Ministry of Urban Development and Housing
Government of Afghanistan

United Nations Centre for Regional Development
Disaster Management Planning Hyogo Office

GUIDELINES

for Earthquake Resistant Design, Construction, and Retrofitting of Buildings in AFGHANISTAN

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Ministry of Urban Development and Housing (MUDH),
Government of Afghanistan

United Nations Centre for Regional Development (UNCRD)
Disaster Management Planning Hyogo Office

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MAIN CONTENTS

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MESSAGE

From His Excellency M.Y. Pashtun

Afghanistan is an earthquake prone country, and is located in one of the most active seismic belts of the world. Statistics in past one decade show that four severe earthquakes hit the country, causing significant damages to the lives and properties. The zoning map indicates that out of 30 provinces in Afghanistan, 19 are located in high to medium high risk of earthquake potential. Most of these provinces are located in the north and northeastern part of country. An estimated of more than 10 million people live in these provinces. Thus, earthquake is a severe problem in the country, which needs urgent attention.

After more than 20 years of conflict and war, the country is now preparing itself for steady and fast reconstruction and recovery. In this process, two major needs are shelter (in form of houses) and livelihood opportunities (in form of jobs). Returnees are going back to their hometowns at a daily basis. With the generous assistance from the international agencies and non-government organizations, the government is implementing huge shelter programs in different parts of the country, including the earthquake-prone areas. In this crucial junction, this is of utmost importance to have a consolidated set of information for the earthquake safety of houses. More than 90% of the country's building stocks are non-engineered constructions, made of mud-bricks and stones. To improve the earthquake safety of those houses, it is important to incorporate the traditional technologies using locally available building materials.

To start the process of earthquake safety in a systematic way, the Ministry of Urban Development and Housing (MUDH) and the United Nations Centre for Regional Development (UNCRD) of Kobe, Japan jointly took the initiative to prepare five sets of guidelines for different construction materials. Professor Anand S. Arya, a renowned expert in this field has kindly developed these guidelines. Earthquake safety measure in the non-engineered construction is a non-ending process, which needs decades of continued efforts to make a culture of safer building practices. I believe that preparation of the guidelines is the first step of this long-term process.

I hope that the engineers and practitioners of different government, non-government and international organizations working in the field of construction will be benefited from the guidelines, will use it, and will try to improve it for its future application in creating an earthquake safer Afghanistan.

Engineer M. Y. Pashtun
Minister,
Ministry of Urban Development and Housing
Government of Afghanistan

FOREWORD

Afghanistan is undergoing rapid reconstruction after more than two decades of conflict and internal strife. The priorities of the country are numerous while the resources needed to address them are extremely limited. One of the most urgent needs is to rebuild people's houses, and to provide the necessary infrastructure. As Afghanistan is prone to earthquakes, it is of the utmost importance to construct earthquake-safer housing and infrastructure, and to retrofit already existing houses that are vulnerable to earthquakes.

The United Nations Centre for Regional Development (UNCRD) Disaster Management Planning Hyogo Office has initiated a project called "Training and Capacity-Building for Safer Construction Practices: Towards a Sustainable Rehabilitation Programme in Afghanistan," aiming to enhance human safety and security by promoting safer construction practices. The purpose of the project is to enhance the capacities of governments and nongovernmental organizations (NGOs) through development of guidelines for earthquake-safer nonengineered construction practices in Afghanistan.

Incorporating field survey data, an international consultant, Prof. Anand S. Arya, developed a set of five guidelines for the use of engineers for a variety of construction practices suitable to Afghanistan. These were translated into the local language by Shelter for Life International (SFL) with the assistance of Kabul University. A training workshop was held in Kabul in June 2003, jointly organized with the Ministry of Urban Development and Housing (MUDH), inviting central and local governments, NGOs, and international organizations. The developed guidelines were presented during the workshop. The workshop's training programme included a shake table testing of housing models as a means of confidence-building, which was performed by a Nepalese mason and engineers.

The important elements of a rehabilitation programme should be strong leadership of the Afghan people, close collaboration between the government organizations and NGOs, and effective capacity-building among local government organizations. We hope that these guidelines will be used broadly for the training of government officers, engineers, community leaders, and masons in Afghanistan and that they will eventually contribute to a sustainable rehabilitation programme in Afghanistan.

Kenji Okazaki
Coordinator,
Disaster Management Planning Hyogo Office
UNCRD

PREFACE

United Nation Centre for Regional Development (UNCRD) Disaster Management Planning Hyogo Office offered a Consultant Contract to the author, through United Nations Department of Economic and Social Affairs (UNDESA), for performing the following specific services:

1. To develop a guideline for earthquake safe construction with mud (new construction) and stone houses (both new construction and retrofitting) to be used by masons and house owners;
2. To develop training materials for use of engineers in the design and construction of masonry buildings of all types and detailing of reinforced concrete buildings for achieving adequate performance during earthquakes;
3. To develop a model design of earthquake safe school and a community center, using appropriate locally available materials with elements for its earthquake protection;
4. To provide advisory services during the training of engineers in Kabul, Afghanistan, and;
5. To submit a report to UNDESA-UNCRD, including the guidelines, training materials and model design.

In order to fulfill the requirements of preparing the guidelines for earthquake safe construction including new constructions and retrofitting of masonry buildings as well as to develop training material for use of engineers in the design and construction of masonry buildings of all types and detailing of reinforced concrete buildings for achieving adequate performance during earthquakes, the Consultant has planned to prepared the guidelines in following five parts so that they could be conveniently used for various purposes of training and guidance.

PART A	Earthquake Resistant Design of Buildings
PART B	Earthquake Resistant Design and Construction of Rectangular Unit Masonry Buildings
PART C	Earthquake Resistant Construction of Stone Buildings
PART D	Repair, Restoration and Seismic Retrofitting of Masonry Buildings
PART E	Earthquake Resistant Construction of Earthen Houses

PART A: Earthquake Resistant Design of Buildings covers the principles of earthquake resistant design of buildings taking to account the seismic zones of Afghanistan. It also includes the detailing aspects of reinforced concrete buildings. This part will be used for providing training of the engineers in the understanding of earthquakes, the damaging effects on buildings and appropriate care one should take in the ductile detailing of reinforced concrete frames for achieving adequate earthquake performance.

PART B: Earthquake Resistant Design and Construction of Rectangular Unit Masonry Buildings covers the earthquake resistant construction details of masonry buildings with walls constructed using rectangular masonry units such as burned clay bricks, solid concrete blocks, hollow concrete blocks or dressed stones laid in cement or cement lime mortar, taking into account the seismic zones of Afghanistan. In case, clay mud mortar is used, certain architecture planning measures will have to be constrained. This part will be useful for providing training of the engineers as well as masons, and providing help in improving the safety of such building in future probable earthquakes.

PART C: Earthquake Resistant Construction of Stone Buildings covers the earthquake resistant construction details of random rubble buildings constructed using mud and cement mortar taking into account the seismic zones of Afghanistan. This part will be useful for providing training of the engineers as well as masons, and providing help in improving the safety of such building in future probable earthquakes.

PART D: Repair, Restoration and Seismic Retrofitting of Masonry Buildings covers the topic of restoration of lost strength of cracked masonry walls, cosmetic repair, as well as their seismic retrofitting. Methods of seismic retrofitting will equally apply to existing weak masonry buildings for upgrading their seismic safety in various seismic zones of Afghanistan. This part will be useful for providing training of the engineers as well as masons, and providing help in improving the safety of such building in future probable earthquakes.

PART E: Earthquake Resistant Construction of Earthen Houses covers the earthquake resistant construction details of earthen houses taking into account the seismic zones of Afghanistan. This part will be useful for providing training of the engineers as well as masons, and help in improving the safety of such buildings in future probable earthquakes.

Anand S. Arya
Consultant

bricks, solid concrete blocks, hollow concrete blocks or dressed stones laid in cement or cement-lime mortar, taking into account the seismic zones of Afghanistan. In case, clay mud mortar is used, certain strengthening measures will have to be incorporated. This part will be useful for providing training of the engineers as well as masons, and providing help in improving the safety of such buildings in future possible earthquakes.

PART C: Earthquake Resistant Construction of Stone Buildings covers the earthquake resistant construction details of random rubble buildings constructed using mud and cement mortar taking into account the seismic zones of Afghanistan. The part will be useful for providing training of the engineers as well as masons and providing help in improving the safety of such building in future probable earthquakes.

PART D: Repair, Restoration and Seismic Retrofitting of Masonry Buildings covers the topic of restoration of lost strength of cracked masonry walls, concrete members, as well as their seismic retrofitting. Methods of seismic retrofitting will equally apply to existing weak masonry buildings for upgrading their seismic safety in various seismic zones of Afghanistan. This part will be useful for providing training of the engineers as well as masons, and providing help in improving the safety of such building in future probable earthquakes.

PART E: Earthquake Resistant Construction of Earthen Houses covers the earthquake resistant construction details of earthen houses taking into account the seismic zones of Afghanistan. This part will be useful for providing training of the engineers as well as masons, and help in improving the safety of such buildings in future probable earthquakes.

Anand S. Arya
Consultant

PART A

Earthquake Resistant Design of Buildings

CONTENTS – PART A

1. A OBJECTIVES, SCOPE AND TERMINOLOGY

1.1.A INTRODUCTION

These guidelines have been framed in the aftermath of devastation in Afghanistan due to two decades of internal strife and three damaging earthquakes in the same period, in which a large number of houses were either collapsed or damaged beyond repairs.

Afghanistan is an earthquake prone country, and is located in one of the most active seismic belts of the world. Only in, last decade, the earthquake of 1991 resulted a casualty of 1000 people; that of 1998 had a cumulative casualty of 7,500 in two events; and the recent earthquake of March 2002 resulted in a casualty of more than 2,000 people. A preliminary seismic zonation shows that more than 50% of the country is prone to earthquake risk, where around 30% has high risk of severe earthquake.

During the rehabilitation process of housing construction, it is of utmost importance to focus on the seismic resistance of new construction, and retrofitting of already existing houses.

The need of the moment is:

- To provide technical assistance for safer housing construction practices,
- To provide training to the engineers, community leaders and masons, and
- To build capacities of the local governments

These guidelines cover the issues of options of building materials and building construction technologies, which will be appropriate for earthquake resistant construction of houses and buildings in the various seismic zones of Afghanistan. In the absence of building standards of Afghanistan, the various factors involved in achieving earthquake safe buildings are taken as per Indian Standard Codes and Guidelines. The applicable details are illustrated for easy understanding of the professionals involved in building design and construction.

1.2.A OBJECTIVES OF THE GUIDELINES

The following are the main objectives of these guidelines:

i) To prepare guidelines on earthquake resistant design principles for training of engineers
ii) To select appropriate building materials and building construction technologies for earthquake safe buildings in Afghanistan.
iii) To prepare guidelines for repair and seismic retrofitting of damaged stone buildings.

1.3.A SCOPE OF THE GUIDELINES

The Guidelines have been prepared in the following five parts for convenience of use in the country:

Part A Earthquake Resistant Design of Buildings in Afghanistan.
Part B Earthquake Resistant Design and Construction of Rectangular Unit Masonry Buildings in Afghanistan.
Part C Earthquake Resistant Construction of Stone Buildings in Afghanistan

Part D Repair, Restoration and Seismic Retrofitting of Masonry Buildings in Afghanistan

Part E Earthquake Resistant Construction of Earthen Houses in Afghanistan.

In planning the above guidelines, attempt has been made to make them as self contained as possible with minimum reference to other guides. This has certainly needed some duplication, but adopted for convenience.

These guidelines will cover houses and buildings of Schools, Health Centres, and other community buildings situated in the rural and urban areas using load bearing walls. The buildings in good strength brick masonry, solid/hollow concrete blocks and stone are included. The roof can be flat or sloping. The earthquake resistant provisions are indicated for seismic intensities MSK IX, VIII and VII as appropriate for the earthquake affected areas. Limitations in construction material, number of storeys, length of walls etc. as appropriate are indicated.

The design of reinforced concrete frames are not covered in the guidelines, and it is expected that a proper analysis, design and detailing will be carried out by qualified engineers as per codal requirements. But detailing of reinforcement in beams, columns and their joints is presented as required for adequate performance during maximum probable earthquake Intensities so as to provide guidance to those who would construct such buildings.

It is not the intension to reproduce provisions of the Codes but to highlight the important provisions. Hence at many places, only reference is made to the clauses of the Indian Standard Codes/Guidelines.

These guidelines cover the following features from earthquake safety view point:

a) Siting and foundations
b) Architectural design features
c) Structural analysis and design
d) Construction and strengthening features in load bearing walls
e) Construction and strengthening features of roofs and floors

1.4.A TERMINOLOGY

Some of the technical terms used herein are defined below:

1.4.1.A Band

A reinforced concrete, reinforced brick or timber runner provided in the walls to tie them together and to impart horizontal bending strength in the walls. Plinth band, lintel band, roof band, eave level band and gable band are names used for the band depending on the level of the building where the band is provided.

1.4.2.A Centre of Mass

The centre of gravity of all the masses of roofs/floors and the walls above any storey of the building.

1.4.3.A Concrete Grades

28 day crushing strength of concrete cubes of 150 mm size, in Mpa; for example, for *Grade M20* of IS 456:2000, the concrete strength will be equal to 20 Mpa (N/mm^2)

1.4.4.A Design Horizontal Seismic Coefficient

The value of horizontal seismic coefficient computed taking into account the seismic zone factor, the type of base soil, the response reduction factor and the importance factor as specified in IS: 1893-2002.

1.4.5.A Engineered Buildings

Buildings designed by architects and/or engineers and properly supervised by engineering staff during construction such as reinforced concrete and steel framed buildings.

1.4.6.A Non-engineered Buildings

Those buildings which are spontaneously and traditionally built by masons and carpenters without inputs from architects or engineering staff in design or construction, such as houses built using traditional materials namely, stone, burnt-brick, clay mud or adobe, wood and other bio-mass materials.

***Note 1**: Reinforced concrete or steel column-beam construction carried out by masons without proper analysis and design for lateral seismic loads will also fall in the category of non-engineered buildings.*

1.4.7.A Earthquake Safe Non-Engineered Buildings

Those non-engineered buildings which comply with the provisions in IS:4326, IS:13827 and, IS:13828 in their construction.

1.4.8.A Semi-Engineered Buildings

Buildings which have certain elements structurally designed such as roof slabs and foundations but certain elements not properly designed such as walls of masonry buildings, and in which the supervision may be through engineering staff or otherwise. Many buildings of this type are planned by architects and built by parties through petty contractors without efficient supervision.

1.4.9.A Seismic Zone

The seismic zones AB, C and D as classified in seismic zoning map of Afghanistan. (Fig. 9A)

1.5.A INDIAN STANDARD CODES AND GUIDELINES

The most used Indian Standard Codes and Guidelines for structural design of all types of buildings and structures including earthquake resistant measures are listed for ready reference.

1.5.1.A General Structural Design

1. "IS:456-2000, *Code of Practice for Plain and Reinforced Concrete*", Bureau of Indian Standards, New Delhi.
2. IS-SP: 16-1980, *Design Aids for Reinforced Concrete to IS: 456-1978*", Indian Standards Institutions, 1980.
3. "IS: 800-1984 *Code of Practice for General Construction in Steel*" Indian Standards Institution, Feb. 1985.
4. "IS:SP6(6)-1972, *ISI Handbook for Structural Engineers*", Bureau of Indian Standards, New Delhi.
5. "IS:1904-1978, *Code of Practice for Structural Safety of Buildings*: Shallow Foundations", Bureau of Indian Standards, New Delhi.
6. "IS:1905-1987, *Code of Practice for Structural Safety of Buildings*: Masonry Walls", Bureau of Indian Standards, New Delhi.

1.5.2.A Earthquake Resistant Design and Construction

1. "IS:1893-2001, *Criteria for Earthquake Resistant Design of Structures – Part I* (Fifth Revision)", Bureau of Indian Standards, New Delhi.
2. "IS:4326-1993, *Earthquake Resistant Design and Construction of Buildings – Code of Practice* (Second Revision)", Bureau of Indian Standards, New Delhi.
3. "IS:13920-1993, *Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces – Code of Practice*", Bureau of Indian Standards, New Delhi.
4. "IS:13828-1993, *Improving Earthquake Resistance of Low Strength Masonry Buildings- Guidelines*", Bureau of Indian Standards, New Delhi.
5. "IS:13827-1993, *Improving Earthquake Resistance of Earthen Buildings-Guidelines*", Bureau of Indian Standards, New Delhi.
6. "IS:13935-1993, *Repair and Seismic Strengthening of Buildings*", Bureau of Indian Standards, New Delhi.
7. "*Guidelines for Earthquake Resistant Non-Engineered Construction*", The International Association for Earthquake Engineering, Tokyo, Japan, Oct. 1986.

2.A BUILDING MATERIALS AND CONSTRUCTIONS IN AFGHANISTAN

2.1.A LOCAL CONDITIONS

The choice of building materials and construction technologies will depend upon the local conditions such as social living pattern, economic affordability, accessibility of the site, yearly and daily temperature variations and the rainfall in the area. Besides the prevalent materials and constructions which will need improvements for seismic resistance, appropriate new advances must be introduced for the sake of safety at economical cost.

2.2.A TEMPERATURE VARIATION

In Afghanistan, the temperature of the coldest month ranges from +5 degree centrigrade to –20 degree centigrade. The minimal temperature registered is –52 degree centigrade. In two third of the country the average temperature for four to five month in a year is less than 0 degree centigrade. Temperature of hottest month ranges from +5 degree centigrade to +30 degree centigrade. Maximum temperature registered in Afghanistans is +51 degree centigrade.

The South–west part of country is hot and of hot semi desert character, the North–west part is cold semi desert to dry temperate character. The North–east part of the country has diversified cold climate ranging from glacial to cold desert character. The South–east part is hot semi desert to cold dry seasoned character.

2.3.A PRECIPITATION

The South-west and southern parts of Afghanistan receive minimum precipitation of less than 100 mm to 200 mm, and in the other parts of the country the mean annual precipitation is 200 mm to 800 mm, few small areas receiving upto 1000 mm of precipitation in the form of rain or snow.

2.4.A PREVALENT HOUSE TYPES

It is seen that the following main types of houses are used in Afghanistan:

(i) Brick (Sun dried) wall with wooden roof (use of wood logs)
(ii) Brick (Sun dried or burned) wall with timber roof (use of sawn timber)
(iii) Wooden wall/Nuristan houses
(iv) Stone wall with wooden roof
(v) Brick (Sun dried or burned) wall and Dome roof
(vi) Contemporary modern building materials like Burnt brick, Cement Concrete, R.C.C. frame structure etc.

Main types of house construction use Sun dried brick or Adobe walls with wooden roof, and Sun dried brick and Dome. Mud is the main construction material. In Afghanistan 95% of construction is with mud. Only in urban areas, contemporary modern building materials are used.

Rural area layout of village is organic. Most of the settlements are located in hilly terrain, and houses are built both on hills and in the plains. One complete house is on a plot of approximate size of 500 sq.m. with two rooms and one passage. Mostly front portion of house is of L shape and is located in one corner of plot. Opposite to the L shaped house, two rooms and other utility spaces like bathing, washing space, etc. are constructed. Some time on contour site, house is with a basement room. This basement room is mostly used for storing fodder and agriculture produce. Usually the house has a compound wall with height ranging from 2.5 m to 3.5 m. In new construction, large glazed window having dimensions of 1.5 m x 1.5 m to 1.8 m x 1.8 m are also used. The location of the window is usually at the center of the wall and some time at the corner.

2.5.A FAMILY LIVING

Usually the family size is big. The average family size varies from 8 to 15 persons all living in one house. Extended families also are accommodated in the same house. Built up area of houses ranges from 60 to 100 sq.m. Due to thick walls, the usable carpet area of a house is considerably less than the plinth area.

In rural areas, construction of 'ground plus one' house is a normal practice. New construction is normally only the ground floor and future extension is usually to build the first floor instead of horizontal expansion.

Urban areas like Kabul, Baglan, Pulixumri which are the main centers of provinces and towns are planned. But in outskirt, organic development is mostly on the hills. Kabul is conglomerate of bungalows, apartments, multistoried buildings, and mud house (G, G+1 and some time G+2) also form part of cityscape. Type of new construction ranges from R.C.C. framed structures to mud houses. Typology of house in outskirt of the city is almost similar to the rural houses. Few buildings in Kabul are G+9. During the regime of Russian Government, several G+3 to G+4 building were built with prefabricated materials. High compound wall is common feature of all the houses.

2.6.A COMMUNITY BUILDINGS

2.6.1.A School Buildings

After decades of conflict years, the Government at present is setting up educational systems. Education system at present consists of Primary Section, High School Section, Higher Secondary Section and University. Separate school for boys and girls is culturally accepted. The girl schools are of closed type with openings at the central court.

In towns and urban areas, usually the primary schools consist of 8 rooms. If school has provision for primary and high school, the school building consists of 12 class room plus room for Administration and other rooms.

New design of School buildings are expected to come up in near future with the support of NGOs presently involved in Rehabilitation activity in Afghanistan.

2.6.2.A Health Centers

There are medical facilities available at different province headquarters. Some of the big villages have a primary health center. The process of planning for construction or the construction is in progress in villages which do not have a primary health center or it was destroyed.

2.6.3.A Other Community Spaces

Madrassa and Mosque are other major community structures.

2.7.A BUILDING MATERIALS AND WALL CONSTRUCTION

2.7.1.A Stone and stone Masonry

Random rubble stone is available almost everywhere except in the desert areas and some plains. Usually hard compacted sand stone is used in construction. Traditionally, stone is used for foundation and plinth. In hilly region where good clayey soil is not available, hard compacted san stone is used for super structures. In stone construction, wooden logs are used for strengthening of corners and wooden band is used at lintel level. Sometimes even at sill level wooden band is used.

In foundation the general practice is to use dry rubble masonry with sand packing or mud mortar. The general practice in plinth construction is use of mud mortar or dry masonry.

2.7.2.A Brick Walls

Normally good quality burnt brick is available near urban areas and main centers of provinces like Zalalabad, Kabul, Mazaresarif, Kandhar and Hearat.

Bricks are usually of good quality with almost even size (not bent), giving metallic sound when struck with each other. The common size of brick is 20cm x 10cm x 5 to 6 cm. It is understand that in Afghanistan the compressive strength of burnt bricks ranges from 50 kg/cm^2 to 80 kg/cm^2.

2.7.3.A Sun Dried Brick (Adobe)

In Pastun the Sun dried Brick is called Khiste–Kham. Different sizes of the mud brick are available i.e. 20 cm x 10cm x 5 to 6 m, 38 cm x 38 cm x 8 cm and 25 cm x 12 cm x 6 cm. Mud bricks are easily available and used in construction activity almost all over the country. Compressive strength data is not generally available. Two samples from Nahrin and Kabul for testing dry compressive strength of mud brick, tested in laboratory at Kutch Nav Nirman Abhiyan gave about 70 kg/cm^2, and a density of 1650 kg/m^3. This data can not be taken as representative, but just gives some idea of the material and can be considered as excellent. Mud mortar is used for mud brick masonry. Quality of masonry is average. Two layers of burnt brick are put on the wall once the wall is raised to full height to prevent washing of the mud in rains. Sometime the burnt bricks are replaced with grass or wooden planks to prevent the mud from washing out in rains.

It is known that 95% of the construction in Afghanistan is with mud and construction with mud is part and parcel of Afghanistan culture. In all construction activity in the near future, mud is likely to remain the main constituent as the most affordable. So whatever Code/ Guidelines is developed, must deal with mud Construction for construction activity in Afghanistan.

