 8 mm TOR, 10 mm TOR, 12mm TOR or MS as required
- ✓ Galvanized WWM as per the NDMD Government Guidelines.
- ✓ Binding wire
- ✓ 10 mm studs approximately 220 mm long.
- ✓ 1"x4" Planks
- ✓ 4" Wood nails with washer
- ✓ 2.5 mm or 3 mm GI wire

Glossary

English	Urdu	Pronounciation
Damaged	مخدوش	*Makhdush*
Shaking	تھراہٹ	*Thartharaahat*
Continue	مسلسل	*Musalsal*
Severity	شدت	*Shiddat*
Construction	تعمیر	*Taamir*
Stepped	بتدریج	*Batadrij*
Basic rules	بنیادی اصول	*Buniyadi usoolo*
Severely damaged	شدید نقصان	*Shadid nuksaan*
Earthquake	زلزلہ	*Zalzala*
Dismentled	ڈھا دینا	*Dha dena*
Structure	ڈھانچہ	*Dhancha*
Support wall / Load bearing wall	پشتہ کی دیوار	*Pushta ki diwar*
CGI roofing sheets	نالی دار چادر	*Nalidar chadar*
Totally collapsed	شدید نقصان	*Mukammal taur pe gira hua*
Damaged	نقصان زدہ	*Nuksan Zhada*
Restoration	اصلی حالت پر لانا	*Asli halat par lana*
Partially collapsed roof	جزوی طور پر گری چھت	*Zujavi taur par giri chat*
Inadequate	ناکافی	*Nakaphi*
Interlocking between stones	پیوست پتھر	*Bil aakhir*
Eventually	بالآخر	*Ehtiyat*
Fill up	منڈھنا	*Dambal numa*
Carefully	احتیاط	*Surakh*
Dumbell shaped	ڈمبل نما	*Mand na*
Hole	سوراخ	*Pevast Pathar*
Proportion	تناسب	*Tanasud*
End	سرا	*Sira*
Different types	مختلف	*Mukhtalif*
Seismic belt	سیزمک پٹہ	*Sizmik patta*
Lintel	چھتنی	*Chhatni*
Eave	اولتی	*Aulti*
Frame	چوکھٹ	*Chokhat*
Level	سطح	*Satah*
Sloping edge	ڈھلواں سطح	*Dhalwah satah*
Galvanized	جستہ	*Jasta*
Raking	کریدنا	*Kuredana*

English	Urdu	Pronounciation
Reinforcement	سلاخ	*Salakh*
Inadequate bonding	ناکافی بندھن	*Nakaphi bandhan*
Option	اختیار	*Ikhatiyar*
Satisfactory bond	اطمینان بخش	*Itmenan Bakhsha*
Opening	شگاف	*Shighaf*
Anchor	پیوست	*Pevast*
Encase	خانہ بند	*Khana band*
All around	اردگرد	*Ird-gird*
Wooden / Truss	شہتیر	*Shatir*
Diagonal bracing	ترچھی لکڑی	*Tirchhi lakadi*
Strut	لمبی لکڑی	*Lambi lakadi*
Wood plank	تخت	*Takht*
Features	خصوصیات	*Khususiyat*
Affordable	قابل برداشت	*Kabile bardasht*
Easy to execute	آسان عمل	*Amal Aasan*
Local	مقامی	*Maqami*
Quality	معیار	*Mayar*
Same time, Together	بیک وقت	*Bayak-waqt*
Buttresses	پشتہ بندی	*Pushta bandi*
Resistant	مزاحم	*Muzahim*
Metal strap	دھات کی پٹی	*Dhat ki patti*
Wire-nail	تار کی کیل	*Tar ki kil*
Number, Quantity	تعداد	*Tadad*
Control	محدودرکھنا	*Mahdood rakhana*
Bond / Stitch	پیوند	*Pevand*
Enclose	احاطہ کرنا	*Ahata karna*
Plumb	شولہ	*Shola*
Tongue groove	چیری زیب	*Chiri Zheb*
Lap	وُڈبدھر	*Wudbathar*
Staggered	ٹھان پٹ	*Than pat*
Header	سیرو	*Siro*
Stretcher	باہی	*Bahi*
Through stone	بینڈ اسٹون	*Bond stone*
Wood chisel	تیشہ	*Tesha*
Saw	آری	*Aari*
Jack plane	رندھا	*Randha*
Hand drill	برما	*Barma*