2.7.4.A Stack wall (Pakhsa Wall)

Stack walls are made out of mud locally available without any additives. The mud is mixed with water, puddled and left for 24 hours. With this preparation, mud lumps are made and stacked in order to construct a mud wall. The wall is constructed in layers and each layer has a thickness of 70 to 80 cm and layer height of 70 to 80 cm. One layer is put in a day and the next is put on the dried up layer the next day. Sometimes a stone or sun dried bricks is inserted at the edges and the junctions between two layers of stacked wall. A locally made tool known as Paksha Taras is used to dress the wall. The final finish of the wall is done with mud plaster. The mud plaster is made out of mud, water and rice or wheat husk. No scaffold is used for constructing the wall. Usually the mason sits on the wall itself while constructing. Normally the brick masonry work is also executed in the similar fashion. As in Adobe walls, two layers of burnt brick are put on top once the wall is raised to full height to prevent washing of the mud in rains or grass or wooden planks are used for rain protection of the mud.

2.7.5.A Roofing

Mud covered roofs with timber understructure and domes are commonly used as roofing in both rural and urban areas. In urban areas corrugated Galvanized Iron sheets (CGI) and RCC roofing systems are also used along with the other covering materials. Tiles, as used in India, are not used as roofing material in Afghanistan.

2.8.A OTHER BUILDING MATERIALS

2.8.1.A Cement

There were three cement manufacturing facilities in Afghanistan. But at present only one of the plants at Pluximbri is producing cement (OPC), production capacity being 1000 bags (50 kg each) per day. The quality of cement is good. The remaining requirement of cement is met through imports.

In rural areas as most of the construction is made using mud, the use of cement is nil, but in the case of community structures there is some use of cement. The use of cement is predominantly in the urban areas, where close to 40% of construction activities calls for use of cement. It is to be noted that 60% of the remaining construction in urban areas uses mud.

2.8.2.A Lime

Lime deposits are found in almost all regions of Afghanistan, but there are no large scale manufacturing plants for extraction of lime of construction quality. The people have developed a system of producing lime along with brick production in kilns (bhatta). The two bottom layers in the brick producing kilns are spread with limestone and unslaked lime is produced. Lime is also commonly used in mortar 1:1:6 (cement, lime, sand) for construction activities.

2.8.3.A Sand and Coarse Aggregate

River sand (bakrami) suitable for construction is available across all regions of Afghanistan.

But there is a shortage of coarse aggregate for construction activities. Stone quarries are found in all major provinces, but lack of working stone crushing units is causing the lack of aggregate. Almost all the stone crushing units have been destroyed in the war. River pebbles are being used as a substitute for coarse aggregate for construction activity.

2.8.4.A Wood

Wood is used in door/windows, for corner strengthening, and also for the roofs. *Chinare Sokat*, a local species is cultivated across Afghanistan for wood, but it is good enough to be used only in the roof. Of late due to increasing demand for construction activities, wood is imported from Pakistan. The wood is not treated before being used in construction as they do not face any problems due to termites. Sawn wood is also available in all regions.

2.8.5.A Steel

100% of requirement is met through importants from Russia and Pakistan. Steel is not used in any of the rural construction (not even in reinforcements), its use being restricted to construction in the urban areas.

2.9.A POSSIBILITY OF USING VARIOUS CONSTRUCTION MATERIALS

2.9.1.A Cement Concrete (CC) blocks

The scarcity of cement and coarse aggregate will make the possibility of using CC block technique for reconstruction a difficult proposition. There is also a lack of infrastructure and skills required for using CC blocks.

2.9.2.A Bricks

Bricks of good quality are easily found in the main centers and can be used for any future construction.

2.9.3.A Stabilized compressed earth

The soil in most of the region is of clayey nature. The easy availability of sand makes it suitable for stabilized block production. The cost of cement and nature of soil may make stabilized compressed earth block somewhat costlier. However, the possibility of using stabilized compressed earth block can be looked into since it will be more economical than fired brick or CC block, eco-friendly and people friendly.

2.9.4.A Construction skills and mechanization

Traditional manpower is available for construction activity. The level of mechanization in construction activity is insignificant. Only in areas around Kabul could one see some signs of mechanization. There, concrete mixers, dumper trucks and cranes are used in the construction activities.

The training facilities are almost nil in Afghanistan after the collapse of the educational system. After the reopening of the Kabul University, there is a possibility of reopening of the engineering and architecture departments. However the ministry is open to conducting training programmes in construction and related activities. As there are trained professionals having a competence in English, there should be no problems in translating manuals and other technical documents into the local languages.

3.A EARTHQUAKES AND THEIR EFFECTS

3.1.A EARTHQUAKE VIBRATIONS

Vibrations of earth's surface caused by waves coming from a source of disturbance inside the earth are described as 'Earthquake'.

The most important earthquakes from an engineering standpoint are of tectonic origin, that is, those associated with strains in the crust of the earth. The entire earth surface is made up of several wide, thin and rigid plates which are in constant motion relative to each other. This is also referred as 'plate tectonics'. This causes most earthquakes at their edges and also within them. This movement is very slow but at some places it is as much as 5 cm per year. The theory describing this phenomenon is termed as Elastic Rebound Theory, according to which the strain energy that accumulates due to deformation in the earth mass, gets released when the resilience of the storing rock is exceeded. The stored strain energy released through rupture is propagated in the form of waves to the earth mass and vibrate the structures standing on in (Fig. 1A).

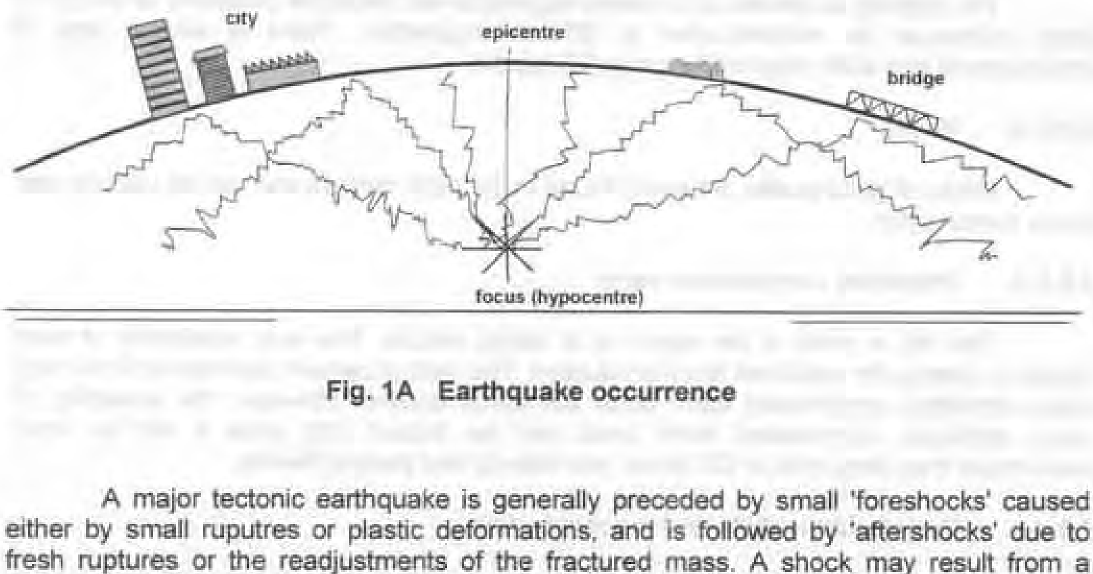


Fig. 1A Earthquake occurrence

A major tectonic earthquake is generally preceded by small 'foreshocks' caused either by small ruputres or plastic deformations, and is followed by 'aftershocks' due to fresh ruptures or the readjustments of the fractured mass. A shock may result from a rupture of rock over a length of few to hundreds of kilometres and several kilometres wide and thick. The bigger is the mass that ruptures at one time, the bigger is the earthquake.

Small earthquakes are also caused by volcanic eruptions, rock-bursts or subsidence in mines, blasts, impounding of reservoirs, pumping of oil, etc. They may cause considerable damage in small areas, but vast areas are shaken only by tectonic movements across active faults explained above.

3.2.A MEASUREMENT OF GROUND MOTION

Basically, two types of instruments are used to record earthquake motions. The instruments called seismographs are generally sensitive and meant for recording weak motions of earth. For engineering measurements, the instruments generally operate when the ground motion exceeds a threshold value which is pre-adjusted, and are expected to record the strongest ground motion. Both types are complementary to each other and provide useful data in seismology and earthquake engineering.

3.3.A EPICENTRE, HYPOCENTRE AND EARTHQUAKE WAVES

The point inside the earth mass where slipping or fracture begins is termed as 'focus' or 'hypocentre' and the point vertically above the focus on the earth's surface is termed as 'epicentre', as shown in Fig. 1A. The position of the hypocentre is determined with the help of seismograph records obtained at many seismic stations around the world, which indicate the arrival times of different types of energy waves. 'Compression' waves, which are also termed as 'longitudinal' or 'primary' (P) waves, travel the fastest; the 'shear' or 'transverse' or secondary (S) waves, travel slower and the 'surface' or 'Rayleigh' (R) or 'Love' waves the slowest. Thus on a seismograph station they arrive at different times, see Fig. 2A. Using this time difference and the average velocities of different waves, the distance of the 'focus' from a point of observation is obtained. Such observations at several stations are used to locate the 'focus' and consequently the 'epicentre'.

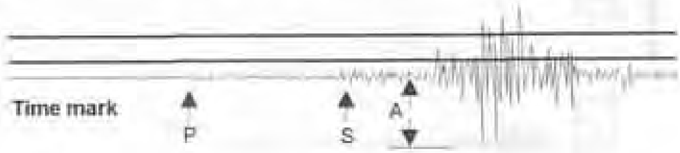


Fig. 2A A Typical earthquake record

3.4.A STRONG GROUND MOTION

The basic data needed for design of engineering structures is a record of ground acceleration versus time. Accelerographs are rugged and have the characteristics so as to withstand major shocks and for recording strong motion data. A typical strong motion acceleration has three accelerometers, two horizontal to record motion data in X and Y directions respectively and one vertical for data in the Z direction. A typical strong motion record is shown in Fig. 3A.

The instrument, unlike the seismograph, does not operate continuously. A trigger is used which operates the recoding in the accelerograph unit when the ground acceleration exceeds a particular predetermined threshold level. The instrument would continue to record, for a fixed time beyond the last pulse exceeding the threshold level.

3.5.A MAGNITUDE AND ENERGY OF AN EARTHQUAKE

As designated by Richter, the 'Magnitude' of an earthquake is standardized as "Logarithm (to the base 10) of the maximum amplitude of the ground motion as recorded in microns (1 micron = one thousandth of a millimeter) at a distance of 100 km from the epicenter on a Wood-Anderson Torsion Type seismograph with period of 0.8 second and magnification of 2800". Since the distance of the instrument from the epicenter will usually not be exactly 100 km, the following equation will determine the Magnitude 'M':

$$M = \log A - \log A_o \qquad (1.A)$$

where 'A' is the trace amplitude (refer to Fig. 2A) at any station and $\log A_o$ the distance correction for near as well as for distant earthquakes. A correction, for the type of instrument or reliability of observations depending upon local conditions, is further applied to get the true magnitude 'M'. Values obtained at various stations are then compared and a mean value of Magnitude is assigned to the earthquake.

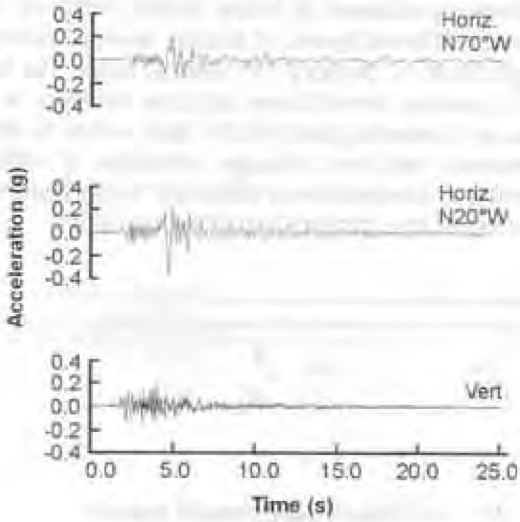


Fig. 3A Accelerograms of earthquake recorded at Gopeshwar during Chamoli (India) Earthquake in March 29, 1999 (Peak value = 0.35g)

***Note**: Magnitude computed from surface waves recorded at larger distances show values more than those worked out from records obtained in nearby observatories.*

Earthquakes may have a magnitude from less than 1 upwards to almost 9, but shocks smaller than 5.0 do not cause appreciable damage. The extent of damage also depends upon the depth of focus, shallower earthquakes causing higher damage in smaller areas. Very shallow shocks even of small size could cause damage locally. Usually earthquakes have their focus not shallower than about 5 km and could go deeper than 300 km.

An earthquake of magnitude 5.0 may cause damage within a radius of about 8 km but that of magnitude 7.0 may cause damage in a radius of 80 km and that of 8.0 over a distance of 250 km. Fortunately, damaging earthquakes (M>5.0) are not as frequent as the smaller ones, and the major ones (M>7.0) occur only rarely (see Table 1A). But whenever such a large earthquake does occur, the devastation caused is indeed very large. It may be clarified that the damage-area of an earthquake is not circular but rather elliptical in one direction with the epicenter eccentrically placed in it. Also the damage area may be extended along river courses due to local soil effects.

Table 1A : Approximate relationships between magnitude, intensity and felt area

Earthquake magnitude Richer M	Maximum expected intensity MSK	Radius of felt area Km
4.0 – 4.9	IV-V	50
5.0 - 5.9	VI-VII	110
6.6 – 6.9	VII-VIII	200
7.0 – 7.9	IX-X	400
8.0 – 8.9	XI-XII	800

Source : Don De Nevi, 1977

A relationship between strain energy 'E' released by an earthquake and its Magnitude is given by Richter as follows:

$$\text{Log}_{10}E = 11.4 + 1.5M \qquad (2.A)$$

Energy released in earthquakes of different magnitudes give an idea of their relative destructive power. In a damaging earthquake it will be of the order of 10^{20} to 10^{25} ergs. Due to the logarithmic scale, the destructive energy of an earthquake of M+1 is about 31.6 times that of magnitude M. Thus E of magnitude 8.0 earthquakes will be 1000 times that of M 6.0 earthquake.

3.6.A FORCE GENERATION MECHANICS

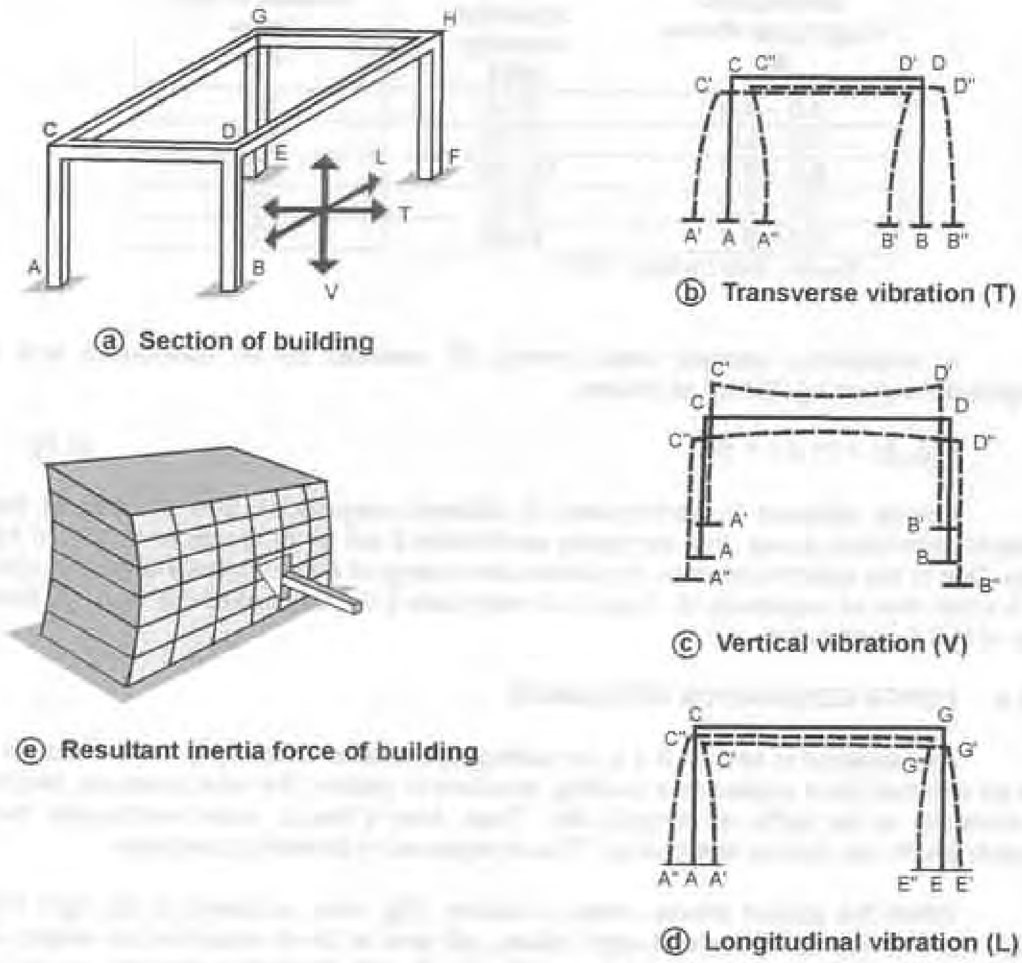
As explained in section 3.4.A, an earthquake causes vibratory ground motion. It is not an external force applied to a building, structure or system like wind pressure, weights of materials or the traffic on bridges, etc. Then, how is the so called earthquake force caused which can destroy every thing? This is explained in following paragraph.

When the ground moves under a building (Fig. 4Aa) suddenly to the right (Fig. 4Ab), the columns which were straight before, will tend to bend since the top weight will tend to remain behind and an inertia force will act to the left. Similarly, when the ground will move to the left, the inertia force will occur to the right. Since the ground vibrates randomly both ways, the top weight will also vibrate both ways from the mean position. Similar effects take place when the earthquake vibrations shake the building vertically up and down as shown at (c) or longitudinally as shown at (d) in Fig. 4A. Since the earthquake motion can be resolved in three perpendicular directions, the building usually vibrates and develops forces along all three axes. Hence the ground motion creates forces in the building (Fig. 4Ae) due to the fact that,

i) the building has weight (or mass)

ii) the mass is connected with the ground through columns (or walls) which resist the forces created by the relative movement of the top with respect to the base.

It can be shown through vibration mechanics that greater the mass and stiffer the resisting member, larger the force produced in the structure. Thus the *earthquake ground motion is converted by the structure itself into forces* that act on its various elements.



ⓐ Section of building

ⓑ Transverse vibration (T)

ⓒ Vertical vibration (V)

ⓓ Longitudinal vibration (L)

ⓔ Resultant inertia force of building

Fig. 4A Seismic vibration of a building and resulting earthquake forces

3.7.A NATURE OF SEISMIC STRESSES

The structural elements such as walls, beams and columns which normally bear only vertical loads, have to carry horizontal bending and shearing effects as well during an earthquake. When the bending tension due to earthquake exceeds the vertical compression, net tensile stress occurs. If the building material is weak in tension, such as brick or stone masonry, cracking occurs which reduces the effective area for resisting bending moment, as shown in Fig. 5A. It follows that the strength of *material in tension and shear is important for earthquake resistance.*

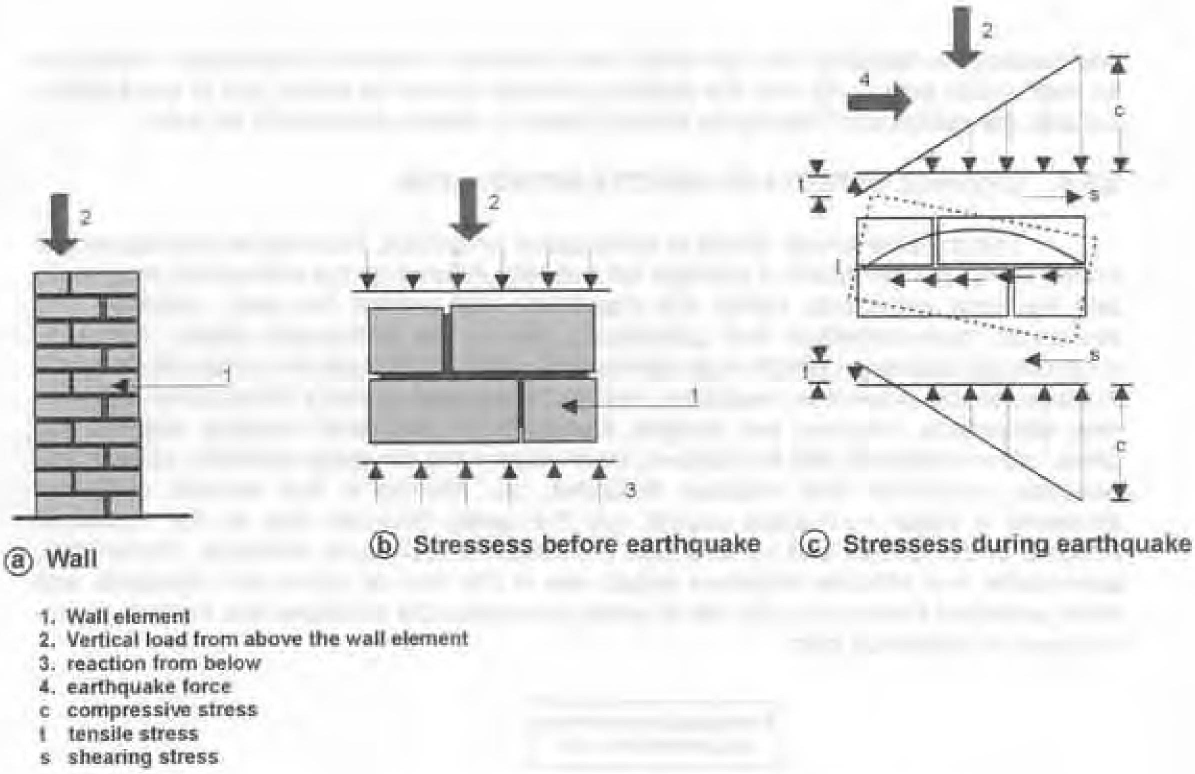


Fig. 5A Stress condition in a wall element

3.8.A CAUSES OF STRUCTURAL DAMAGE

Whether a building or structure will remain undamaged, get somewhat damaged, or collapse completely, will depend on the following three factors:

i) The intensity of earth shaking (indicated by the ground accelerations caused at the base of the structure)

ii) The dynamic parameters of the structure (namely, the masses of various elements, their stiffness, and deformation-energy dissipating capacity or damping)

iii) The strength of the foundation soils and the load resisting capacity of the individual building elements, their connections and the whole assembly for carrying the earthquake forces produced in conjunction with other concurrently applied dead and live loads.

Since the soils, the buildings and other structures, vary greatly in their characteristics as well as strength of materials and the design details, it is not surprising that they show quite different behaviour during a given earthquake occurrence. Apparently those of weaker materials such as earthen walls, stone masonry and brickwork built using clay, mud or weak lime mortars, and having heavy roofs, suffer much more severe damage including collapse, than those built using good cement or cement lime mortar and lighter roofs or those light weight wooden buildings which are provided with secure connections. Similarly, reinforced concrete or steel buildings of good design and detail usually escape without damage except in very high intensity earthquakes, but those of poor design quality and inadequate detailing may fail even under moderate intensity earthquakes. Therefore for earthquake safety, not only the building materials should be strong and of good quality but also the design and detailing as well as quality of construction should be good.

3.9.A OVERALL EFFECTS OF MAJOR EARTHQUAKES

The possible overall effects of earthquakes on ground, buildings and structures are shown in Fig. 6A the extent of damage will naturally depend on the earthquake magnitude and the local conditions, higher the magnitude and weaker the soils, buildings and structures, more extensive and catastrophic will be the earthquake effects. Hence to minimize the disastrous effects of an earthquake, which would have the probability to occur in future, ample preventive measures need to be adopted in every construction scheme: new settlements, buildings and bridges; transportation and canal systems: airports and dams; communications and fire stations; water supply and sewerage systems; schools and hospitals; community and religious structures; etc. Nothing in fact remains unshaken whenever a major earthquake occurs, and the safety depends only on the measures adopted in the design and construction from seismic resistance viewpoint. Fortunately, appreciable and effective knowhow exists now in the form of codes and standards and other published literature by the use of which non-collapsible structures are feasible at not-too-great an additional cost.

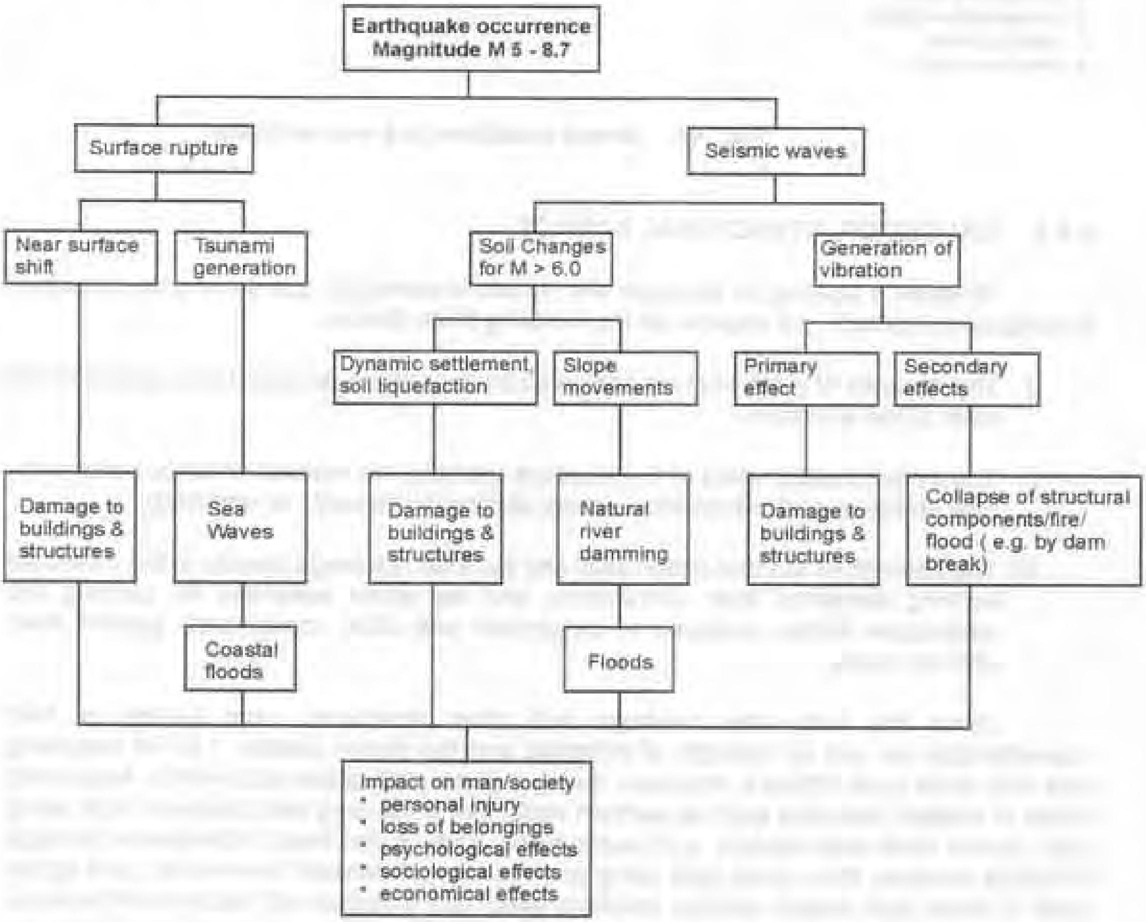


Fig. 6A Possible overall effects of earthquake hazards *(Source UNDRO)*

4.A FACTORS AFFECTING DAMAGE AND DAMAGE CATEGORIES

4.1.A EFFECT OF SITE CONDITIONS

Experience from past earthquakes has shown that site condition significantly affects the building damage. Earthquake studies have almost invariably shown that the intensity of ground motion is closely related to the type of soil layers supporting the building Structures built on solid rock and firm soil frequently fare better than buildings on soft ground. This was dramatically demonstrated in the 1985 Mexico City earthquake, where the damage on soft soils at an epicentral distance of 400 km, was substantially higher than at closer locations. In the 1976 Tangshan, China earthquakes, 50% of the buildings on thick soil sites were razed to the ground, while only 12% of the buildings on the rocky land near the mountain areas totally collapsed. Rigid masonry buildings resting on rock may on the contrary show more severe damage than those built on soil during a near earthquake as in Koyna (India) earthquake of 1967 and North Yemen earthquake of 1980. Buildings constructed in old river course in Philippines were destroyed in Bagio earthquake due to liquefaction.

Lessons learnt from recent earthquakes also show that the topography of a building site can also have an effect on damage. Buildings built on sites with open and even topography are usually less damaged in an earthquake than buildings on strip-shaped hill ridges, separated high hills and steep slopes.

4.2.A BUILDING CONFIGURATION

An important feature is regularity and symmetry in the overall shape of a building. A building shaped like a box, such as rectangular both in plan and elevation, is inherently stronger than one that is L-shaped or U-shaped, such as a building with wings. An irregularly shaped building will twist as it shakes, increasing the damage. Some configuration irregularities in buildings are shown in Fig. 7A. Such irregularities also increase the complexity in design and the cost of earthquake resistance.

4.3.A LARGE OPENINGS IN WALLS

In general, large window and door openings in walls of a building tend to weaken the walls. Therefore, fewer and smaller the openings lesser the damage suffered during an earthquake. If it is necessary to have large openings, special provisions should be made to ensure structural integrity

4.4.A UNEVEN RIGIDITY DISTRIBUTION

The rigidity distribution in a building along the vertical direction should be uniform, since the changes in the structural rigidity of a building from one floor to the next (see Fig. 7A) will increase the potential for damage, and should be avoided. Columns or shear walls should run preferably continuously from foundation to the roof. Buildings on stilts are worst example of irregularity in rigidity distribution.

4.5.A LACK OF DUCTILITY

By ductility is meant the ability of the building to undergo large deformations without serious damage or collapse. On the other hand brittle materials crack under load; e.g. walls made of adobe, brick and concrete blocks. It is not surprising that most of the damage during the past earthquakes was to unreinforced masonry structures constructed of brittle materials, poorly tied together. However, addition of steel reinforcements can add some ductility to brittle materials. Masonry and concrete, for example, can be made ductile by proper use of reinforcing steel.

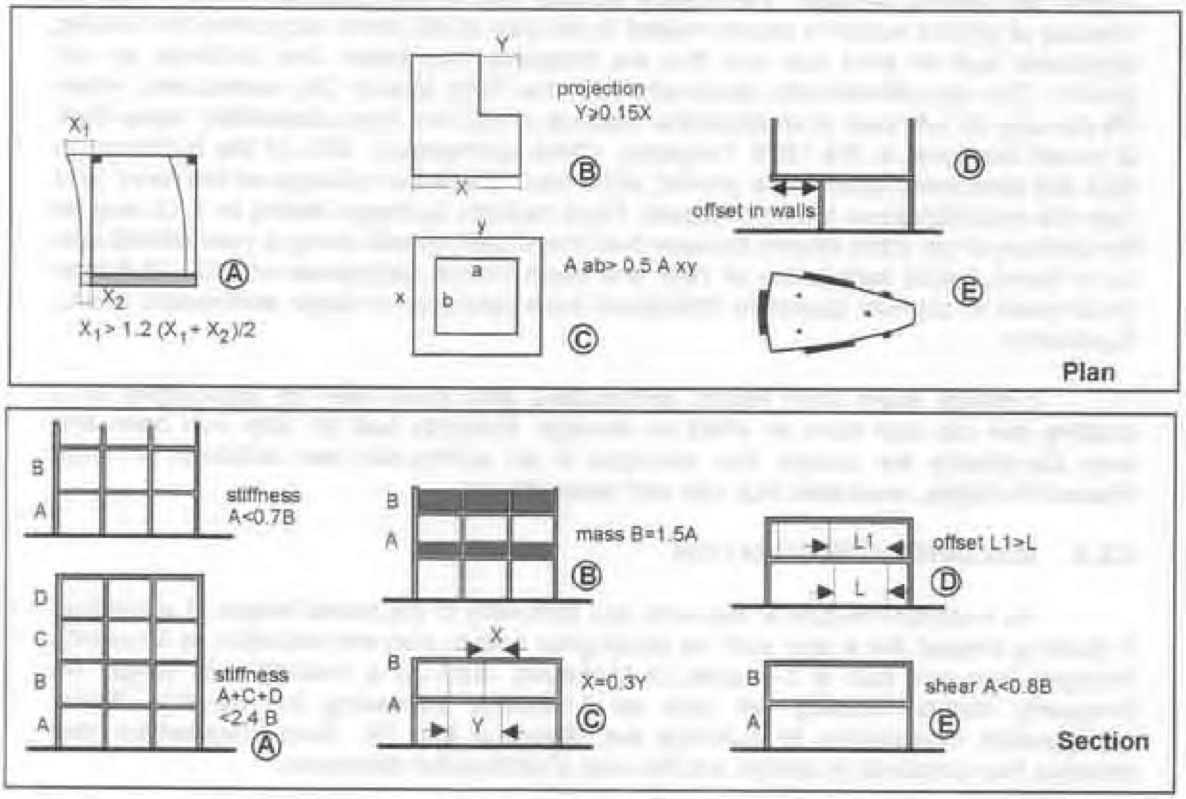


Fig. 7A Configuration irregularities
(Source: Uniform building code of USA, 1988)

4.6.A INADEQUATE FOUNDATION

Buildings which are structurally strong to withstand earthquakes sometimes fail due to inadequate foundation design. Tilting, cracking and failure of superstructure may result from soil liquefaction and differential settlement of footings.

Certain types of foundations are more susceptible to damage than others. For example, isolated footings of columns are likely to be subjected to differential settlement particularly where the supporting ground consists of different or soft types of soil. Mixed types of foundations within the same building may also lead to damage due to differential settlement.

Very shallow foundation deteriorate because of weathering, particularly when exposed to freezing and thawing in the regions of cold climate or wetting and drying of black cotton (expansive clay) soils.

4.7.A POOR QUALITY OF CONSTRUCTION AND MAINTENANCE

In many instances the failure of buildings in an earthquake has been attributed to poor quality of construction, use of substandard materials, poor workmanship, and careless maintenance. Example are : inadequate skill in bonding, absence the "through stone" or bonding units in field stone masonry, use of unsoaked dry bricks while laying in cement mortar, lack of curing of masonry and concrete, that is, improper and inadequate construction.

4.8.A GRADES OF EARTHQUAKE DAMAGE

As a consequence of the combination of various factors, damages occur in the buildings and structure of various grades from minor cracking to total collapse. An outline of damage is described in Table 2A on the basis of past earthquake experience. Therein the appropriate post-earthquake action for each Grade of damage is also suggested. This information is found most useful in post-earthquake surveys and in estimating the cost of rehabilitation of buildings.

4.9.A EARTHQUAKE BEHAVIOUIR OF SOILS AND FOUNDATIONS

A summary of damaging effect of earthquakes on foundations in various soil types designated as *Type I Hard*, *Type II Medium* and *Type III Soft* in seismic zones of intensities MSK 8 and 9 such as likely to occur in seismic zones AB of Afghanistan are summarized in Table 3A. The threes soils are defined as follows:

Type 1 Hard – Rock *or* well graded gravel and sand gravel mixtures with or without clay binder, and clayey sands or sand clay mixtures (GB, CW, SB, SW, and SC as defined in IS: 1498) having standard cone penetration N value above 30.

Type 2 Medium – All soils with N value between 10 and 30, and poorly graded sands or gravelly sands with little or no fines (SP) with N > 15.

Type 3 Soft – All soils other than SP with N < 10.

Table 2A : Grades of Seismic Damage

Damage Grade		Extent of Damage in General	Suggested post-Earthquake Actions
O	No damage	No damage	No action required
G1	Slight Non-structural Damage	Thin cracks in plaster, Falling of plaster bits in limited parts.	Building need not be vacated. Only architectural repairs needed.
G2	Slight Structural Damage	Small cracks in walls, falling of plaster in large bits over large areas; damage to non – structural parts like chimneys, projecting cornices, etc. The load carrying capacity of the structure is not reduced appreciably.	Building need not be vacated. Cracks in walls need grouting. Architectural repairs required to achieve durability. Seismic strengthening in desirable.
G3	Moderate Structural Damage	Large and deep cracks in walls; widespread I.c,. cracking of walls, columns, piers and tilting or falling of chimneys, the load carrying capacity of structure is partially reduced.	Building needs to be vacated, to be reoccupied after restoration and strengthening. Structural restoration and seismic strengthening are necessary after which architectural treatment may be carried out.
G4	Severe Structural Damage	Gaps occur in walls; inner or outer walls collapse; failure of ties to separate parts of buildings. Approximately 50 percent of the main structural elements fail. The building takes a dangerous state.	Building has to be vacated. Either the building has to be demolished or extensive restoration and strengthening work has to be carried out before reoccupation.
G5	Collapse	A large part or whole of the building collapses.	Clearing the site and reconstruction.

Source : International Association of Earthquake Engineering(IAEE) Guidelines 1986

Table 3A : Soils and Foundations, Earthquake Effects and Resisting Features (for MSK VIII and IX Zones)

Type of soil	Damaging Effect of Earthquake	Earthquake Resisting Features
Type I Hard	None	Use any foundation type
Type II Medium	Relative lateral movement possible	Use tie beams in case of individual column foundations.
Type III soft a) Low water table	Relative lateral movement possible	Use tie beams to connect individual column foundations or combined column footings or provide rafts or piles as needed for the loads.
b) Liquefiable with high water table	Liquefaction resulting in tilting/overturning of buildings and structures likely.	Driven piles preferable. OR Improve the soil to a depth of 7 to 8 m or upto stable layer if met earlier, by dynamic compaction or by compaction piles.

4.10.A EARTHQUAKE BEHAVIOUR OF BUILDING WALLS

The damaging effects of earthquakes observed in the past on various types of walls namely those having rectangular building units or random rubble or wood framing or earthen walls of clay and Adobe are summarized in Table 4A. The appropriate earthquake resisting features which will reduced the damaging effects are also included.

4.11.A EARTHQUAKE BEHAVIOUR OF ROOFS AND FLOORS

The damaging effects of earthquake on building floors and roofs observed in the past are summarized in Table 5A. The roofs and floors considered are jack arches resting on steel girders, and sloping roofs of various types varying from raftered to truss type. The appropriate earthquake resisting features are also included for ready guidance.

Table 4A : Building Walls, earthquake effects and earthquake resistant features

S. No	Type of wall	Damaging Effect of Earthquake	Earthquake Resisting Features
1	Walls having rectangular masonry units (with flat roofs)	a) Shattering of masonry in heap of materials	Use of good quality building units with cement sand or cement-lime-sand mortar and good quality of construction
		b) Cracking and separation of walls at corners and junctions of walls	Use of lintel band in all internal and external walls with continuity in the reinforcement.
		c) Diagonal cracking in piers between windows and doors	Control on size and location of openings and use of reinforcing bars at jambs.
		d) Horizontal cracks near base of storeys	Use of vertical reinforcing bars at corners and junctions of walls.
2	Walls having rectangular masonry units (with pitched roofs)	a) to d) above, e) cracking and falling of gable walls	As above Use of bands at eave level in all walls and on top of gable walls integrated with the eave bands.
3.	Random rubble masonry walls	a) to e) as above,	As above
		f) Delamination of inner and outer wythes of the wall, bulging and falling of wythes	Use of walls not thicker than 450 mm with provision of 'through' stones or bonding elements in the walls and at the corners & T-joints. (use of good cement mortar reduces chances of declamination).
4.	Wood stud wall	Deforms and collapses	'sill' should be held down to footings by bolts, diagonal braces must be provided in vertical plane of walls and in the horizontal plane at top of wall connecting to perpendicular wall.
5.	Wood frame with brick nogging	Brick nogging falls out of wall	Use hold-fasts to hold the nogging.
		Deformation of wood frame	Use diagonal braces in vertical and horizontal planes as for wood-stud wall construction.

6.	Clay / Adobe / Unburnt brick walls	Shattering of walls in heap of material	Use better quality clay to make adobe and clay mortar, also control on wall length and height
		Cracking and separation at corners	Use lintel band in all walls with continuity between perpendicular walls
		Wide cracking and instability of piers between openings	Control on size and location of openings.
		Overturning of walls	Use of pilasters in long walls and at corners and T-junctions of walls

Table 5A : Building Roofs and Floors, Earthquake Effects and Resisting Features

S. No	Type of Roof/Floor	Damaging Effect of Earthquake	Earthquake Resisting Features
1	Raftered Roof	Rafters get displaced and fall down, damage walls by pulling and pushing	Use full trusses or A-frame arrangement by connecting rafters in pairs through ties.
2	Trussed Roof	Anchors get broken, gables pushed out and damaged, trusses shift and fall down	Provide X-bracings in planes of rafters in about every 4^{th} bay, and in horizontal plane of main ties in similar bays.
		Failures of truss joints in wooden trusses	Provide adequate iron straps on wood truss joints
		Long walls get toppled since there is no lateral support at top.	Provide eave level trussed bracing in long rooms in addition to eave level band to provide diaphragm action.
3.	Sloping roof using RC prefab elements	The prefab elements get disturbed, separated and may fall down.	Connect the elements together and hold them to peripheral R.C. bands
4.	Beams/Joists supporting stone pattis, or prefab PC or RC elements	The prefab elements and the beams/joists are disturbed, the elements may fall down, beams fall down if bearing length is small	Keep the bearing length of beams at least 200 mm, integrate the roofing elements by RC screed, the whole roof/floor be bounded by RC band.
5.	Jack arches resting on Steel girders	The arches get cracked longitudinally, tend to shift the girders horizontally and may fall down.	Weld lateral ties with all steel girders and embed into RC band provided all round
		Girders may fall down by slipping longitudinally	Weld diagonal braces to steel girders to convert the roof/floor into a horizontal grillage. Encase ends of steel girders into all-round RC band.
6.	Tiled roofs	Tiles get disturbed, broken and fall down	Use tiles with lug having holes and tie them to purlins by binding wire.

5.A INTENSITY SCALES, ISOSEISMALS, AND SEISMIC ZONING

5.1.A INTENSITY SCALES

The intensity of an earthquake as felt or observed through damage is described as 'Intensity' at a certain place on an arbitrary scale. A 10 point scale was first devised by Rossi-Forel (1885) and changed to 12 point later by Mercalli (1904). It was modified in 1931 by Neuman and came to be known as Modified Mercalli Scale. The Intensity Scale was further detailed out in 1964 which is now called MSK as given in Appendix D of IS:1893. The MSK scale, is now in use generally, and is presented in Annex I to this Chapter where the damaging intensities V to IX only are listed for ready reference. From the description it will be seen that the Intensity Scale presents a qualitative description of the effect of shaking experienced at a place. Naturally the Intensity decreases with increasing distance from the epicenter. The bigger the earthquake, higher will be the maximum Intensity caused and larger will be the area covered by each Intensity.

The maximum intensity of shaking attained during an earthquake of given magnitude depends upon the depth of focus as well as soil condition. For shallow focus earthquakes, of depth about 30 km or less, an approximate relationship may be expressed between magnitude and Maximum Intensity in the epicentral area. Representative values were given in Table 1A.

5.2.A ISOSEISMALS OF AN EARTHQUAKE

Observation of Intensities are made after the occurrence of a damaging earthquake through an on-the-spot study of effects and damages according to the Intensity Scale. There are five grades of damage under which the building damage is classified as shown in Table 2A. The Intensity to be assigned to an area will depend on the maximum damage sustained by a building type and percentage of such damaged buildings to the total of this building type in the area.

A map of the affected area is then prepared on which the Intensities assigned to various places are marked. Areas having the same Intensity are then enclosed by contour lines separating the areas of different Intensities. Such a map is called an 'Isoseismal Map'.

Fig. 8A shows the Isoseismal map of the Uttarkashi (India) Earthquake of Oct. 20, 1991, where the maximum Intensity reached was MSK VIII.

5.3.A SEISMIC ZONING

The earthquake activity in different parts of Afghanistan is not of the same severity. Hence, the country has been classified into four zones, namely, AB, C, D and E (Fig. 9A) so that the forces for which structures are to be designed at any site are varied according to the severity of probable earthquake Intensities. The maximum Intensities considered for the various zones are as follow (see Annex 1 for descriptions of MSK Intensities):

MSK VIII or more in Zone AB
MSK VII in Zone C
MSK VI in Zone D
MSK V or less in Zone E

This zoning had been worked out primarily depending on the known seismic history of the regions, the seismo tectonics of the area, seismogenic potential of the faults, and the indicative time intervals between two consecutive occurrences in the same area.