Abbreviations

Abbreviations		Full Form
AC	=	Asbestos cement
approx.	=	Approximately
BBCM	=	Burnt brick in cement mortar
CM	=	Cement mortar
cm.	=	Centimeter
cmt.	=	Cubic meter
CWM	=	Chicken Wire Mesh
dia.	=	Diameter
Dist.	=	Distance
ea.	=	Each
Eqk.	=	Earthquake
Found.	=	Foundation
g	=	Gauge
GI	=	Galvanized iron
horz.	=	Horizontal
kg	=	Kilogram
km	=	Kilometer
ltr.	=	Litre
m	=	Meter
Max	=	Maximum
Min.	=	Minimum
mm	=	Millimeter
MPT	=	Manglore Puttern tile
MS	=	Mild steel
no./nos.	=	Number/Numbers
RC	=	Reinforced Concrete
RCC	=	Reinforced Cement Concrete
rmt.	=	Running meter
RRM	=	Random Rubble Masonry
sft.	=	Square Foot
smt.	=	Square meter
UCRC	=	Uncoursed rubble masonry in cement mortar
UCRM	=	Uncoursed rubble masonary in mud mortar
vert.	=	Vertical
WWM	=	Welded wire mesh
BMTPC	=	Building Material Technology Promotion Council
NCPDP	=	National Center of Peoples'-Action in Disaster Preparedness
NDMD	=	National Disaster Management Division
UNESCO	=	United Nations Educational, Scientific and Cultural Orgnization

Government of India Technical Guidelines at a Glance

Earthquake-Resistant Reconstruction of Masonry Buildings (Category E) For Wall Length of 5 m max.

Sr. No.	Item	Stone masonry in Mud Mortar	Stone masonry in cement : sand Mortar	Brick masonry in cement : sand mortar	Conc. Block in cement : sand mortar	Additional Information
1	Wall thickness	450 mm 500 max	380 to 400 max	210 mm	200 mm	Stones in wall thickness to be interlocked with each other
2	Mortar	Good quality mud	Foundation 1:6, Wall 1:4	Foundation 1:6, Wall 1:4	Foundation 1:6, Wall 1:4	
3	Height of Masonry Courses	600 mm max.	600 mm max.	NA	NA	
4	Through Stones / Bonding Elements of full length equal to wall thickness	At 600 mm vertical &1200 mm horizontal spacing	At 600 mm vert. and 1200 mm horiz. spacing	Use headers (*Seere*) and stretchers (*Bahia*) and break all vertical joints	Use headers (*Seere*) and stretchers (*Bahia*) and break all vertical joints	50X50 conc. bar with 8mm rod or con.blk. 150X 150mm or wood battens 50X50 can be used
5	Long Stones, Conc.Blocks or wooden batten @ all wall corners & T junctions.	Every 600 mm. height	Every 600mm height	NA	NA	Long Stones to be 600 mm long, Conc. Blocks 150x150x500 mm.
6	Height of one storey	2.7 m max.	3.2 m. Max.	3.2 m Max.	3 m Max.	
7	Max. no. of stories	One	Flat roof -2 storeys/ Pitched roof - 1 Storey + Attic	Flat roof -2 storeys/ Pitched roof - 1 Storey + Attic	Flat roof -2 storeys/ Pitched roof - 1 Storey + Attic	
8	Span of walls between cross-walls	5.0 m max.	7.0 m max.	7.0 m max.	7.0 m max.	

Earthquake-Resistant Reconstruction of Masonry Buildings (Category E) For Wall Length of 5 m max.						
Sr. No.	Item	Stone masonry in Mud Mortar	Stone masonry in cement : sand Mortar	Brick masonry in cement : sand mortar	Conc. Block in cement : sand mortar	Additional Information
9	Pilaster/butress needed at intermediate point if span of wall is more than specified above					
	Spacing between pilasters	3.5 m max.	5.0 m max.	5.0 m max.	5.0 m max.	
	Top width equal to main wall thk.	450 mm	380 to 400 mm	210 mm	210 mm	
	Base width	450 mm or 1/6 of wall height	1/6 of the wall height	1/6 of the wall height	1/6 of the wall height	
10	Control of openings in walls					
	(a) Total length of all openings in a wall	0.33 of wall (outer) length	0.5 of wall outer length in single storey, 0.42 in double-storey bldg.	0.5 of wall outer length in single storey, 0.42 in double-storey bldg.	0.5 of wall outer length in single storey, 0.42 in double- storey bldg.	
	(b) Distance of opening from inside corner	length, Less than 600 mm	Less than 450 mm	Less than 450 mm	Less than 450 mm	
	(c) Pier width betwee consecutive openings	Less than 600 mm	Less than 600 mm	Less than 560 mm	Less than 560 mm	
11	Vertical reinforcement at jambs of openings					