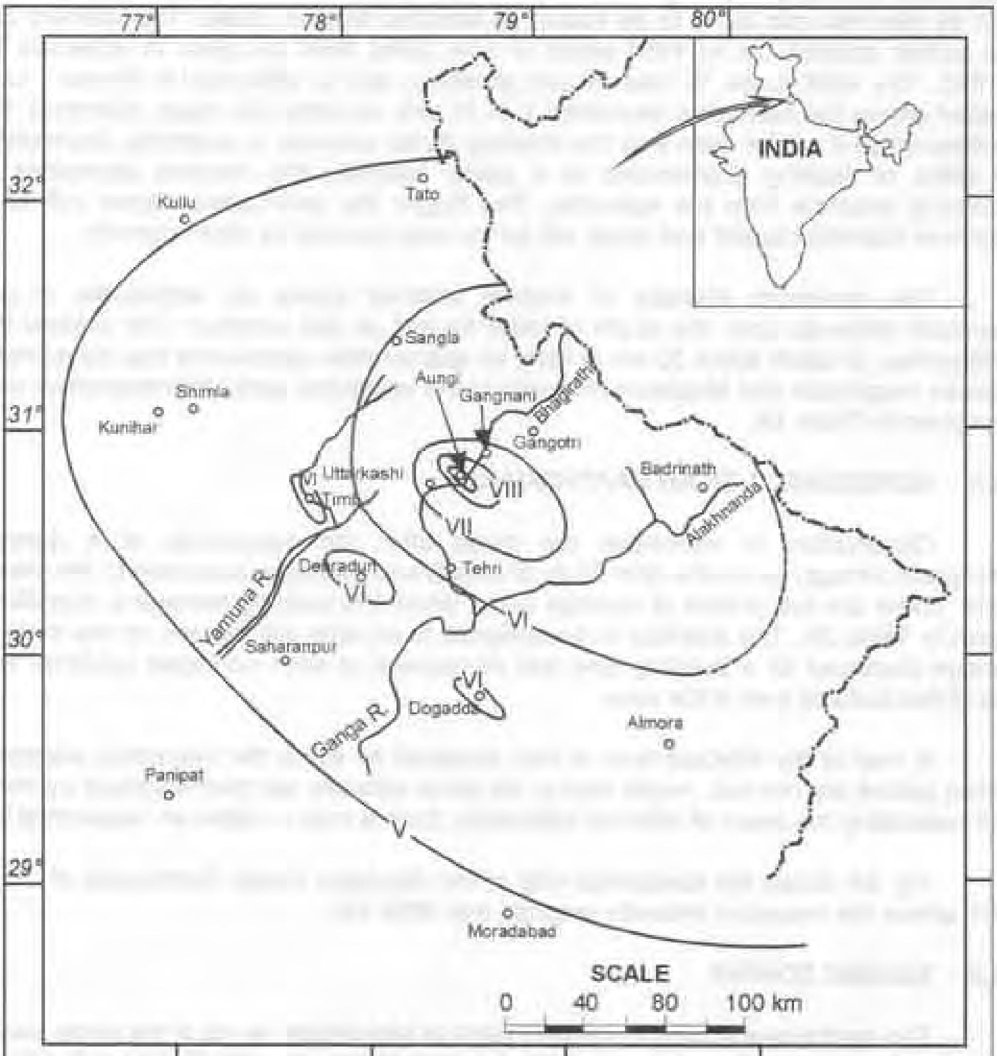


Fig. 8A Isoseismic of Uttarkashi Oct. 20, 1991 earthquake

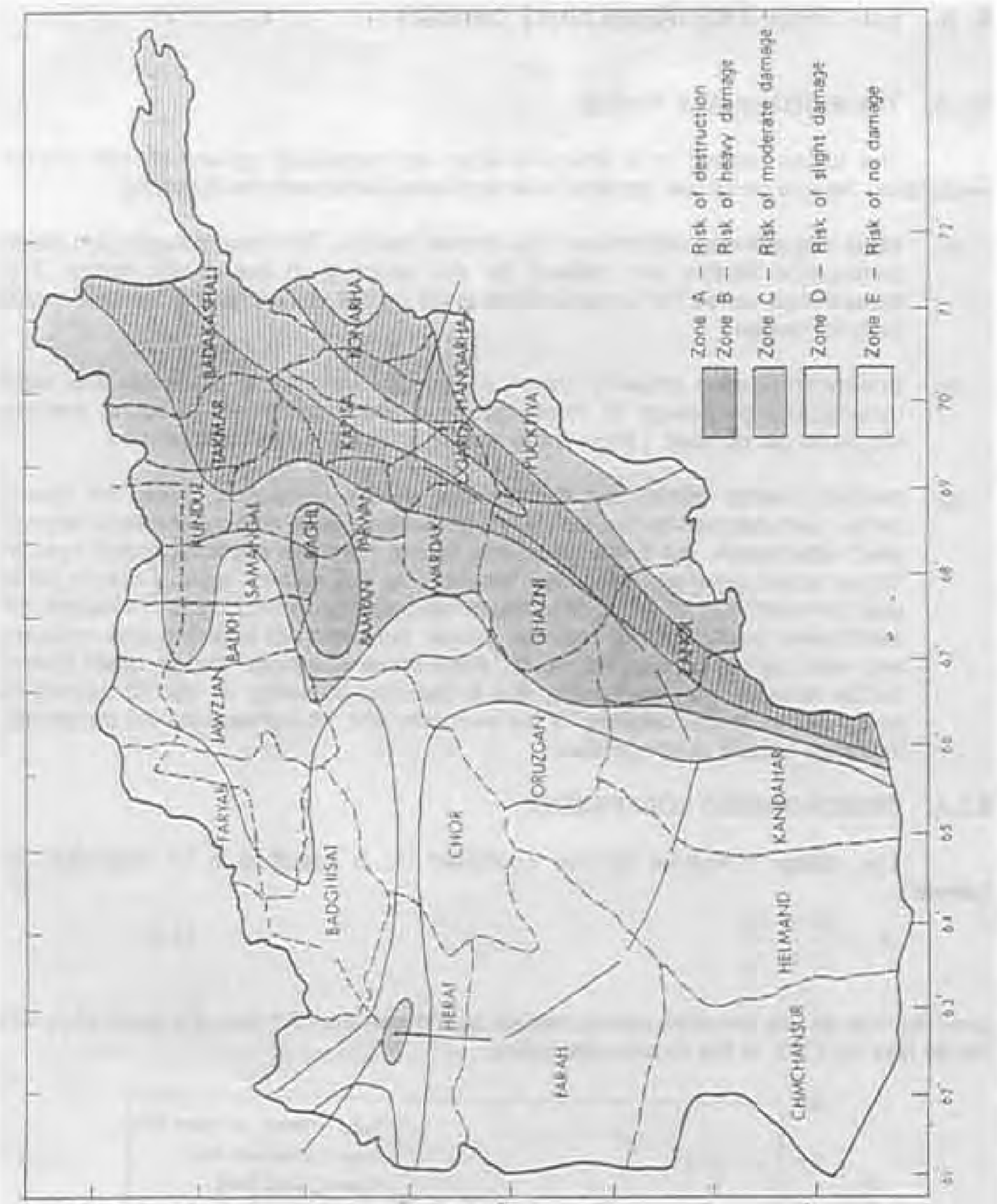


Fig. 9A Seismic Zones of Afghanistan
(Source: A.S. Arya, UNESCO Bangkok Report, 1973)

6. A EARTHQUAKE RESISTANT DESIGN

6.1.A THE EARTHQUAKE FORCE

The forces caused in a structure when an earthquake ground motion passes underneath depend on its own dynamic characteristics, particularly the following

(a) *Mass and stiffness distribution:* The natural periods. The mode shapes and mode participation factors are derived for the structure in the elastic range. The fundamental period T of natural vibrations is crucial in determining the earthquake force for design.

(b) *Energy dissipation property:* When a structure vibrates, it dissipates the input dynamic energy through its elements, the supports and the foundations, and the vibrations get damped. Larger is the damping, less is the force developed.

(c) *Inelastic energy dissipation:* Besides the energy dissipation during the elastic range, well designed ductile structure can dissipate large amount of energy beyond yield deformation. But brittle structures do not have this capacity except through friction which develops after their cracking. In this respect steel is ductile while plain concrete and all types of unreinforced masonry remain brittle. Therefore, for earthquake safety against collapse, proper reinforcing of concrete and masonry with steel bars is considered crucial. Steel frame structures, though made from a ductile material, may also suffer due to buckling instability, or due to fracture at joints. Hence proper detailing of the elements and the connections will be equally important in steel buildings also.

6.2.A DESIGN SEISMIC COEFFICIENT

The design horizontal seismic coefficient A_h is specified in IS:1893-2002 as follows:

$$A_h = \frac{Z}{2} \cdot \frac{I}{R} \cdot \frac{Sa}{g} \qquad (3.A)$$

provided that for any structure having natural period less than 0.1 sec, the value of A_h will not be less than Z/2. In the above relationship,

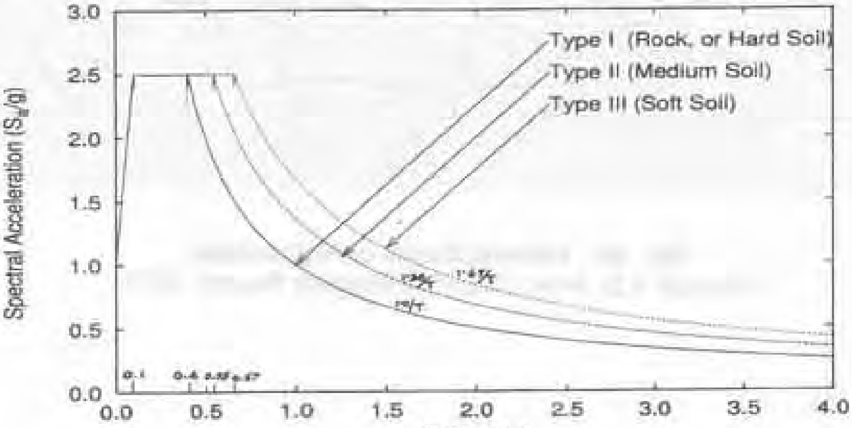


Fig. 10A Design Earthquake Average Acceleration Spectra

Z = Zone factor for the *maximum considered earthquake* for the zone and the factor 2 in denominator is used to reduce the value corresponding to *design basis earthquake*.

Z = 0.36 in Intensity IX zone, 0.24 in Int. VIII and 0.16 in Int. VII zone.

I = Importance factor depending on functional use of structure, hazardous consequences of its failure, historic and economic importance,

I = 1.0 for ordinary buildings for housing

= 1.5 for important buildings, e.g. schools, hospitals and other community buildings; buildings for large gatherings, water supply, fire fighting, telephone exchanges, etc.

R = Response reduction factor based on ductile or brittle character of the structure, provided that I/R should not be greater than 1.

R = 1.5 for unreinforced masonry
2.5 for masonry walls with horizontal seismic bands, and
3.0 for masonry walls having horizontal and vertical reinforcements

Sa/g = Average acceleration coefficient read from Fig. 10A (same as IS: 1893-Fig.2) based on soil type, the time period of the building and 5 percent of critical damping.

For masonry buildings, of upto 3 storeys, the value of T will be less than 0.5 sec, hence Sa/g will be 2.5. Since all buildings in Zone AB have to be reinforced horizontally and vertically, R = 3.0, and in Zone C only horizontal reinforcing will be necessary, R = 2.5 will be taken. Thus the design seismic coefficient will take the values shown in Table 6A.

Table 6A : Design Seismic Coefficients

	Zone C	Zone AB	
	Int. VII	VIII	IX
Housing	0.08	0.10	0.15
Community Buildings	0.12	0.15	0.225

6.3.A VERTICAL SEISMIC ACCELERATION

Usually the horizontal seismic forces as determined earlier are sufficient for designing buildings. In some cases, however, vertical seismic forces also become important and should be considered in design, either alone or in combination with the horizontal seismic forces. For this purpose the vertical design coefficient acting upward or downward is given by (IS: 1893) as:

$$A_v = 2\,A_h/3 \quad (4.A)$$

Consideration of A_v in design is particularly important where stability against overturning is concerned, and in the design of horizontal cantilevers and their anchorages. For protection of lives and property from the fall of horizontal projections like balconies, chajjas, large cornices, etc., larger seismic co-efficient than for the main structure are specified in IS: 1893, that is, the vertical force for their design should be based on five times the value of A_v.

6.4.A LATERAL LOAD ANALYSIS

Analysis of building frames for the lateral earthquake loads could be carried out by a number of methods, e.g. (a) some approximate methods based on statical equilibrium making the frame statically determinate by a number of assumptions, such as pier analysis for masonry buildings (b) some more accurate methods using plane frame approximation but considering stiffnesses of the beams and columns, and (c) computer analysis using 2D or 3D idealizations. While the methods (a) and (b) are suitable for quick approximate preliminary design, the methods (c) are the most accurate and should be used for final design and checking. In addition, it is important to realize the importance of the points given in the following paras.

6.5.A OTHER CONSIDERATIONS IN DESIGN

6.5.1.A Torsion

Building are subjected to torsion, when the center of gravity of masses above any storey and the center of stiffnesses of the elements of the storey donot coincide and there is , thus, an eccentricity between the actuating and the resisting forces (see Fig. 11A). This happens even in symmetrical frames due to 'accidental' eccentricity, though to a lesser extent. Hence torsional shear and resulting moments in the elements must be analysed, particularly in view of the fact the post-earthquake damage studies have found torsion to be one of the predominant factors contributing to structural damage and collapse.

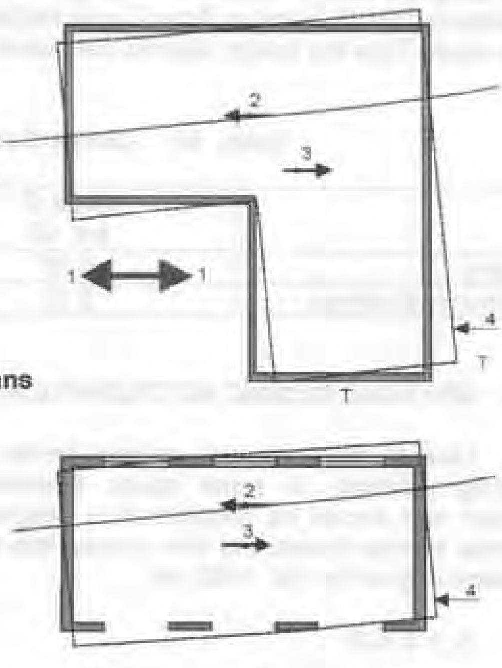


Fig. 11A Torsion of unsymmetrical plans

1. Earthquake force
2. Centre of stiffness or resisting force
3. Centre of gravity or the applied inertia forces
4. Twisted building

6.5.2.A Appendages

Frequently buildings have parapets, water tanks, smoke chimneys and small barsatis projecting above the building roof. Due to 'whipping' effect of the earthquake motion, these are subjected to much larger seismic acceleration. Hence these and their supports and connections with the structural frame should be designed for $5A_h$ where A_h is used for the building as a whole (IS: 1893).

6.5.3.A Secondary Elements

Attention should be paid to the design and detailing of secondary elements of the building, such as the staircases *mumties*, the infill wall panels, the internal permanent partitions and the expansion joints (see the provisions in IS:1893-2002, IS:4326 - 1993, IS:456-2000).

6.6.A ARCHITECTURAL DESIGN FEATURES

There are certain features which if taken into consideration at the stage of architectural planning and design of building, improve their performance during earthquakes appreciably. Some of these are stated below.

6.6.1.A Lightness

Since the earthquake force is a function of mass, the building should be as light as possible consistent with structural safety and functional requirements. Roofs and upper storeys of buildings, in particular, should be designed as light as possible.

6.6.2.A Projecting and Suspended Parts

(i) Projecting parts like large cornices, facia stones, parapets, etc., should be avoided as far as possible, otherwise they should be properly reinforced and firmly tied to the main structure, and their design shall be in accordance with IS: 2002.

(ii) Ceiling plaster should preferably be avoided, otherwise it should be as thin as possible and applied with care to ensure good adhesion.

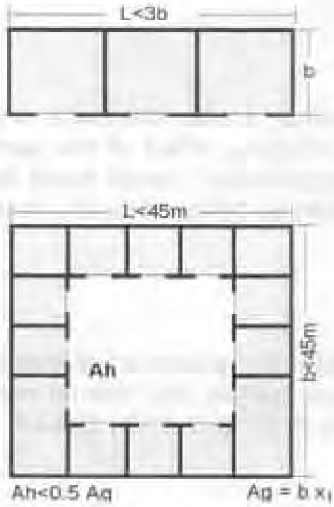
(iii) Suspended ceiling should preferably be avoided. Where necessary, it should be light, adequately framed and securely connected.

6.6.3.A Building Configuration

(a) Plan

The building should have a simple rectangular plan and be symmetrical both with respect to mass and rigidity, or centres or mass and rigidity of the building should be made to coincide with each other, so as to avoid torsional effects as was shown in Fig. 11A

If symmetry of the structure is not possible in plan, elevation or mass distribution, provision must be made for torsional and other effects due to earthquake forces in the structural design. Also, structurally, a cellular plan with floor space divided into separate rooms will be more resistant to seismic forces than on large room with mobile partitions (Fig. 12A).



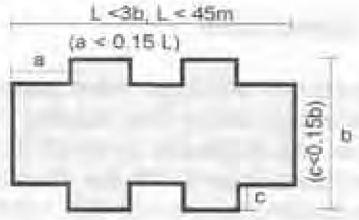


Fig. 12A Building Plan Guidelines

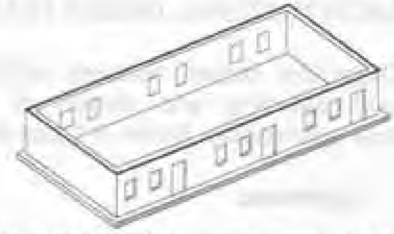
(b) Long Buildings

As shown in Fig. 13A, the total length of a building should be less than 3 times its width. Long rooms without lateral walls are structural weaker since the long unsupported walls tend to overturn under earthquakes (Fig. 13Aa). Therefore the long walls should be supported by RC columns or buttresses (See Fig. 13A).

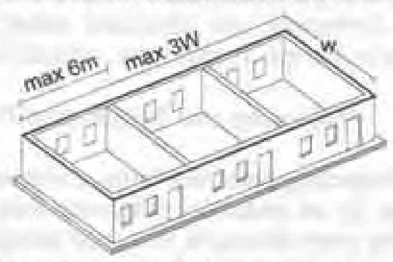
(c) Separation of Wings

Large buildings as for schools and hospitals having plans with shapes like, L, C, T, E and Y should preferably be separated into rectangular blocks by providing
separation sections at appropriate places. Separation section is a gap of specified width between adjacent buildings or parts of the same building, either left uncovered or covered suitably to permit movement in order to avoided hammering due to earthquake. Crumple section is a separation section filed or covered with appropriate material, which can crumple or fracture in an earthquake.

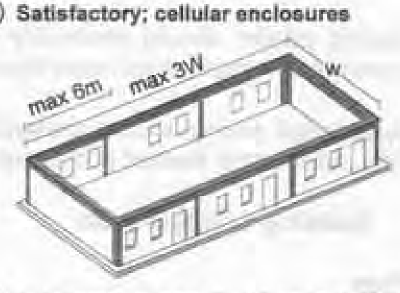
Note: Single houses normally have small projections causing unsymmetry. These should preferably be limited as shown in Fig. 12A.



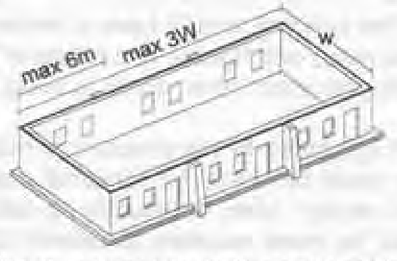
ⓐ **Unsatisfactory; long unsupported walls**



ⓑ **Satisfactory; cellular enclosures**



ⓒ **Satisfactory; long walls supported by R.C. columns**

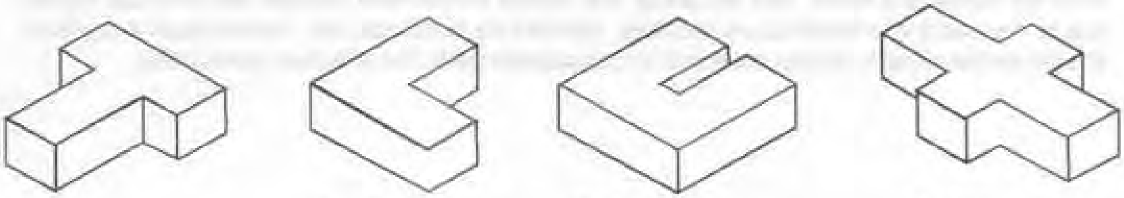


ⓓ **Satisfactory; long walls supported by buttresses**

Fig. 13A Lateral supports to long walls

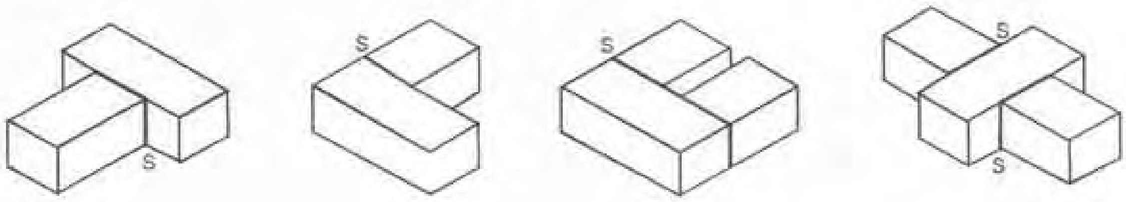
Where separation is necessary, a complete separation of the parts should be made except below the plinth level. The plinth beams, foundation beams and footings may be continuous. Where separation sections are provided in a long buildings, they should take care of movement owing to temperature changes also. For details, refer IS: 4326.

In case of framed construction, members should be duplicated on either side of the separation or crumple section. As an expensive and not so good alternative, in certain cases, such duplication may not be provided, but the portions on either side designed to act as cantilevers.



T - plan L - plan U - plan X - plan

@ unsymmetric plans



@ use of seperation sections (S)

Fig. 14A Architectural Planning of Large Buildings

6.7.A SITING OF SETTLEMENTS AND BUILDING SAFETY

Building safety starts by choosing a safe site. Such a choice is usually not available to many people due to limitations of site as possessed by them. Unsafe sites should be improved for achieving safety of the building.

Steep sites may have problems of landslides and rock falls and should either be avoided or effectively improved if adopted.

A steep sloping site may be improved by terracing and constructing breast wall and retaining walls.

Plain sites with loose fine sands with high water table are liable to liquefaction and subsidence under earthquake intensities VII and higher. These sites should be avoided unless improved, for building construction. Such areas should better be reserved for parks, play ground, etc.

A site liable to liquefaction or subsidence may be improved by compaction, stabilization, or sand piling, etc. (see IS: 1893 – Table 1 Note 3)*

It may be mentioned that the improvement method, usually involve large expense which should be carefully considered before hand.

Relocation of Site after Disaster

After a severe disaster which affects most parts of a village or township, question sometimes anses as to where and how to relocate the settlement. It is a very difficult decision since, firstly, uprooting the agricultural population may increase their distance from the farms and fields, and secondly, the capital investment needed will be much higher due to the costs of infrastructure facilities, community buildings, etc. Hence such a decision should be taken with utmost care and in consultation with the affected community.

---

* The desirable values of N (corrected values) at the founding level are given below:

Seismic Zone	Depth below ground level (in metres)	N Values	Remark
AB and C	≤ 5 ≥10	15 25	For values of depths between 5 metres and 10 metres, linear interpolation is recommended

Note 3: If N – if soils of smaller N –values are met, compacting may be adopted to achieve these values or deep pile foundations going to stronger strata should be used.

Note 5: The piles should be designed for lateral loads neglecting lateral resistance of soil layers liable to liquefy.

Note 7: Isolated R.C.C. footings without tie beams, or unreinforced strip foundation shall not be permitted in soft soils with N < 10.

7.A SEISMIC SAFETY OF REINFORCED CONCRETE FRAMES

7.1.A STATEMENT OF THE PROBLEM

Reinforced concrete construction has now become so common that not only R.C. slab and beam floors and roofs are constructed by experienced masons without proper analysis and calculations, but also frame-type R.C. post-beam construction going to few storeys are being attempted in the same way (Fig. 15A). The result is that the slabs, beams and columns may either have under-strength or over strength as compared with the design required as per the Indian Standards IS:456-2000. Hence they could be unsafe, under-safe or oversafe even under the specified normal dead and live loads. But tragically, the frame-looking constructions always suffer from lack of strength in the beam-column joints and insufficient lateral strength in the columns and the beams sections near the supporting columns. The concept of lateral loading caused on the building by wind or earthquake is completely missing in such non-engineered or semi-engineered RC frame looking buildings. Since the subject is too vast to be included in these guide-lines, only some important points are highlighted to invite the attention of the concerned authorities approving the building plans.

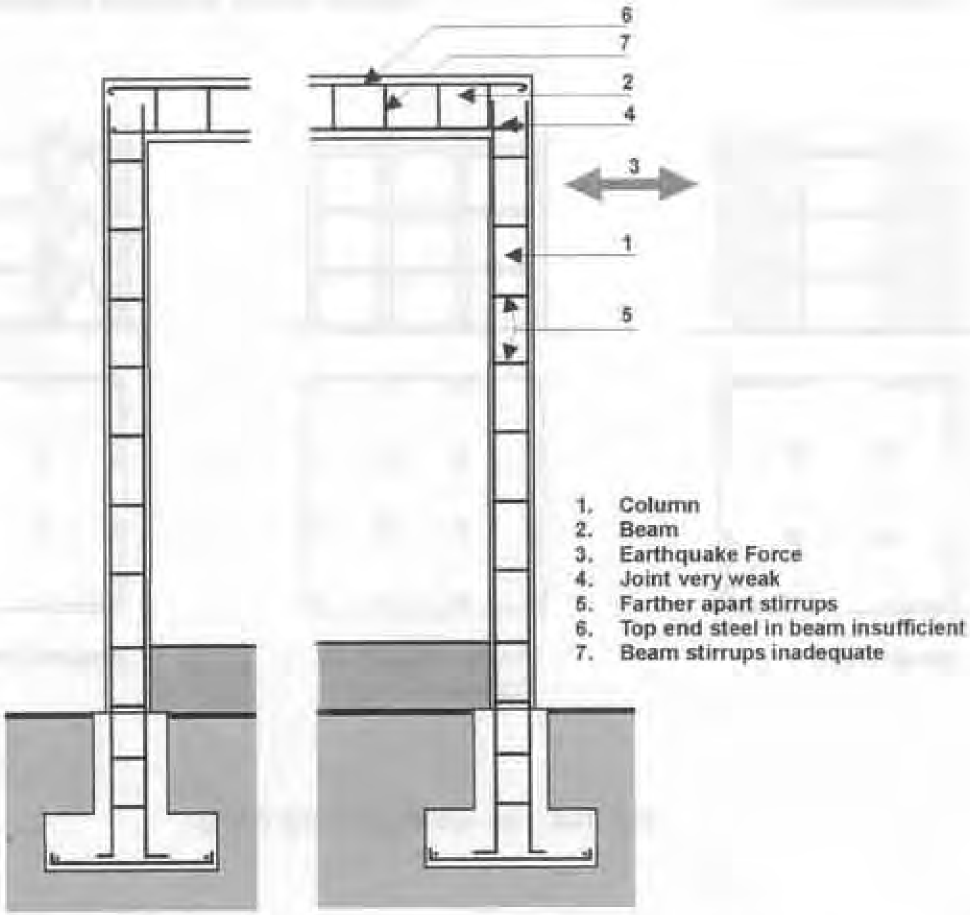


Fig. 15A Commonly constructed post-beam form

7.2.A OPTIMAL SEISMIC DESIGNS

It should be well understood that the predominant horizontal component of the earthquake force may act along any horizontal axis of a building. Hence the reinforced concrete building must possess adequate strength in both axes in the horizontal direction. A few optimal seismic designs are shown in Fig. 16A. Some special features and their beneficial effects are as follows:

Features	Beneficial Effects
Low height to base ratio	Minimize tendency to overturn
Equal floor height	Equalises storey stiffness
Symmetrical plan	Reduces torsion
Identical resistance in both axes	Balanced resistance in all direction
Seismic resisting elements at periphery	Maximum torsional resistance
Redundancy (Rigid connections)	Tolerance of failure of some members
Ductile detailing	Reserve energy to prevent collapse.

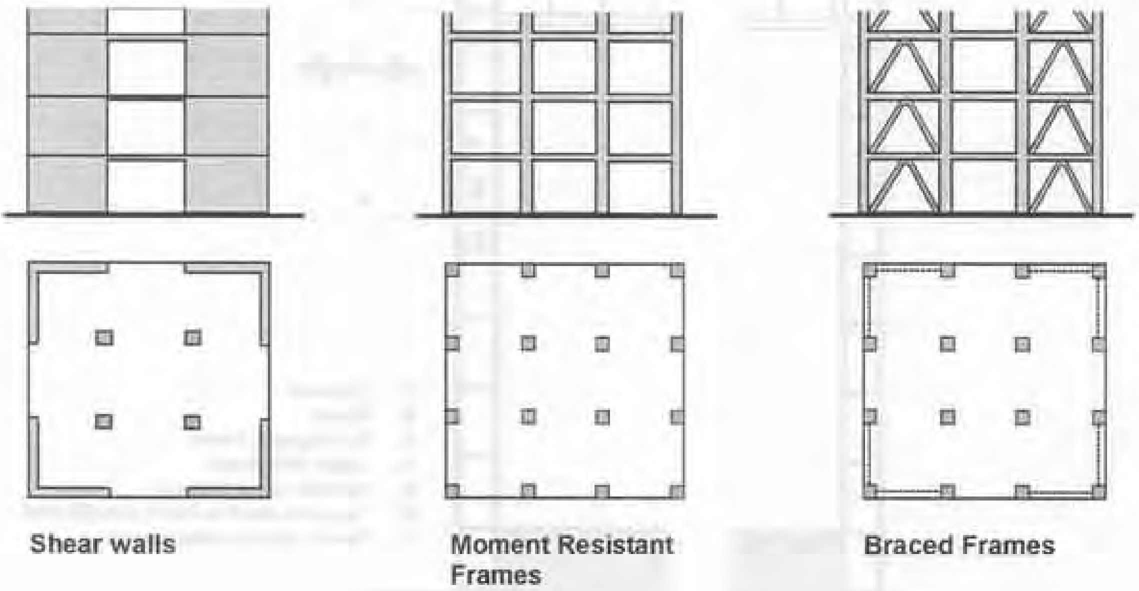


Fig. 16A The optimal seismic design

7.3.A NEED FOR DUCTILITY IN STRUCTURAL FRAMES

The currently adopted performance criteria in the earthquake codes can be stated as the following:

i. The structure should resist moderate intensity of earthquake shaking without structural damage. Such an intensity which could occur a number of times in the life span of the structure, is catered for by the code-based design seismic coefficients, A_h.

ii. The structure should be able to resist exceptionally large intensity of earthquake shaking without collapse. Such an intensity, which could occur not more than once in the life of the structure, is not catered for by the codal design seismic coefficients A_h but taken care of by incorporating details for ductile deformations.

Providing earthquake resisting capability costs money, which increases geometrically as the design intensity increases if ***no-damage*** design is adopted as the criterion. Such an approach though feasible is exhorbitantly expensive for residential or community buildings. The Code has therefore adopted lower than maximum probable acceleration coefficients A_h for the seismic zones to take care of the frequent low intensity earthquakes, and insisted on appropriate reinforcing details for achieving adequate ductile deformations beyond yielding (or first crack occurrence in structural members) to take care of large intensity of once-in-life earthquake intensity occurrence. Thus the criterion adopted is ***no-collapse*** design.

7.4.A DETAILING OF R.C. FRAMES

The critical zones in reinforced concrete frames where ductility of sections and confinement of concrete by closely spaced stirrups or spiral is required are shown in Fig. 17A and explained below:

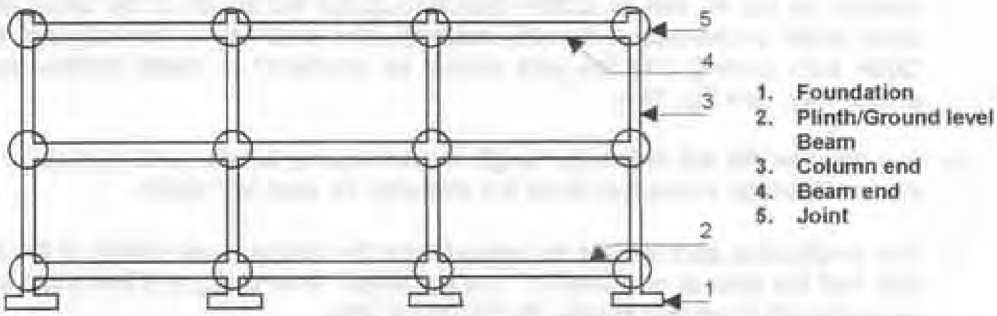


Fig. 17A Critical sections of frames

i. Ends of beams upto a length of about twice the depth of the beam where large negative moments and shears develop are likely locations for plastics hinges. Here shear and moment reversal is also possible under large seismic forces.

ii. Ends of columns where maximum moments develop due to lateral forces. Values of maximum column moments closely approaching plastic moment capacity can be expected and these moments are likely to undergo full reversal. High lateral shears of reversible nature can be developed based on moments of opposite sign at the column ends. The length of such zones is about one-sixth of the clear height of the column between floors.

iii. Joint regions between beams and columns undergo very high reversible local shears. Diagonal cracking and local deformation may occur causing significant local rotation at joint.

7.4.1.A Concrete and steel grades

For buildings, the concrete of grade M20 (1:1.5:3) and steel reinforcement of grade Fe 415 should be used. Use of TMT steel of grade equal to or more than Fe500 is also permitted.

7.5.A DETAILING OF BEAMS

i. Web width b_w should be 200mm or more, and overall depth not more than 0.25 of clear span.

ii. The tension steel area ratio should not be less than p_{min} and not more than 0.025, where

$$p_{min} = 0.24\frac{\sqrt{f_{ck}}}{f_y} \tag{5.A}$$

For concrete of M20 and steel Fe 415, the steel ratio p_{min} will be .00259.

iii. The beams should have at least two bars satisfying the minimum reinforcement criterion on top as well as bottom face throughout the length of the beam with full bond length anchorage in the end columns, and continuity in the adjacent spans. Other bars coming into the joint should be anchored or made continuous in a similar way. See Fig. 18A.

iv. Full bond length will mean the length for developing tensile yield L_d *plus* 10 times the bar diameter *minus* two times the diameter for each 90° bend.

v. The longitudinal bars should be spliced near the quarter-span points of the beam, only half the bars at one section. The lap length shall be L_d and the splice should be contained in stirrups spaced @ 150mm or less.

vi. The transverse stirrups should be designed to ensure the shear capacity of the beam to exceed the flexural load capacity (See IS: 13920 clause 6.3)

vii. The spacing of stirrups (Fig. 18A) shall not exceed d/4 or $8D_b$ but not less than 75mm, in the end 2d length of the beam; elsewhere the spacing not to exceed d/2. D_b is the diameter of main bars in the beam and d the effective depth of the beam.

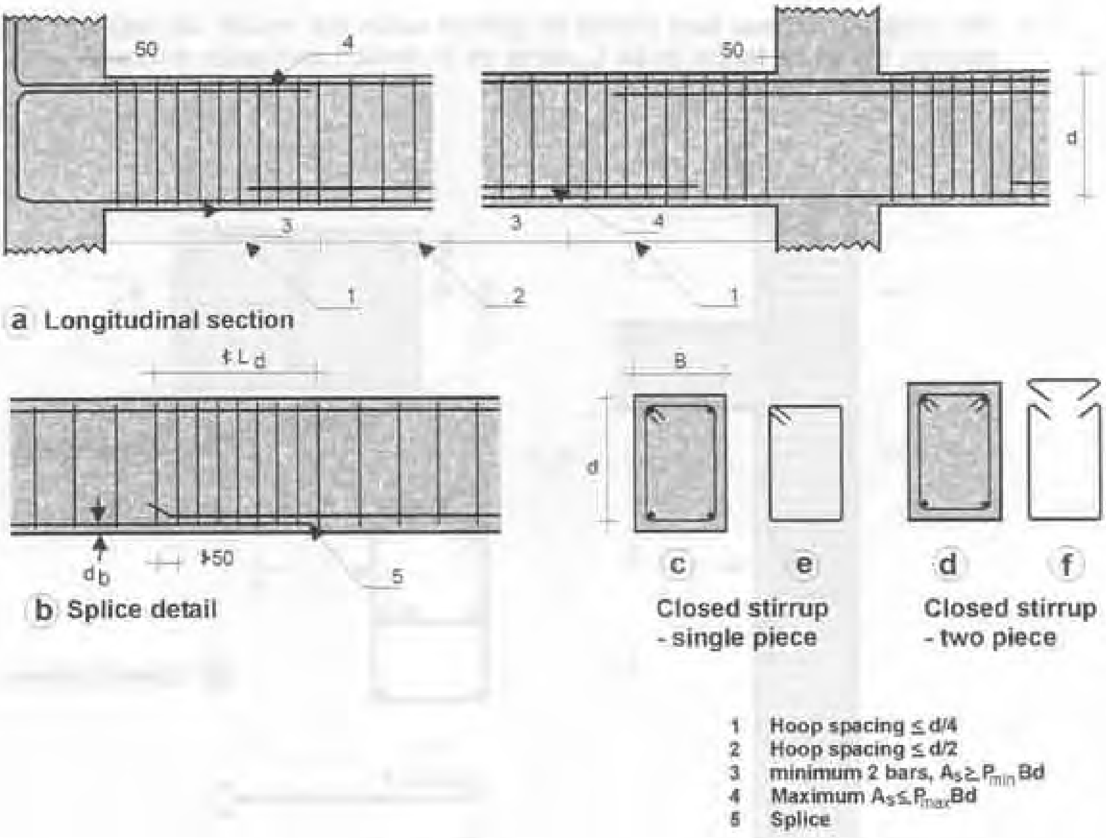


Fig. 18A Beam reinforcement

7.6.A DETAILING OF COLUMNS

i. Columns shall have a minimum side of 300 mm for frames of three or more number of storeys and designed as per IS: 456-2000 using Design Aids SP: 16-1980 for direct and bending stresses combined.

ii. Transverse ties shall be in the form of closed hoops (see Fig. 19A).

iii. Special confining hoop reinforcement shall be computed (IS:13920 clause 7.4.7) and provided near ends in a length equal to 450mm, or one-sixth of clear height of column, or the longer side of the rectangular column, (or the diameter of circular column), whichever greater. The spacing of these hoops will not exceed 0.25 of the minimum width of the column but not less than 75 mm and not more than 100mm.

iv. The transverse steel requirement shall also be worked out for the shear caused by lateral loads and that which could possibly be caused in the column by the moment capacities at its ends (IS: 13920 Clause 7.3.4) whichever larger.

v. The longitudinal steel bars should be spliced within the middle 2/3 height of the column, the splice length to be L_d same as in tension and splice enclosed within closed hoops of 6mm 100 to 150 mm apart.

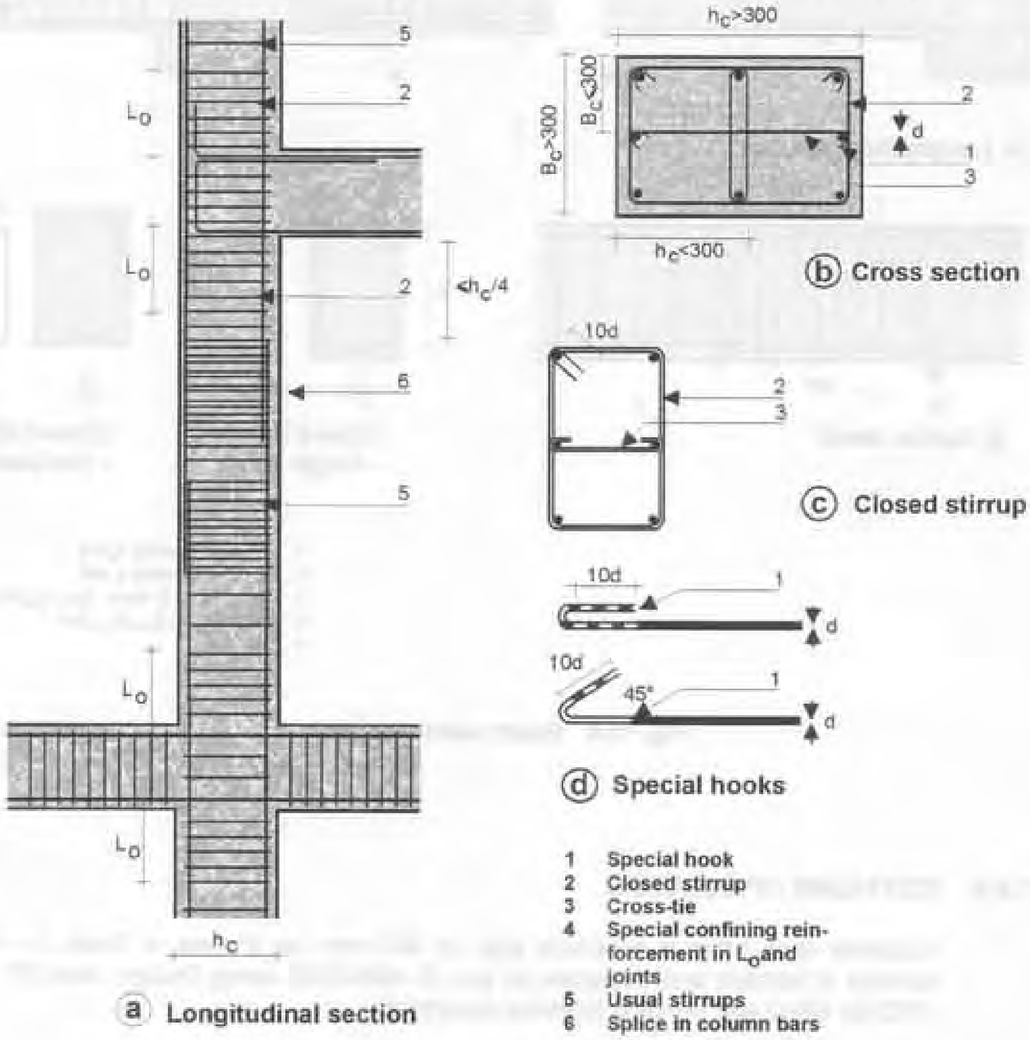


Fig. 19A Reinforcement detailing in RC column

7.7.A DETAILING OF BEAM-COLUMN CONNECTIONS

The concrete forming the common area of beams and columns in the joint gets subjected to complex stresses due to bending compression, tension and shearing. In order to avoid jumbling of bars from all sides, it will be appropriate to do the following (See Fig. 20A).

i. Pass the column reinforcement 'through' the joint without splicing within the joints.

ii. Pass the beam reinforcement 'through' the column without anchoring in the joint except in the end columns; and

iii. Provide confining hoops, like that in the lower column, in the joint also which will take care of the diagonal tensions as well.

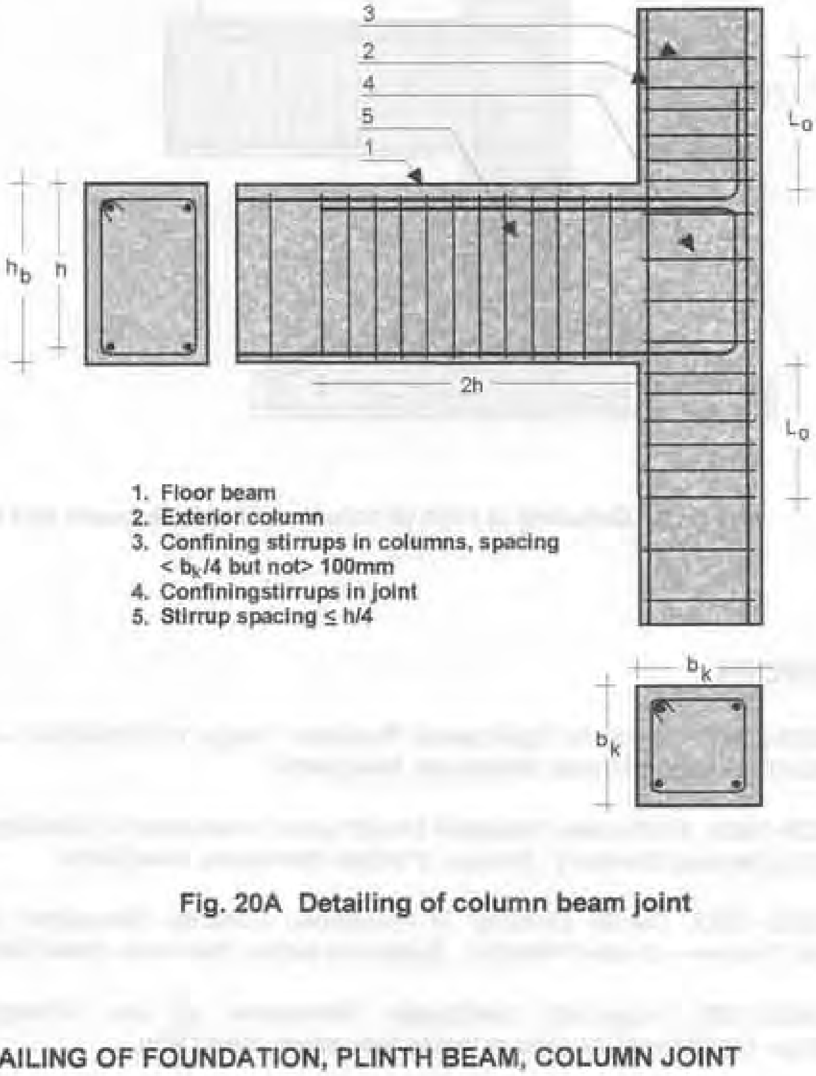


Fig. 20A Detailing of column beam joint

7.8.A DETAILING OF FOUNDATION, PLINTH BEAM, COLUMN JOINT

i. Individual column footings resting on soft to medium soils or piles, and pile groups, are to be connected together at ground or plinth level by struts/ties along both axes (IS: 4326 clause 4.3.4). The strut/tie shall be a minimum of 200x200 mm in section with 4-10 mm dia H.S.D. (Fe 415) bars longitudinally and 6mm stirrups @ 150mm.

ii. Footings can be relieved much from bottom-end moments of the columns, if these struts are designed to resist the column moments. The reinforcement detailing as shown in Fig. 21A may be followed for the case with the strut-beams.

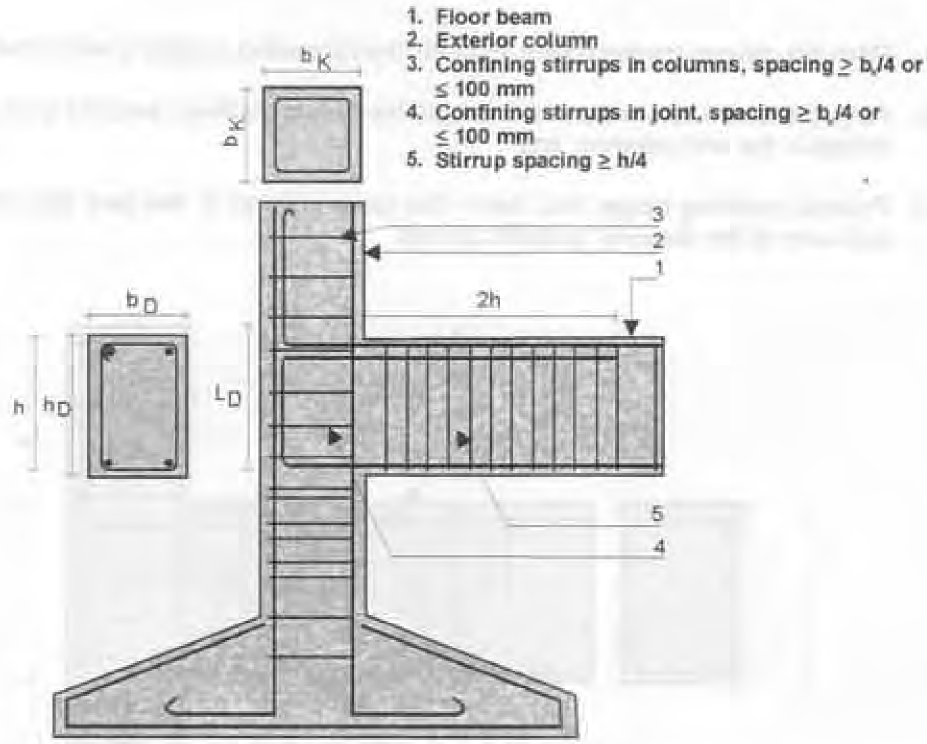


Fig. 21A Detailing of joint of column with plinth beam and footing

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6. "IS:13935-1993, *Repair and Seismic Strengthening of Buildings*", Bureau of Indian Standards, New Delhi.

7. "*Guidelines for Earthquake Resistant Non-Engineered Construction*", The International Association for Earthquake Engineering, Tokyo, Japan, Oct. 1986.