Government of India Technical Guidelines at a Glance

Sr. No.	Item	Stone masonry in Mud Mortar	Stone masonry in cement : sand Mortar	Brick masonry in cement : sand mortar	Conc. Block in cement : sand mortar	Additional Information
	Earthquake-Resistant Reconstruction of Masonry Buildings (Category E) For Wall Length of 5 m max.					
	One-storey bldg. or upper storey in two-storey bldg.	12 mm.TOR	12 mm.TOR	12 mm. TOR	12 mm. TOR	Encase in 75mm concrete 1:2:4
	Ground storey of two-story building.	NA	16 mm TOR	16mm TOR	16mm TOR	Encase in 75mm concrete 1:2:4
	When controls of openings are violated	Box Jambs in RCC 1:2:3	Box Jambs in RCC 1:2:4	Box jambs in RCC 1:2:4	Box Jambs in RCC 1:2:4	Thickness - 75 mm with 2 - 10dia TOR bars.
12	Vertical reinforcement at all inside and outside corners					
	One-storey bldg. or upper storey of two-storey bldg.	12 mm TOR or 'L' section of two timber planks 80x30 & 50x30	12 mm TOR	12 mm TOR	12 mm TOR	Encase rods in 75mm concrete 1:2:4. Nail timber planks to timber bands
	Ground storey of two story building.	NA	16 mm TOR	16 mm TOR	16 mm TOR	Encase in 75mm concrete 1:2:4
13	Continuous Horizontal Seismic Bands of 75mm thickness in all internal and external walls	lintel	lintel	lintel		
	Location of bands in Flat Roof building	Plinth, lintle level and at ceiling level if ceiling is of timber	Plinth, lintel levels in each storey & under floor/ceiling level in case of timber floor/eiling	Plinth, lintel levels in each storey & under floor/ceiling level in case of timber	Plinth, lintel levels in each storey & under floor/ceiling level in case of timber floor/eiling	Use 2-10 dia. Bar with 6mm stirrups @ 150mm c/c Overlap of bars-500 mm.

Earthquake-Resistant Reconstruction of Masonry Buildings (Category E) For Wall Length of 5 m max.						
Sr. No.	Item	Stone masonry in Mud Mortar	Stone masonry in cement : sand Mortar	Brick masonry in cement : sand mortar	Conc. Block in cement : sand mortar	Additional Information
	Location of bands in Pitched Roof building	Plinth, lintel and eave levels and at triangular masonry gable top	Plinth, lintel on each storey, eave, masonry gable top and at timber floor level	Plinth, lintel on each storey, eave, masonry gable top and at timber floor level	Plinth,lintel on each storey, eave, masonry gable top and at timber floor level	When distance betwee eave and lintel level is less than 600 mm, little band can be intigrated with eave band.
	Material for seismic band	Conc.1:2:4 or timber if timber vert. reinforcement is used	Concrete. 1:2:4	Concrete.1:2:4	Concrete.1:2:4	For timber band use 2-75x38mm with cross links 50x30mm @500 mm c/c
14	Corner strengthening with Dowels	L' or 'T' shaped wooden inserts	NA	NA	NA	timber size 30x50 mm.
15	Gable wall materials	ACor CGI on timber frame or *Dhajji* Wall	ACor CGI on timber frame or *Dhajji* Wall	ACor CGI on timber frame or *Dhajji* Wall	ACor CGI on timber frame or *Dhajji* Wall	
Ref : Guidelines for "Earthquake Resistant Reconstruction and New Construction of Masonry Buildings in Jammu & Kashmir State" by Prof. A.S.Arya and Ankush Agrawal.						

Government of India Technical Guidelines at a Glance

Repair, Restoration & Retrofitting of Masonary Buildings (Category E) for Wall Length 5m. Maximum

	Sr. No.	Description	Concrete/ Mortar	Grout/ Plaster Thk.	Weld Mesh (Galvenized)			Size of Belt		Nails / Dowels			Bonding Element	
					Gauge.	Size	Overlap	Width	Length	Dia	Length	Spacing	Hole Size	Bar Size
RESTORATION	1	Crack sealing & grouting with plastic/aluminium 12 mm Dia nipples @ 150 to 200 mm c/c	Sealing mortar cement: sand 1:3	Non-shrink cem: water 1:1										
RESTORATION	2	Crack sealing and Splicing across crack	Sealing mortar non shrink cem sand 1:3	Plaster cem: sand 1:3 thk. 12mm	Splicing with 16 to 14 gauge weld mesh 25X25mm size			200 to 300 mm	450mm on each side of crack	Wire nails 5mm dia.	100 to 150mm			
RESTORATION	3	Reconstruction of damaged wall. Provide headers in RR wall											Stone headers @ 600mm vert. lift & 1.2m apart horiz.	
RESTORATION	3	If existing wall is in mud mortar reconstruct with	1:6 cement sand mortar											
RESTORATION	3	If existing wall is in cem. mortar recostruct with	1:4 cement sand mortar											

Repair, Restoration & Retrofitting of Masonary Buildings (Category E) for Wall Length 5m. Maximum