MSK Intensity Scale (Extract related to buildings)

Intensity

I – IV. Slightly felt:

V. Awakening:

a) The earthquake is felt indoors by all, outdoors by many-many sleeping people awake. A few run outdoors. Animals become uneasy. Buildings tremble throughout. Hanging objects swing considerably. Pictures knock against walls or swing out of place. Occasionally pendulum clocks stop. Unstable objects may be overturned or shifted.

b) Slight damages in buildings of Type A are possible.

VI. Frightening:

a) Felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A few persons lose their balance. Domestic animals run out of their stalls. In few instances dishes and glassware may break, books fall down. Heavy furniture may possibly move.

b) Damage of Grade I is sustained in single buildings of Type B and in many of Type A. Damage in few buildings of Type A is of Grade 2.

VII. Damage of buildings:

a) Most people are frightened and run outdoors. Many find it difficult to stand. The vibration is noticed by persons driving motor cars. Large bells ring.

b) In many buildings of Type C damage of Grade 1 is caused; in many buildings of Type B damage is of Grade 2. Most buildings of Type A suffer damage of Grad 3, Few of Grade 4. In single instances landslips of roadway on steep slopes; cracks in roads; seams of pipelines damaged; cracks in stone walls.

VIII. Destruction of buildings:

a) Fright and panic; also persons driving motor cars are disturbed. Here and there branches of tree break off. Even heavy furniture moves and partly overturns. Hanging lamps are damaged in part.

b) Most buildings of Type C suffer damage of Grade 2, and few of Grade 3. Most buildings of Type B suffer damage of Grade 3, and most building of Type A suffer damage of Grade 4. Occasional breaking of pipe seams. Memorials and monuments move and twist. Tomb stones overturn. Stone walls collapse.

IX. **General damage of buildings:**

a) General panic; considerable damage of furniture. Animals run to and fro in confusion and cry.

b) Many buildings of Type C suffer damage of Grade 3, and a few of Grade 4. Many buildings of Type B show damage of Grade 4, and a few of Grade 5. Many buildings of Type A suffer damage of Grade 5. Monuments and columns fall. Considerable damage to reservoirs; underground pipes partly broken. In individual cases railway lines are bent and roadway damaged.

Notes:

1. **Type of Buildings**

Type A	Buildings in field-stone, rural structures, unburnt-brick houses, clay houses.
Type B	Ordinary brick buildings, buildings of the large block and prefabricated type, half timbered structures, buildings in natural hewn stone.
Type C	Reinforced buildings, well built wooden structures.

2. **Definition of Quantity**

Single, few	=	About 5 percent
Many	=	About 50 percent
Most	=	About 75 percent

3. **Grades of damage**

G1 to G5 are described in Table 2A.

PART B

Earthquake Resistant Design and Construction of Rectangular Unit Masonry Buildings

CONTENTS - PART B

1.B INTRODUCTION

As stated in Part A Section 2.7.A Building Materials and Wall Construction in Afghanistan, good quality burnt brick is available near urban areas and main centers of provinces like Zalalabad, Kabul, Mazaresarif, Kandhar and Hearat. The bricks are usually of good quality with almost even size (not bent), giving metallic sound when struck with each other. The common size of brick is 20cm x 10cm x 5 to 6 cm. It is understand that in Afghanistan the compressive strength of burnt bricks ranges from 50 kg/cm^2 to 80 kg/cm^2.

Also experience in most developing countries shows that burnt brick is the preferred wall material with people as soon as they are able to afford it. The other rectangular units based on cement, for instance, solid and hollow concrete blocks, are becoming attractive where fuel for burning bricks becomes expensive and ecologically unacceptable. If availability of cement improves in Afghanistan, concrete blocks could be as easily made by village people as they make clay blocks.

The main purpose of this part is to deal with the earthquake resistant building construction using such rectangular masonry units.

2.B OBJECTIVES OF THE GUIDELINES

The following objectives are set for these Guidelines

1) To deal with the construction details of rectangular unit masonry appropriate to earthquake safety;

2) To provide architectural planning measures in masonry buildings suitable to good seismic performance;

3) To detail out the essential reinforcing elements for 'non-collapse' earthquake safety of the masonry buildings.

3.B SCOPE OF THE GUIDELINES

These guidelines cover the following features, from earthquake safety view point, in rectangular unit masonry buildings, such as, brickwork, concrete block work and ashler stone work, as may be used for upto four storeyed housing and community buildings in the seismic zones of Afghanistan (Fig. 9A):

a) Siting and foundations
b) Architectural design features
c) Construction and strengthening features in load bearing walls
d) Construction and strengthening features of roofs and floors

4.B BUILDING UNITS

Some building units for considered in this Guide are shown in Fig. 1B, as follows:

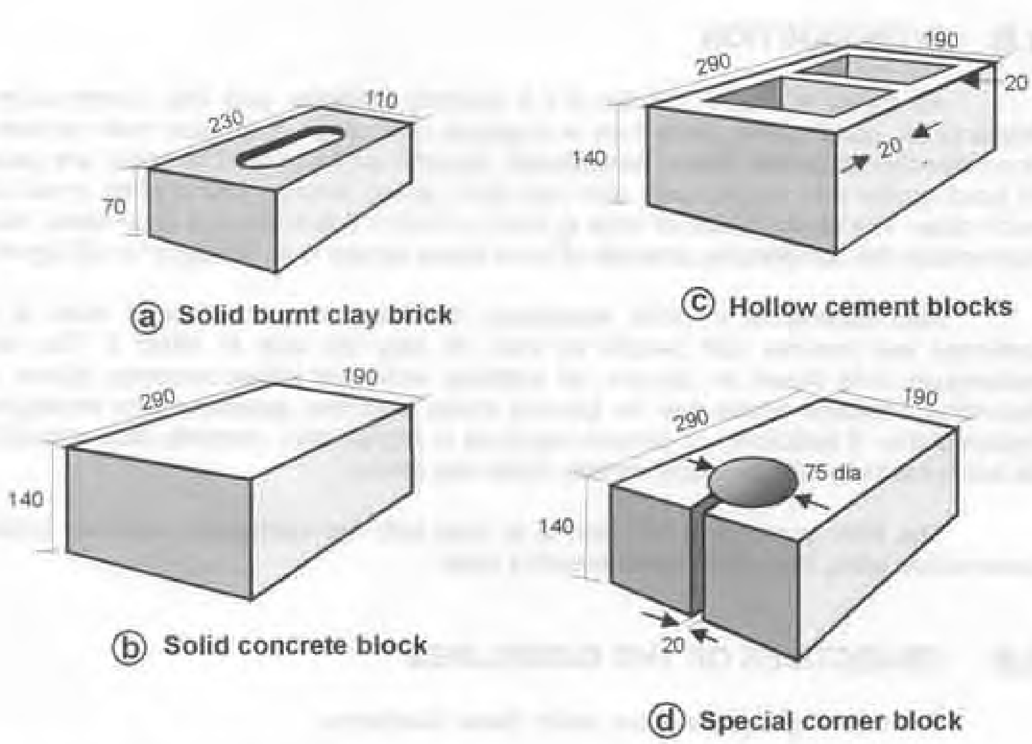


Fig. 1B Masonry Units

i. Burnt Bricks of nominal size 230 x 110 x 70mm
ii. Solid concrete blocks of nominal size 300 x 200 x 150mm.
iii. Hollow concrete blocks of nominal size 300 x 200 x 150mm

The minimum crushing strength of the masonry units on their gross area and the mortar mix should be as given in Table 1B.

Table 1B : Strength of Masonry Units

No. of Storeys	Storey	Wall thickness	Minimum crushing strength
1 and 2	Both	200 – 300 mm	3.5 Mpa (35 kg/cm^2)
3 and 4	Upper two	200 – 230 mm	3.5 Mpa (35 kg/cm^2)
	Next lower	300 – 340 mm	0 kg/cm^2)

4.1.B Burnt Bricks

i. Burnt bricks are normally used in English bond (Fig. 2Ba) giving wall thickness of 100 - 114 mm for partition walls to be built in 1:4 cement-sand mortar; and 200 - 230 or 300 - 340 mm for load bearing walls.

ii. For one storeyed lower cost houses, walls may be built using Rat-trap bond (see Fig. 2Bb) with Mortar of 1:4 mix. This will save about 25% of bricks and provide better thermal insulation also.

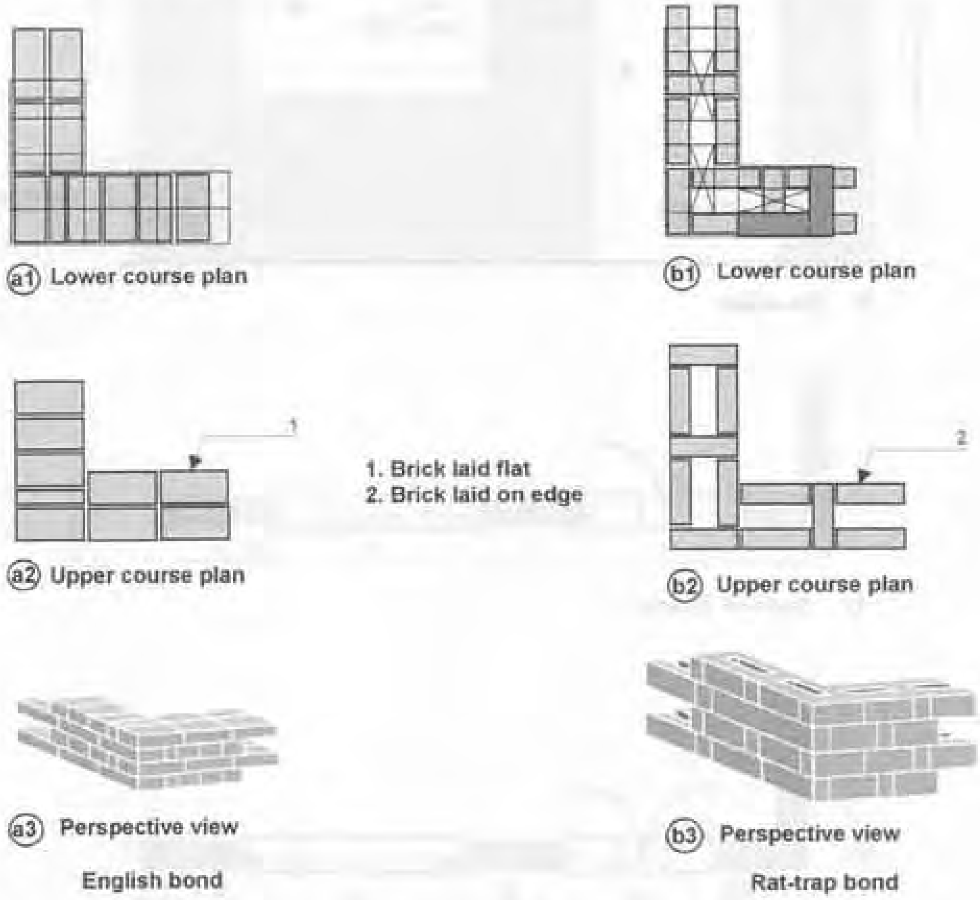


Fig. 2B English and Rat-trap bonds

4.2.B Solid Concrete Blocks

i. Using the concrete blocks of 300 x 200 x 150mm nominal size, non-load bearing walls of 150mm thickness and bearing walls of 200 and 300mm thickness may be built. The bearing surfaces of the blocks should be made rough in the casting procedure itself to develop good bond with the mortar.

ii. Since breaking of block is not convenient, special blocks having length of 150 mm and 100mm should also be cast and used to break the continuity of vertical joints (See Fig. 3B)

iii. Also, so as to fit the units without breaking, the size of doors, windows, built-in cupboard, open shelves, ete. and piers between them should be kept in multiples of modular dimension of 100 or 150 mm (See Fig. 3B).

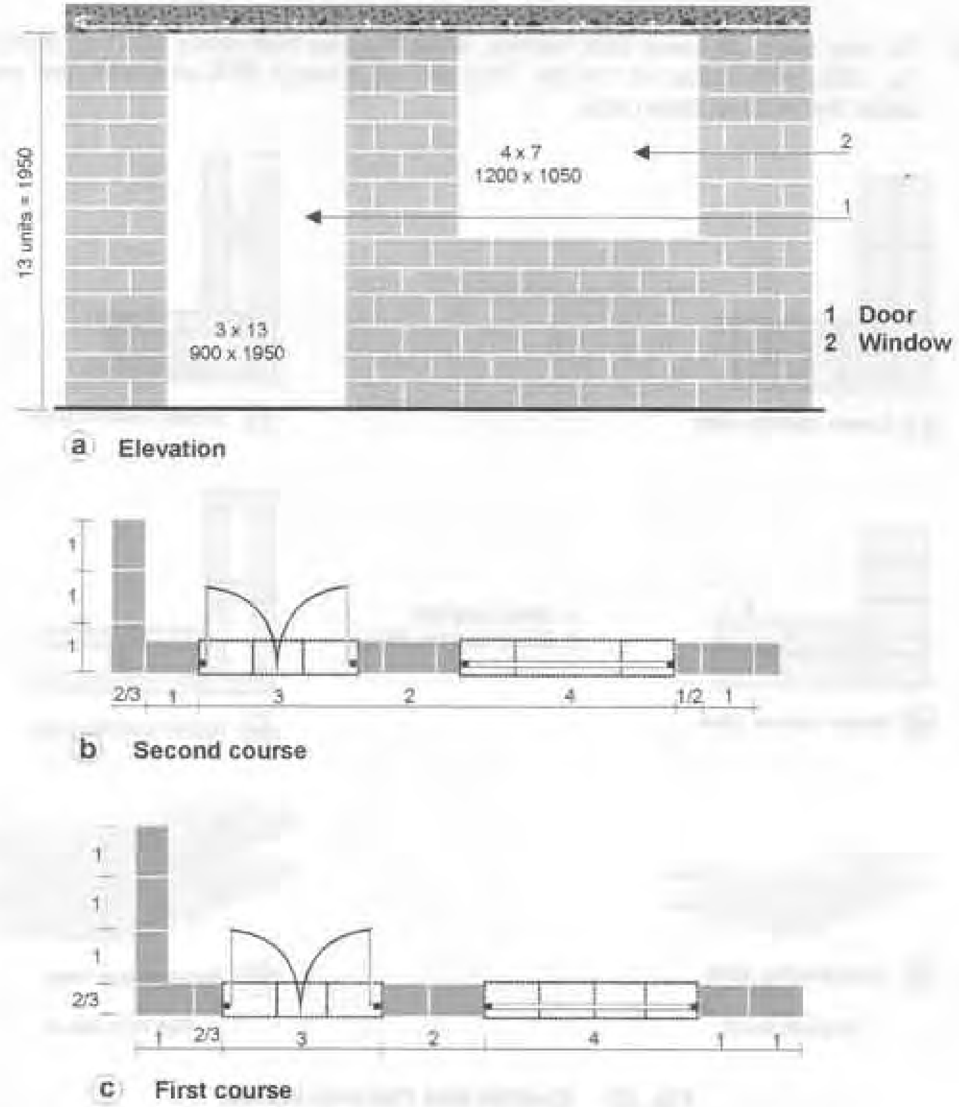


Fig. 3B Block Construction (Modular Dimensions)

4.3.B Hollow Cement or Microconcrete Blocks

Hollow blocks have the volume of hollows about half of the gross volume, hence also the unit weight is about 50%. But due to thin walls, they tend to get larger breakage loss during transportation than the solid blocks. Hence a higher crushing strength on the solid portion of the hollow block is essential. To achieve this, the minimum crushing strength of the blocks on the solid area should be kept 7.0 Mpa and on the gross area as 3.5 Mpa.

Hollow blocks give the advantages of better thermal insulation, less weight on the foundation and also less horizontal seismic force as compared to the solid blocks.

4.4.B Use of Dressed Stones (or Ashlar Masonry)

Fully dressed stones as used normally in various countries may be used just like the solid concrete blocks. Use of long 'corner stones' at the wall junctions will very much enhance the seismic stability of the stone walls. Creation of surface grooves, about 6 mm deep, in the longitudinal direction of the stones at the top surface while dressing the stones, will create shear keys in the mortar, improving lateral shear strength of the walls to a great extent.

4.5.B Use of Cellular Light Weight Concrete (CLC) Blocks

CLC consists of Fly Ash, Sand, Cement, Stable Foam, Water and Additives. The quantity of the foam and fly ash in CLC determine its density hence its compressive strength. It does not require coarse aggregate nor vibration for compaction. CLC of 1200 kg/m^3 density gives 6.0 N/mm^2 (60 kg/cm^2) compressive strength and will be suitable for load bearing walls. Density of 800 – 900 kg/m^3 will give 2.5 – 3.5 N/mm^2 (25 – 35 kg/cm^2) strength and suitable for non-load bearing infill and partition walls. Normal sizes of blocks are 400x200x190, 500x200x190 and 600x250x200 mm. The CLC blocks can be cut, sawn and nailed like wood, hence very convenient to use in residential buildings. Due to reduced unit weight of units, they offer the same benefits as hollow concrete blocks.

5.B OPTIONS FOR ROOFS AND FLOORS

There are three main type of roofs and floors adopted in houses using stone masonry in Afghanistan. These are

1) Wood logs supporting reeds or wooden planks, topped with earth fill
2) Sawn wood joists with wooden planks topped with earth fill
3) Masonry domes

There is no tradition of using sloping roofs with light covering such as burnt clay tiles or sheet roofing. The main reasons may be the extreme temperature conditions under which such light roofs will not provide the necessary comfort which is admirably provided by earthen roofs of various types as mentioned above. Therefore the appropriate options of roofs and floors may be as follows:

A. Flat Roof Types

(i) Wood joist/log type traditional system with improvement
(ii) RC joist replacing wood joists/logs
(iii) Reinforced concrete joists + Precast RC planks + RC screed + earth cover
(iv) Cast in situ RC slabs with earth cover for insulation

The roof should have adequate slope for free drainage of rain water.

B. Choice of Floor Types

The same systems as stated above will be suitable for floors also except that instead of thick earth insulation, the finishing may be done with thinner layer of brick tiles, clay mud or plain concrete.

6.B REQUIRED EARTHQUAKE SAFETY PROVISIONS

For the Seismic Zones (Fig. 9A) AB, C & D (M.M. Intensity VIII or higher, Int. VII and Int. VI respectively) the following safety provisions are specified.

6.1.B Building Categorisation (as per IS: 4326-1993)

In accordance with the value of the design seismic coefficient (See Part A, 6.2.A), the Building Category may be taken as follows for selecting earthquake resistance features:

Table 2B : Building Categories

	Zone D	Zone C	Zone AB
Housing	B	C	D
Community Buildings	C	D	E

6.2.B Measures for Achieving Seismic Safety

6.2.1.B For all Building Categories **B** to **E**

In all seismic zones, the following measures should be adopted as per IS-4326 for masonry walls of all types.

(i) Control on length, height and the thickness of walls in a room.
(ii) Control on size and location of openings.
(iii) Control on material strength and quality of construction.

6.2.2.B Additional for all building categories **C** to **E**

(iv) Seismic band at plinth level (may be omitted if founded on rock or hard soil)
(v) Seismic band at door-window lintel level in all cases.

Where flat roof is adopted:

(vi) Seismic band at ceiling level of floors or roofs consisting of joisted roofs or jointed prefab elements.
(vii) Stiffening of prefab elements in roofs/floor where used (using peripheral seismic band and RC screed integrated together).

If and where sloping/pitched roof is used:

(viii) Seismic band at eave level of sloping roofs.
(ix) Seismic band at top of gable wall and ridge wall top.
(x) Bracing in roof structure of trussed as well as raftered roofs.

6.2.3.B Additional measures for 2-4 storeyed buildings of Category C and all buildings of Category D or E.

(xi) Seismic band or dowels at corners and T-junctions at window sill level.
(xii) Vertical steel reinforcing bars at jambs of doors and large windows.

Note: *The vertical reinforcement at jambs of small windows and ventilators (say 600 mm x 600 mm or less) may be omitted.*

7.B MORTAR MIX

From earthquake safe requirements, the masonry should have good tensile and shearing strength. These in turn depend on the strength of the mortar and its bond with the masonry units. The following mortar mixes are specified in IS: 4326-1993 for the superstructure masonry in various categories of buildings:

Table 3B : Mortar Mixes

Building Category	Cement-sand Mix	Cement-lime-sand
D & E	1 : 4	1 : 1 : 6
B & C	1 : 6	1 : 2 : 9

8.B CONTROL ON QUALITY OF CONSTRUCTION

Good quality of construction is the key to strength and durability of masonry as well as safer seismic performance. The following control measures will be significant for good quality construction:

1) Soaking the bricks in water and moistening the surface of other building units before laying;
2) Consuming the mortar fully within 60 minutes maximum after mixing of water in the cement mortar;
3) Filling of all vertical joints between the units in the walls fully (if in doubt, use mortar grout to fill, before the next layer of mortar is spread on the bedding plane).
4) Filling of all toothed joints, wherever used, fully with mortar while building the new masonry, (See Fig. 4B);
5) Curing the masonry by repeated sprinkling of water for at least 7 days after the masonry is constructed using cement mortar.

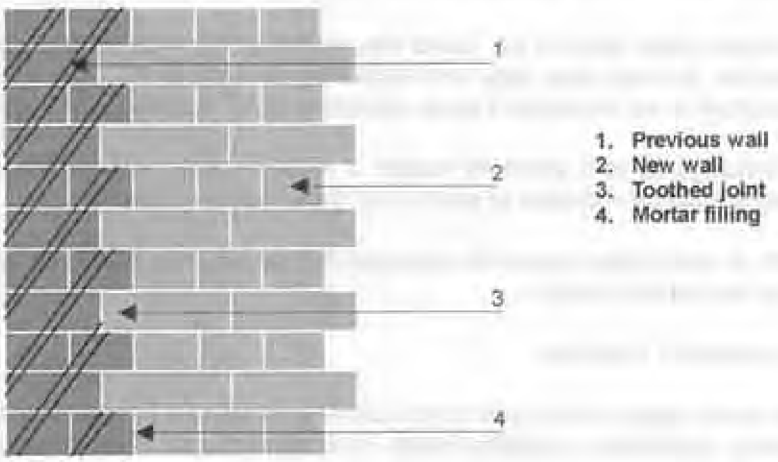


Fig. 4B Toothed Wall

9.B SITING AND FOUNDATIONS

9.1.B Building Site

- The building site should not be prone to flooding.
- Building should not be built on unstable sloping ground and where there is danger of landslides or rock falls due to rains or ground shaking.
- All wall footings should be set back from the edge of slope (Fig. 5B).

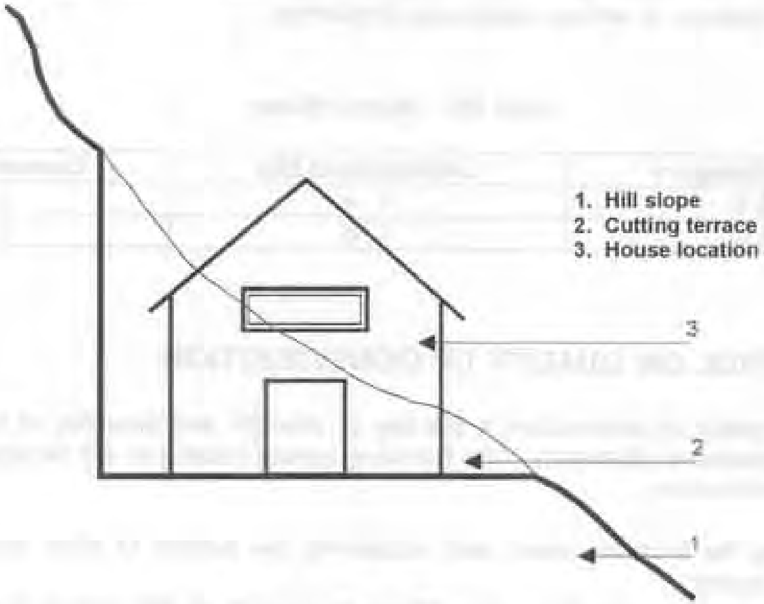


Fig. 5B House on hill slope

9.1.1.B Soil Investigation

(i) In relocated village sites it will be essential to carry out soil exploration using borelogs for soil classification and determining Standard Cone Penetration values "N" (SPT value "N") or Dynamic Cone Penetration Value.

(ii) In compact sites upto 0.4 ha, bores may be done one near each corner and one in the centre. In large sites, one bore each may be done at 100 m x 100 m grid point, the number to be increased if large variations in "N" values are observed.

(iii) For buildings up to 3 storeyed height, 3 m deep boring will generally suffice. "N" values should be recorded at every one meter depth below G.L.

(iv) Depth of water table should be recorded for each site by boring or by inquiries for dry as well as wet season.

9.1.2.B Liquefaction Potential

(i) If the water table is within 5 m depth below ground level in any season and the soil is sandy, liquefaction potential needs investigation upto 10 m depth particularly in Zone AB.

(ii) As per IS: 1893-2002, in Zone AB, the minimum field values of N to avoid liquefaction are 15 at 5 m depth increasing to 25 at 10 m depth. See 6.7.A in Part A.

(iii) If the above conditions are not satisfied, the site is liable to liquefaction and should be avoided for building construction. It may be used for playgrounds, parks, etc.

(iv) For any building to be constructed in liquefiable area, either the soil will have to be compacted to satisfy N value requirements as at (ii) or deep pile foundation will have to be used.

9.2.A New Foundations

a. *Rocky Ground or Boulder Site*

Weathered, jointed and fissured rock may be levelled by chiselling, in steps of about 150mm and stepped strip footing built on it, with the foundation width of 600 mm for houses upto two storeys. Boulder site may be levelled by removing small boulders but leave large boulders in place.

If the rock is massive, the surface should be roughened by chiselling and stepped strip footing built on it. Foundation width of 700mm will suffice for houses upto two storeys. In all cases, the base concrete of sufficient thickness (with a minimum of 100 mm) should be used for levelling before starting the masonry. For each additional storey, width may be increased by 300mm.

b. *Soil Site*

Stepped-strip foundation with minimum depth of 750mm below ground level and width of 700mm may be used (upto 2 storeyed houses), Fig. 6B. For each additional storey width may be increased by 300mm. The footing masonry should be brought upto the plinth level. This masonry can be done in coursed rubble masonry as shown or using bricks, concrete blocks or dressed stone as desired in 1:6 cement mortar.

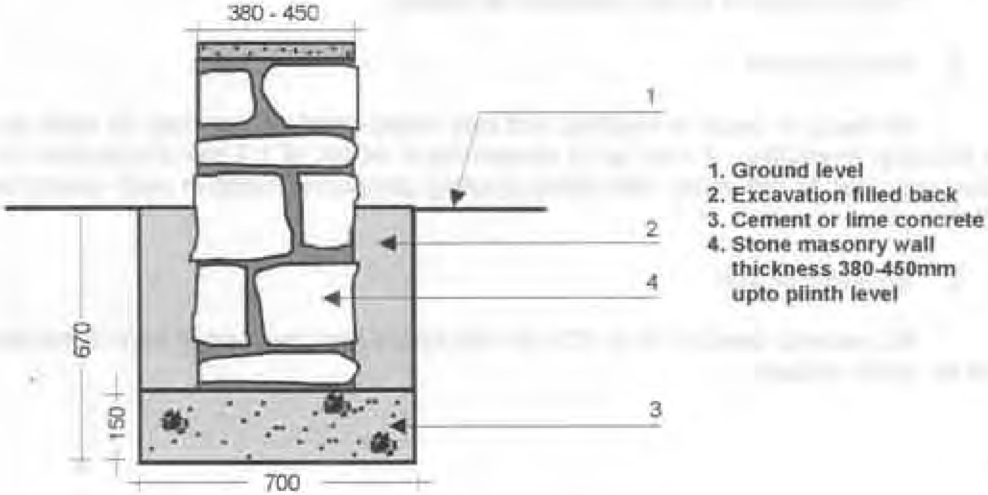


Fig. 6B Strip foundation on soil sites

9.3.B Use of Existing Old Foundation

Houses of pre-earthquake dimensions and heights could be built on existing foundation starting from 230mm below ground level where base concrete 150mm thick is to be cast on the existing lower part of the footing (Fig. 7B). Modifications required, if any, may be carried out by comparing the existing conditions with those recommended under 9.2.B for different soil types. The masonry upto plinth can alternatively be done in rectangular unit masonry of thickness equal to one unit length using the mortar specified for the building category.

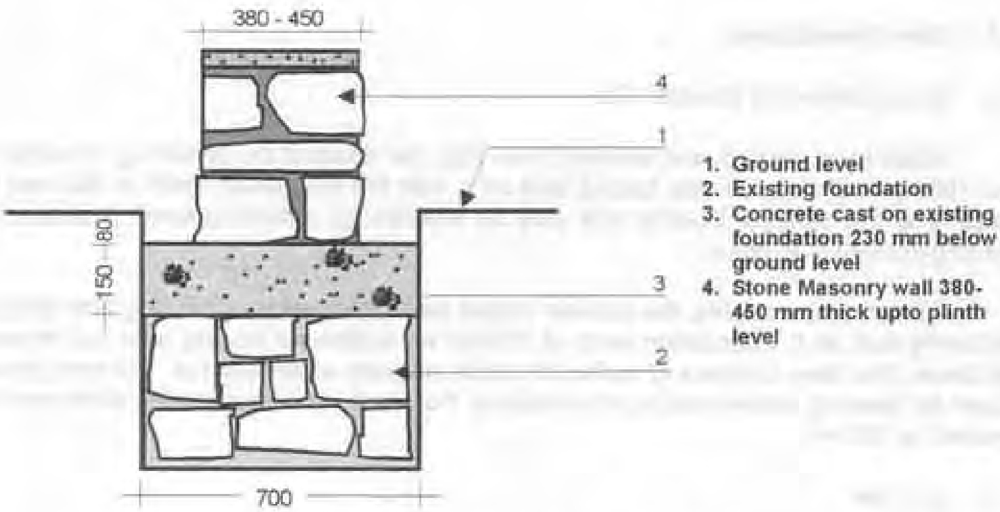


Fig. 7B New strip foundation on existing foundation

9.4.B Treatment at Plinth Level

This will depend on site condition as follows:

a. *Rocky Ground*

No band or beam is required and only damp-proof course may be used as usual on the strip foundation. It may be in cement-sand mortar of 1:3 mix 25mm thick or 1:2:3 micro concrete 38 mm thick, with damp proofing compound mixed in each case (See Fig. 8B).

b. *Boulders or Soil*

RC seismic band of 75 to 100 mm thickness may be used in each case (see Fig. 13B for detail of band).

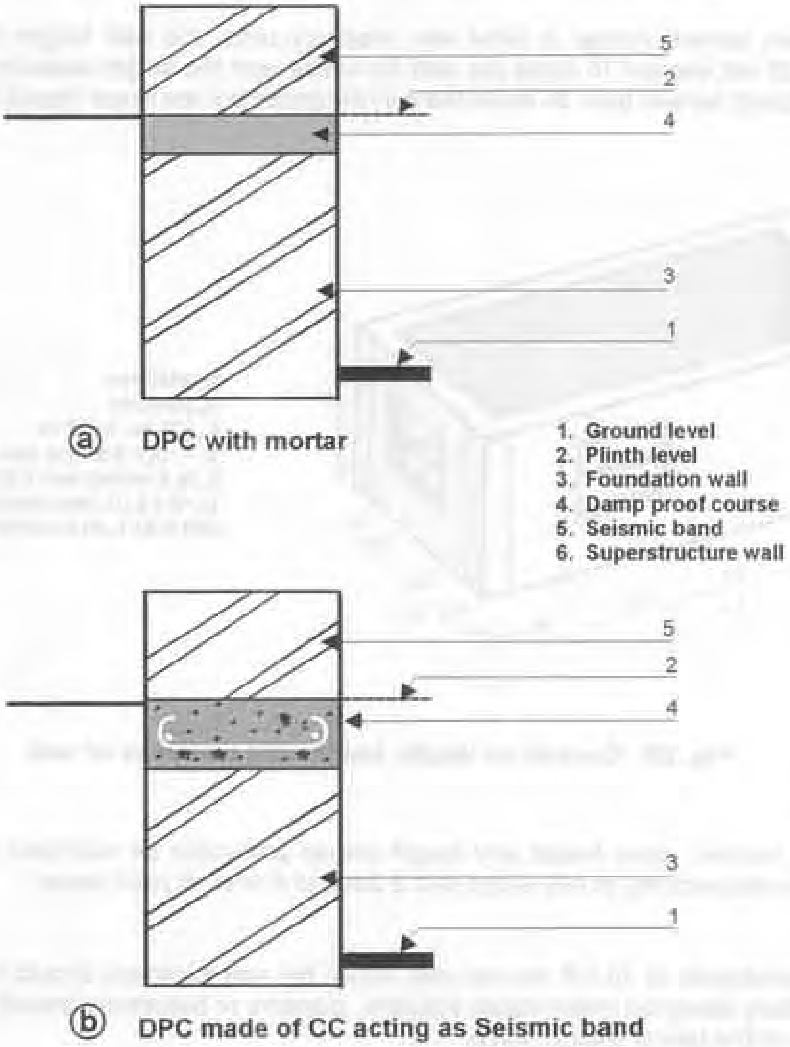
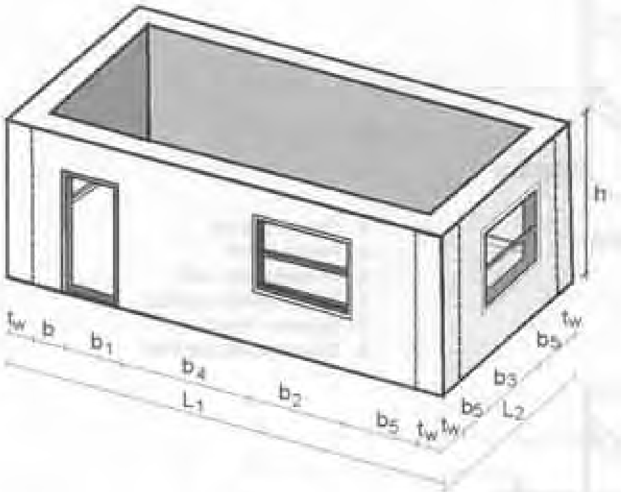


Fig. 8B Damp proofing

10.B CONTROL ON WALL HEIGHT AND LENGTH IN ROOMS

10.1.B When cement mortar is used with masonry units, the wall height from floor to ceiling should not exceed 15 times the wall thickness, and the length between cross-walls in a room should be less than 35 times the wall thickness but not larger than 8.0m. See Fig. 9B.



$b_5 \geq 450mm$
$b_4 \geq 560mm$
$L_1 \leq 35$ tw, $h \leq 15$ tw
$b_1 + b_2 \leq 0.5 L_1$ in one storey, 0.42 L_1 in 2 storey and 0.33 L_1 in 3 storey house
$b_3 < 0.5 L_2$ in one storey, 0.42 L_1 in 2 storey and 0.33 L_1 in 3 storey house

Fig. 9B Control on length, height and openings of wall

Note: *For houses, room height and length should preferably be restricted to 2.7m and 5.0m respectively in hilly areas and 3.2m and 6.0mm in plain areas.*

10.2.B If constraints of 10.1.B are not met, either the wall thickness should be increased or appropriately designed intermediate columns, pilasters or buttresses should be provided to take care of the lateral seismic force.

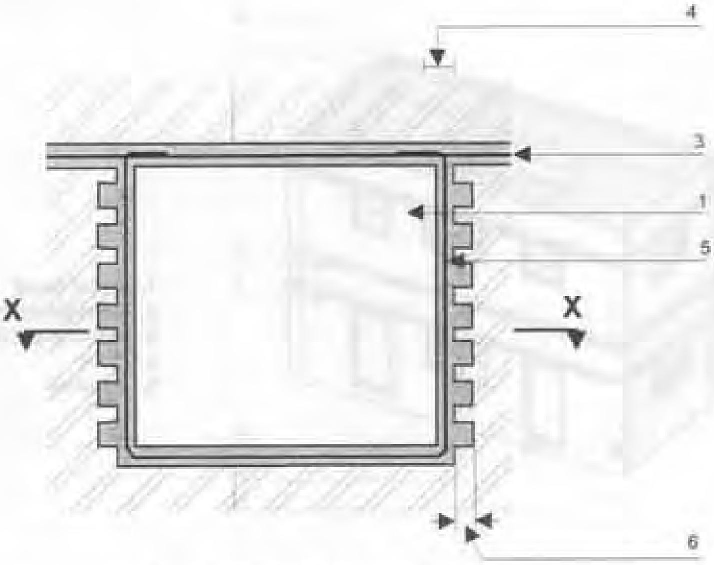
10.3.B Control on Door/Window Openings

10.3.1.B When cement mortar and rectangular units are used in the construction of houses, the following conditions should preferably be met (See Fig. 9B)

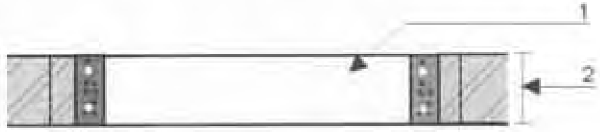
i. Ratio of sum of the widths of openings to the length of the wall in a room $(b_1+b_2)/l_1$ or b_3/l_2 should not exceed 0.50 in one storey, 0.42 in two storey and 0.33 in three or four storeyed building.

ii. Distance of the edge of an opening from the room corner should at least be 450mm and the pier width between two conservative openings atleast 560 mm.

10.3.2.B If the conditions of 10.3.1.B are not met, the openings should be boxed in R.C. with minimum 75 mm thickness and two H.S. bars of 8mm dia in Category C buildings and 10 mm dia in Category D and E buildings (See Fig. 10B).



(a) Sectional elevation



(b) Sectional plan

1. Window
2. Wall thickness
3. Lintel thickness
4. Thickness or Jamb concrete
5. Vertical bar
6. 1/4 of unit length

Fig. 10B Strengthening masonry around window opening

11.B SEISMIC BANDS

11.1.B The overall seismic reinforcing arrangements are shown in Fig. 11B for flat roof buildings and Fig. 12B for sloping roof buildings. These include horizontal seismic bands, vertical reinforcing bars, and bracings in sloping roof under-structure.

11.2.B The seismic bands at plinth, lintel, and ceiling levels, (see 6.2.B and Figs 11B and 132) must be provided in all internal and external load bearing as well as partition walls continuously without break. Requirement of reinforcing bars in RC bands are given in Table 4B and the details of bands are shown in Fig. 13B.

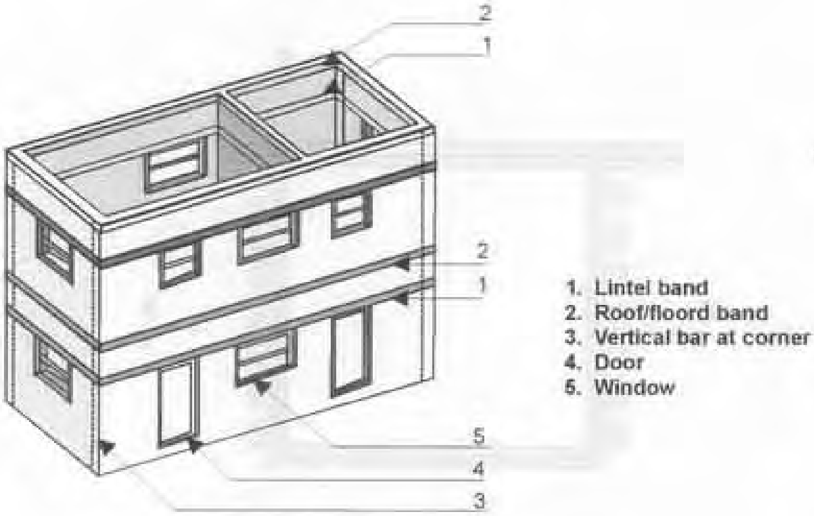


Fig. 11B Overall arrangement of reinforcing in masonry double storey building

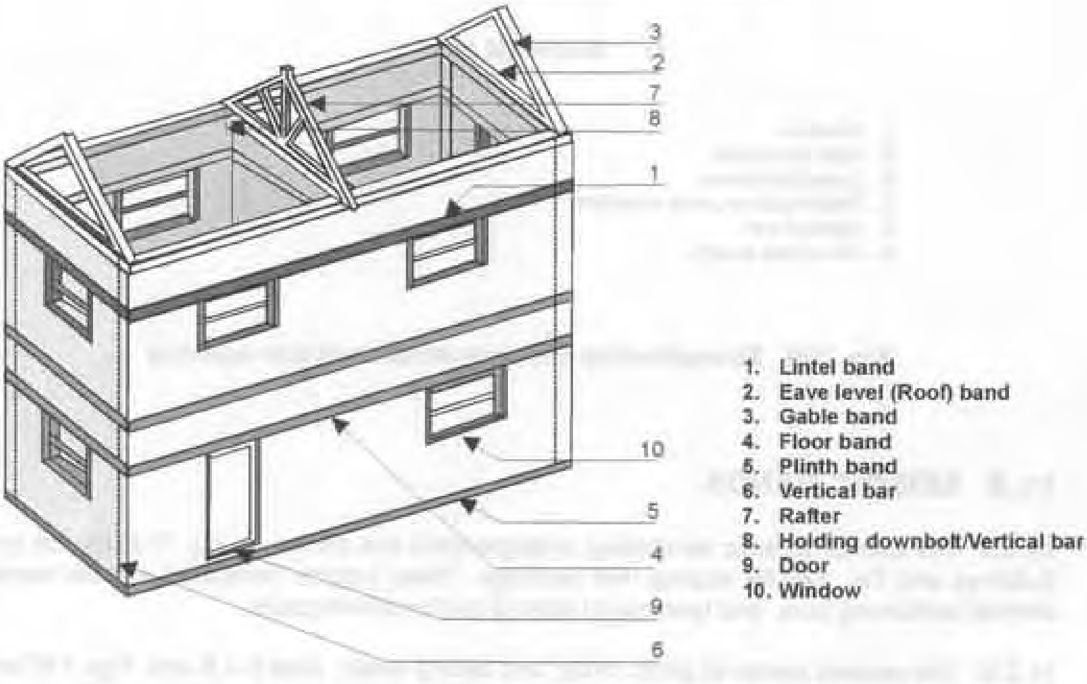


Fig. 12B Overall arrangement of reinforcing in masonry double storey building having pitched roofs

Table 4B : Diameter and number of HSD (TOR) longitudinal bars in reinforced concrete bands

Length of wall in room (m)	Reinforcing Bars in Building Categories					
	Cat. C		Cat. D		Cat. E	
	Nos.	Dia (mm)	Nos.	Dia (mm)	Nos.	Dia (mm)
5	2	8	2	8	2	10
6	2	8	2	10	2	12
7	2	10	2	12	4	10
8	2	12	4	10	4	12

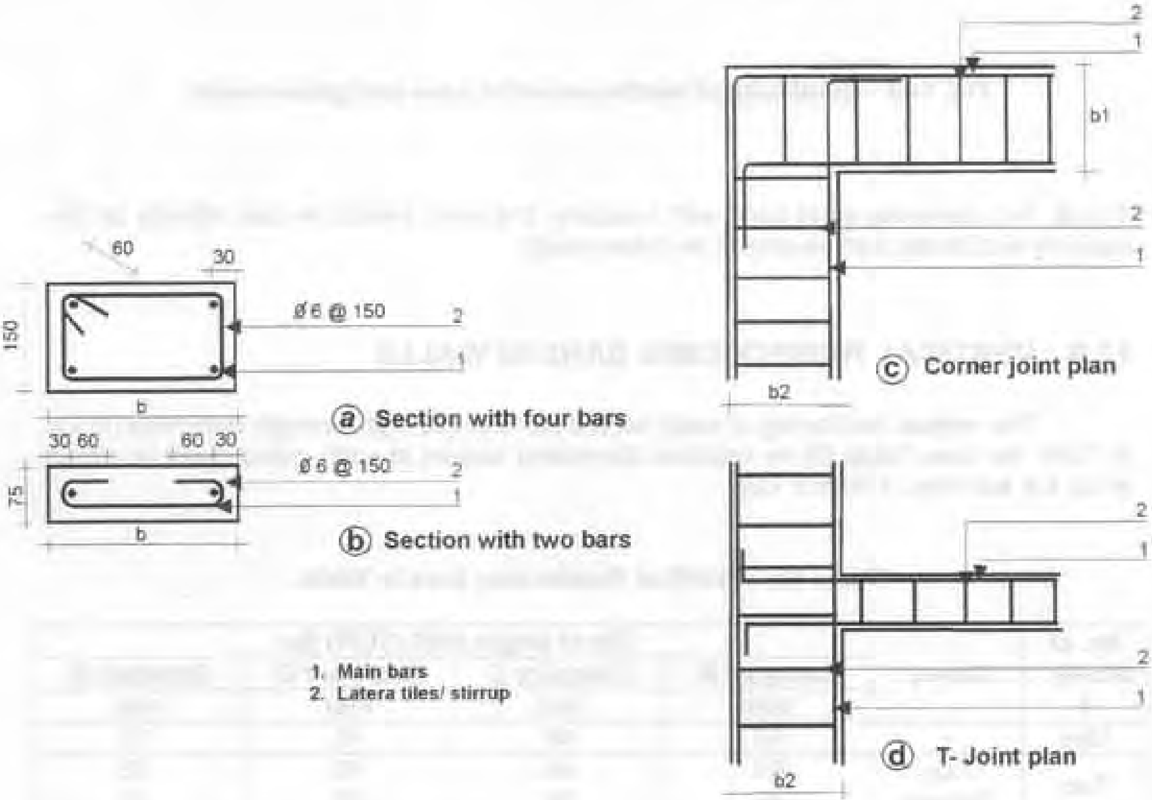


Fig. 13B Reinforcement and bending detail in R.C. band

11.3.B All gable walls, whether internal or external, must have the gable band at their top and made continuous with the eave level band. See Fig. 14B for details.

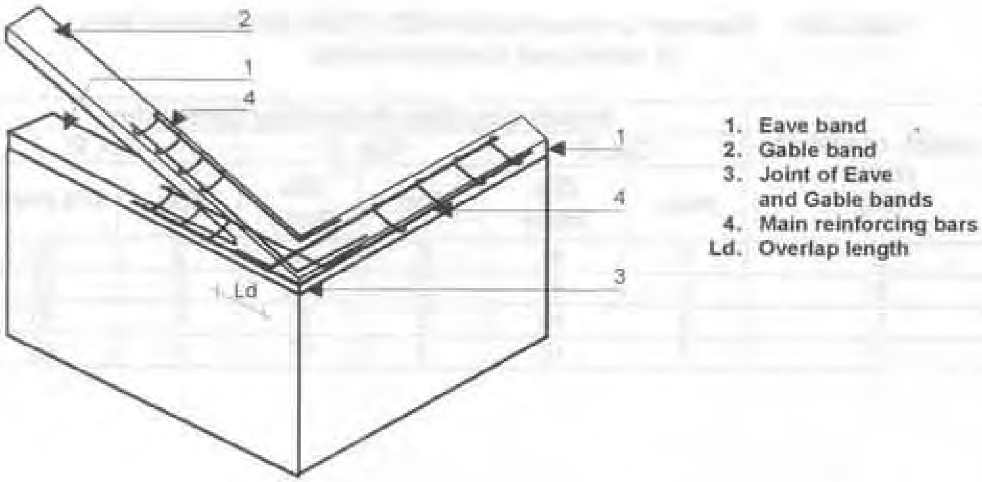


Fig. 14B Continuity of reinforcement in eave and gable bands

11.4.B For achieving good bond with masonry, the band should be cast directly on the masonry and its top surface should be made rough.