	Sr. No.	Description	Concrete/ Mortar	Grout/ Plaster Thk.	Weld Mesh (Galvenized)			Size of Belt		Nails / Dowels			Bonding Element	
					Gauge.	Size	Overlap	Width	Length	Dia	Length	Spacing	Hole Size	Bar Size
RETROFITTING	4	Cast in-situ RCC bond elements horizonatally & vetically 1m. apart with 50 cm. horizontal stagger in RR wall.	cem: aggra: sand 1:2:4 concrete										Dum-bbell shape 75mm dia. Hole	8mm bar hooked @both eands.
	5													
		Horizontal seismic belt to be provided on all walls only on one face when wall length is less than 5m	Cem: sand 1:3 or micro conc. 1:1.5:3	First coat 12 mm, second coat 16 mm+ dia of bars.	Weld mesh 10guag e	longtudn al wires @ 2 5mm x transvers e wires up to150mm	300mm	280 mm with10 longit-udnal wires	conti-nuous	5mm with washer	150mm	300mm c/c		
	6	Vertical seismic belt @ corners - One storey or top storey of 2 storey house	Cem:sand 1:3 or micro conc. 1:1.5:3	First coat 12mm, second coat 16mm+ dia of bars.	10g.	Horizon-tal@ 25mm x vertical @ 50mm	300mm	400 mm with 14 longit-udnal. Wires.		5mm with washer	150mm	300mm c/c		
		Bottom storey of 2 story house		same as above	10g.	same as above	300mm	Same as above with 1-12 dia. bar		5mm	150mm	300mm c/c		

Government of India Technical Guidelines at a Glance

Repair, Restoration & Retrofitting of Masonary Buildings (Category E) for Wall Length 5m. Maximum

	Sr. No.	Description	Concrete/ Mortar	Grout/ Plaster Thk.	Weld Mesh (Galvenized)			Size of Belt		Nails / Dowels			Bonding Element	
					Gauge.	Size	Overlap	Width	Length	Dia	Length	Spacing	Hole Size	Bar Size
RETROFITTING	7	Vertical reinforcing bars at inside corner inleiu of seismic belt- One storey house and in top storey of two storey house	Cem: sand 1:3 or micro conc. 1:1.5:3	min 15mm cover.		12mm bar	300mm						start 450 mm below plinth and continue in to roof/ eave level 7 horizontal band	
		Lower storey of two storey house		min 15mm cover.		16mm	300mm							
		Fix bar with wall with 'L' shaped dowel from cast in situ bond elements		non shrink 1:3 cem: sand						8mm 'L' shape	Vert.leg 400mm horiz. leg 150mm	1 m.	Dumb-bell shape 75mm dia. Hole	hooked on horiz. Leg
	8	Seismic belt around openings	Cem:sand 1:3 or micro conc. 1:1.5:3	First coat 12mm, second coat 16mm+ dia. of bars.	10g.	25mm x 150mm	280mm	280mm with 10 vert. wires		5mm	150mm	300mm c/c		
	9	Strengthening of *Dhajji* Diwari - Install diagonal timber brace				20 mm x 40 mm				10g.	75mm	2 nails at each eands.		
	10	Stiffening flat wooden floor / roof strut & diagonal brace of timber planks				100 mm vide x 25mm				10g.	75mm	2 nails at each ends.		

Ref: Guidelines for "Repair, Restoration and Retrofitting of Masonry Buildings in Earthquake Affected Areas of Jammu & Kashmir" by Prof. A.S.Arya and Ankush Agrawal.

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About NCPDP

National Centre for People's-Action in Disaster Preparedness (NCPDP)

NCPDP was created with a focus on disaster preparedness in October, 2000 at the time of Bhavnagr Earthquake in Gujarat state. This was an outcome of seven years of post-earthquake intervention by its two honorary directors in the regions of Latur, Jabalpur and Chomoli in India. NCPDP played a major role in rehabilitation as well as capacity building for long-term preparedness in Gujarat in the aftermath of the Kutchch earthquake, and also worked on capacity building and technology demonstration in quake-affected Kashmir.

NCPDP is one of a few technology-based organizations in the country with first-hand experience of working at the grass roots. It has a firm belief that building capacity of people from within is the only way to mitigate disasters for a safer world. Hence, we believe that intervention by external agencies in the aftermath of a disaster must work towards this end. Upgrading the skills of building artisans should form the backbone of this approach.

NCPDP strives to bring viable, eco-friendly and sustainable technologies to help people reduce their vulnerability against future disasters. It strives to remain prepared for timely intervention in the aftermath of major disasters. It is continuing to work on disaster mitigation through (a) training of engineers and building artisans, (b) awareness and confidence building programs in communities, (c) preparing ready-to-use technical information for people, (d) research on structural behaviour of masonry structures, (e) building vulnerability studies in different parts of India, (f) vulnerability reduction through retrofitting, and (g) policy interventions.

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