12.B VERTICAL REINFORCING BARS IN WALLS

The vertical reinforcing of walls consists of a single high strength deformed (HSD) or 'TOR' bar (see Table 5B for required diameters) located at each critical point as stated in 6.2.3.B and Figs. 11B and 12B.

Table 5B : Vertical Reinforcing Bars in Walls

No. of Storeys	Storey	Dia of single HSD (TOR) Bar			
		Category B	Category C	Category D	Category E
		mm	mm	mm	mm
One	-	Nil	Nil	10	12
Two	Top	Nil	Nil	10	12
	Bottom	Nil	Nil	12	16
Three	Top	Nil	10	10	12
	Middle	Nil	10	12	16
	Bottom	Nil	12	12	16
Four	Top	10	10	10	Four Storeyed Building not allowed
	Third	10	10	12	
	Second	10	12	16	
	Bottom	12	12	20	

All reinforced bars mentioned in Table 5B must have embedment in the foundation concrete and should be taken continuously and embedded in the roof band or the R.C. roof slab. For bonding with the masonry and providing protective cover against corrosion, the bar must be embedded in M20 grade concrete (1:1.5:3 nominal mix) filled in the surrounding pockets as follows:

12.1.B Vertical Bar in Brick Walls

In solid brick walls, a cavity of 114 x 114mm may be formed by suitably arranging the brick-bats around the bar. See Fig. 15B. When rat-trap bond is used, cavities at the corners are automatically available.

12.2.B Vertical Bar in Solid Concrete Block Walls

Since a cavity formation in solid block wall is not feasible, concrete blocks with one hollow are used at the bar-points. To avoid raising of the blocks high for enclosing the bar in a hollow, special blocks are cast as shown in Fig. 1Bd.

12.3.B Vertical bar in Hollow Block Wall

Here cavities for locating the Vertical bars are automatically available. Slit arrangement in the sides of the hollows for housing the bars will be required as shown in Fig. 15B.

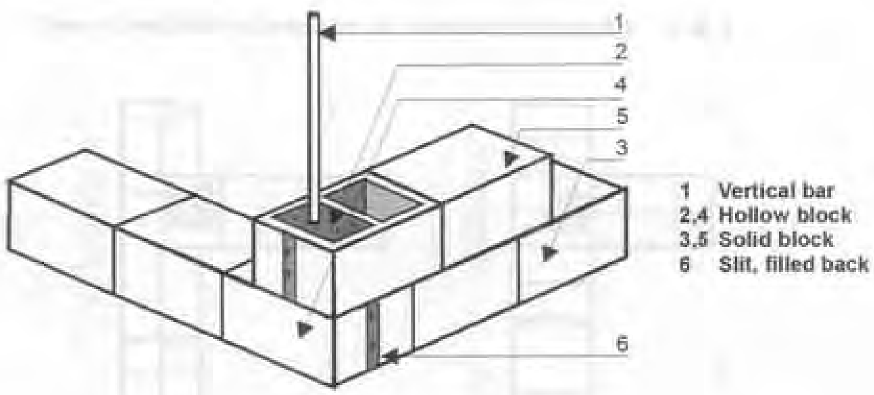
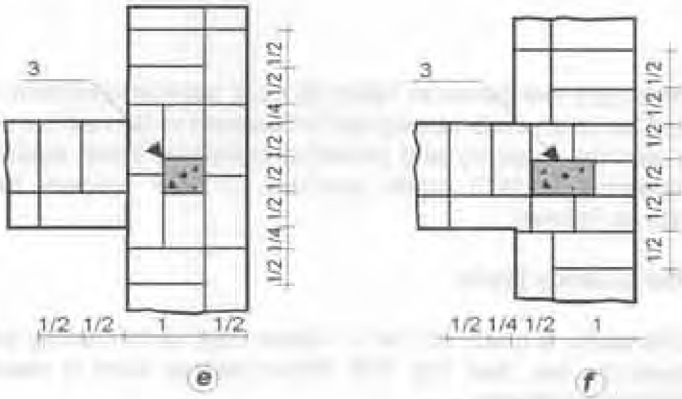


Fig. 15B Vertical bar in concrete block wall

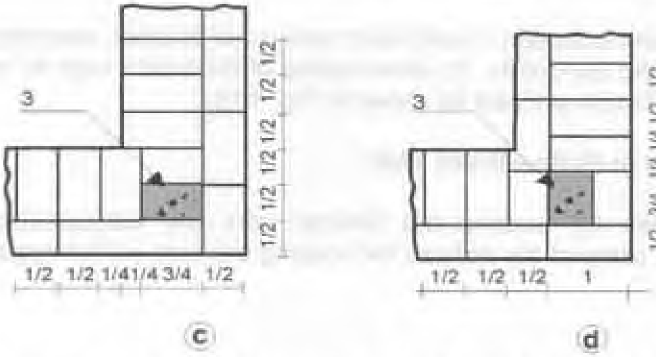
12.4.B Vertical Bar in Dressed Stone Walls

Since a cavity formation in the stone is not feasible, the following two ways may be adopted to provide and build the vertical bars in the stone walls:

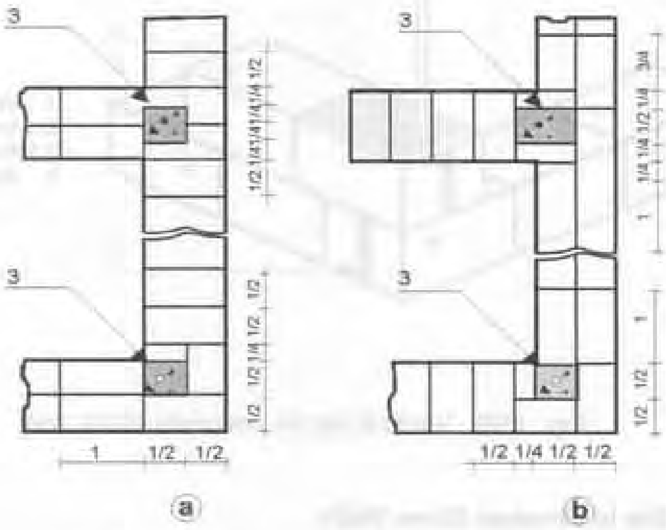
a. Special concrete blocks, with hollow and slit, (as for example in Fig. 1Bd) may be made in the size of the dressed stones and built in the stone wall courses along with the stones, at all the vertical bar locations.



e & f Alternate course at T-junction of one and a half brick wall



c & d Alternate courses in one and a half brick wall



a & b Alternate courses in one brick wall

1 one brick length
1/2 Half brick length
3 Vertical steel bars with mortar/conc. filling in pocket

Fig. 16B Typical details of providing vertical steel bars in brick masonry

b. After erecting the vertical bars, stone masonry may be built in three courses with toothed joint towards the bar, and the space around the bar may be filled with 1:1.5:3 concrete mix using wooden shuttering on two sides only forming a toothed concrete column with the masonry. For ensuring firm connection with the masonry, a hooked steel link 8 mm in diameter should be installed every third course which should engage the vertical bar at one end, the other end going into the masonry by about 200 mm (Fig. 16B).

12.5.B Construction Details

Before casting the foundation, vertical bars must be held in correct positions vertically by using tripods of bamboo or the spare reinforcing bars (See Fig. 17B).

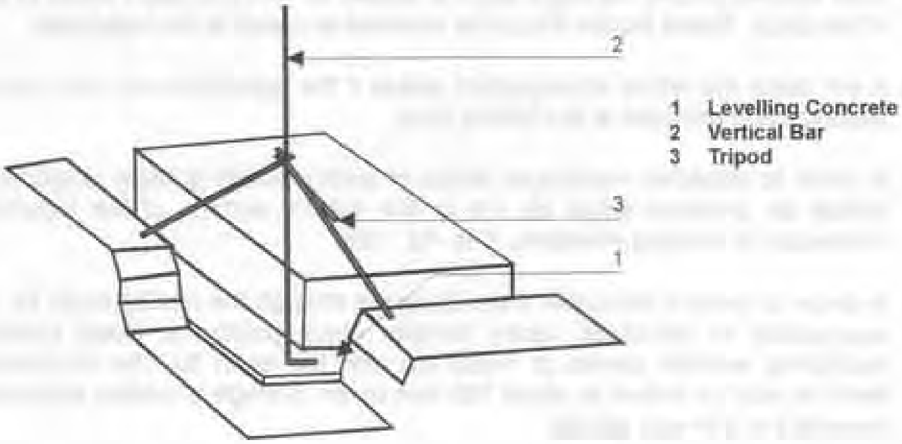


Fig. 17B Keeping the bar vertical

13.B FLOORS AND ROOFS

As stated in Section 5B, there are three main types of roofs and floors used in houses in Afghanistan:

1) Wood logs supporting reeds or wooden planks, topped with earth fill
2) Sawn timber joists with wooden planks topped with earth fill
3) Masonry domes or earthen domes

These roofs are constructed without any seismic resisting measures. These measures are to be specified for earthquake safety in future constructions. Also in view of the better new construction taking place, it will be appropriate to introduce new construction techniques which will make the roofs leakage proof and also more durable.

13.1.B Flat Roofs/Floors with Wood Logs or Timber Joists

The main deficiencies in this system of construction are :

(i) The different elements are not integrally connected, hence liable to separate out even in moderate earthquake shaking, and become unstable.

(ii) Due to insufficient bearing of the logs/joists on the walls, these are likely to leave the bearing and fall down under large displacement.

(iii) Unless carefully covered with water proof flooring, they will leak during rains.

Construction Safe Guards

(i) All wood logs/joists should have two cross *bridging elements* across the logs/joists near their ends properly nailed or screwed to them. The cross section of the bridging member should a minimum of 40 mm x 70 mm.

(ii) All spaces between the logs/joists at the bearing points should be *blocked* using solid wooden blocks, having a width of atleast 40 mm and depth equal to full depth of the joists. These blocks should be screwed or nailed to the logs/joists.

(iii) It will make the whole arrangement stable if the logs/joists are held down to the seismic band provided at the ceiling level.

(iv) In order to establish diaphragm action of such wooden grillage, diagonal bracing should be provided either on top or the bottom surface of the logs/joists and connected to bridging elements. See Fig. 18B.

(v) In order to prevent rain/snow water seepage through the roofing earth fill, it will be appropriate to introduce heavy density black polythene sheet between the supporting wooden planks or reeds etc. and the earth fill. The thickness of the earth fill may be limited to about 150 mm on an average providing adequate slope towards the drainage spouts.

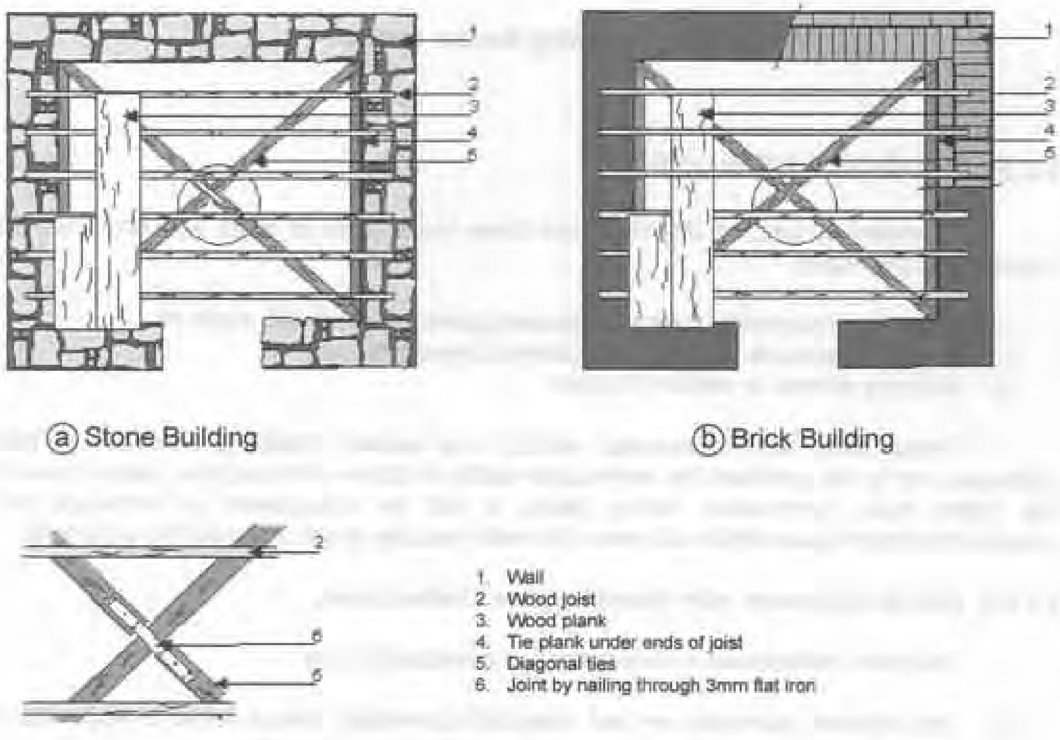


Fig. 18B Earthquake resistant construction of timber joists floor

13.2.B Flat Roof/Floor Using Jack Arches

Multi panel jack arch roofs have to be provided horizontal ties atleast in the end panels and every fourth panel so that the thrust of the arches is balanced by the ties. In earthquake areas particularly in zones AB and C it will be necessary to provide the ties under all panels continuously. See Fig. 19B.

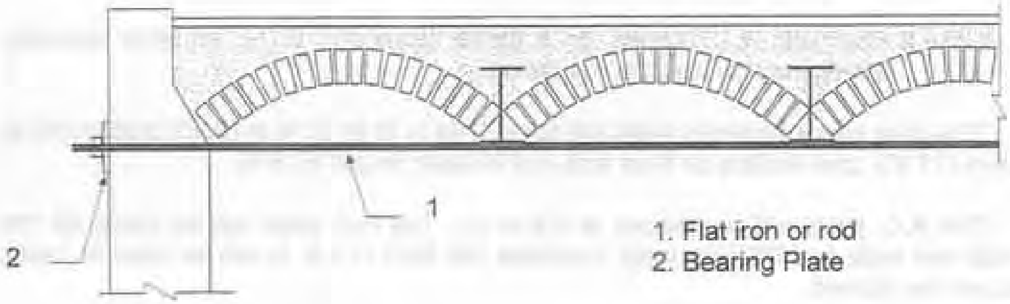


Fig. 19B Seismic Strengthening of Jack arch floor/roof

13.3.B Flat Floor/Roof Using Beams and Prefab Roofing Elements

A large number of schemes using precast roofing elements as well as precast reinforced concrete beams have been developed in India, whose seismic safety has been detailed in IS: 4326-1993. In order to integrate the prefabricated roofing elements and the reinforced concrete joists or inverted T-irons or steel joists, the following points are specified.

(i) The prefabricated plank/shell units when placed on the joists should be interconnected with the reinforcement of the joists, or the spacing between the joists has to be maintained by cross bridging elements.

(ii) The deck so prepared must be covered with reinforced concrete screed of minimum 38 mm thickness, reinforced with 4 mm diameter wires spaced at 60 mm on centers both ways or 6 mm diameter bars at 150 mm center to center both ways. This reinforced screed is to be connected to a peripheral reinforced concrete seismic band cast on the walls along with the screed. The screed performs the function of leak proof membrane as well as creating diaphragm action in the roof.

13.4.B Flat Floor/Roof Using Joists, Plank, RC Screed System

A system developed by the author and used in the reconstruction program after Chamoli earthquake of 1999 in Uttaranchal, India, is presented herebelow as illustration of prefabrication techniques. The advantage of such a techniques is that the shuttering work at site is very much reduced, the members are made in standardized forms and compaction and curing of the elements is properly taken care off. The casting of the screed is to be done in-situ on a ready deck formed on the precast beams and RC planks.

Details of Precast R.C.C. Joist Plank Screed System (Figs. 20B and 21B)

(a) Loading and Span

Two cases of loading and four spans are considered as follows:

Case I: Intermediate floor with R.C Screed, cemented floor or earth fill of 75 mm may be added if desired.

Case II: Roof with R.C Screed, on a gentle slope of 1 in 12, no other covering, thatch may be used for insulation.

The clear spans between walls are taken 2.44 m (8 ft); 2.74 m (9. ft); 3.05 m (10 ft) and 3.6 m (11'9"). Live loading on floor and roof is taken as per IS: 875.

The R.C. joists will be spaced at 0.9 m c/c. The R.C plank will be made 38 mm thick, 450 mm wide and 850 mm long. Concrete mix M20 (1:1.5: 3) will be used in Joists, Planks and the Screed.

(b) R.C Plank

450 x 850 x 38 mm with 4 mm dia reinforcing wires spaced at 60 mm c/c longitudinally with clear cover of 15 mm below. The reinforcement across will be 3 mm dia spaced at 140 mm c/c. The longitudinal bars will be kept protruding out by 50 mm both sides so as to bond with the joists through in-situ concrete filling.

(c) R.C Joists

The details are given in Table 6B and Fig. 20B for intermediate Floor and Roof both.

(d) R.C Screed

Use 38 mm thick, with 5 mm dia bars @ 225 mm c/c parallel to joists and 200 c/c across, at clear cover of 15 mm minimum above the bars. Alternatively Weld Mesh MW 62 (4 mm dia wires @ 200 c/c each way) may be used (Fig. 21B).

IMPORTANT NOTE: The precast joist will be propped from below at mid-point of 2.44 m span and at about 1 m apart in case of 2.74 to 3.60 m spans until the screed and joint filling concrete has cured for at least 10 days.

Table 6B : R.C. Joist Dimensions & Reinforcement

S. No	Case	Clear Span m	Length of joist m	Overal l depth mm	H1 mm	D1 (Bottom) mm	D2 Top mm	D3 (Stirr.) mm	Minim. camber mm
1	Case I - Floor with R.C. Screed	2.44	2.74	166	90-6*	$8\bar{\phi}$ TOR 7ϕTK	$8\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	12
2		2.74	3.04	225	149-6*	$8\bar{\phi}$ 7ϕTK	$8\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	15
3		3.05	3.35	225	149-6*	$10\bar{\phi}$ 8.5ϕTK	$8\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	18
4		3.60	3.90	250	212-6*	$10\bar{\phi}$	$8\bar{\phi}$	6ϕ	20
5	Case II - Roof with R.C. Screed Gentle Slope	2.44	2.74	166	90-6*	$8\bar{\phi}$ 7ϕTK	$8\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	12
6		2.74	3.04	166	90-6*	$8\bar{\phi}$ 7ϕTK	$8\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	12
7		3.05	3.35	200	124-6*	$8\bar{\phi}$ 7ϕTK	$8\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	18
8		3.60	3.90	225	187-6*	$8\bar{\phi}$ 7ϕTK	$8\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	18

* Reduction of 6mm is indicated for 1:4 mortar for bearing under the R.C. plank

Notes: 1. $8\bar{\phi}$ = 8mm dia High Strength Grip Bar like Tor steel with Fy = 415.N/mm^2

7ϕTK = 7mm dia Torkari bar with Fy=550 N/mm^2

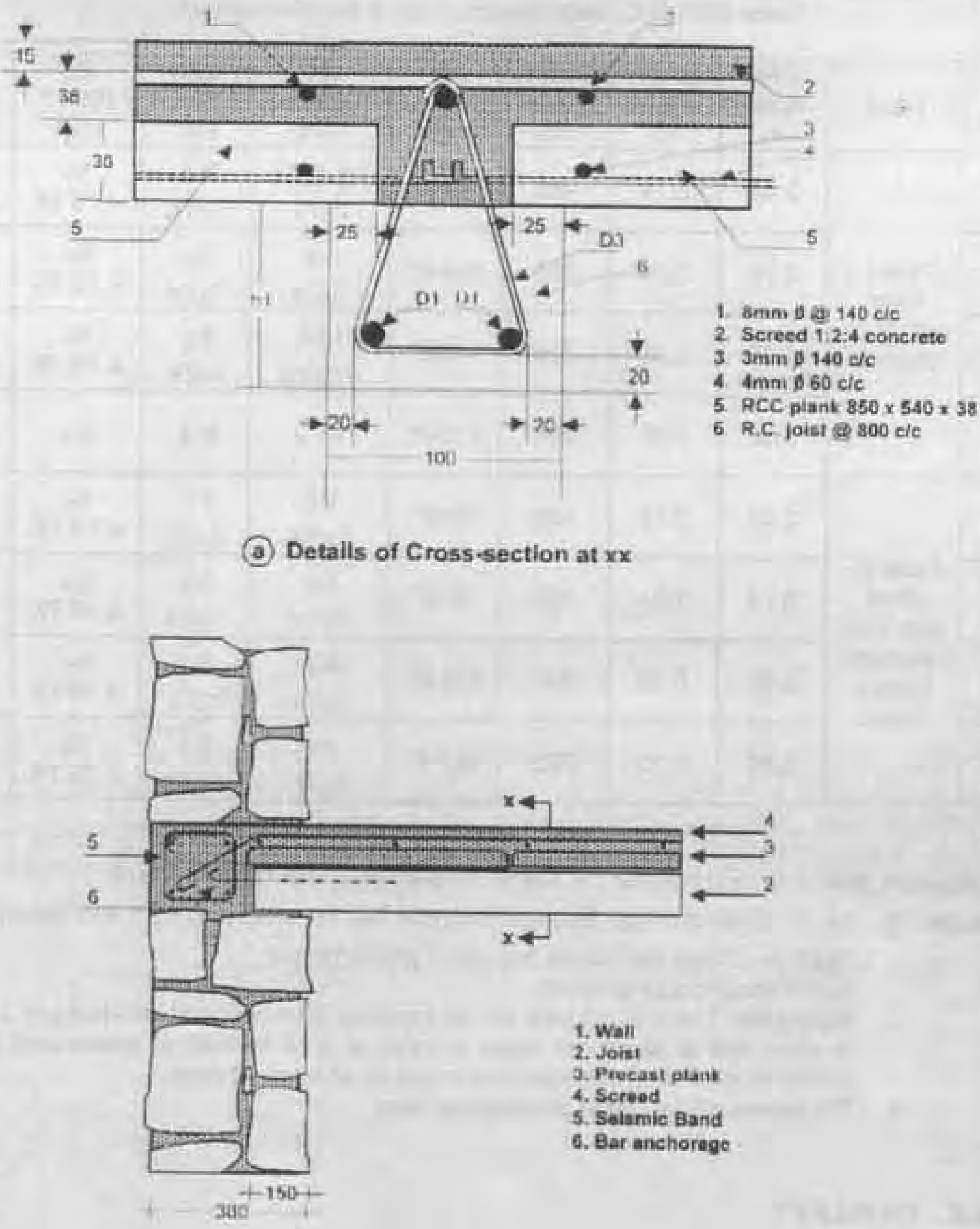
Any of these could be used.

2. ***Important:*** The precast joist will be propped from below at mid-point of 2.44 m span and at about 1m apart in case of 2.74 to 3.60 m spans until the screed or joint filling concrete has cured for at least 10 days.
3. The stirrup will be made of triangular form

14.B PARAPET

Parapets above roofs are unstable vertical cantilever projections which are liable to topple over during earthquake motions. Therefore the height of the masonry parapet should be kept less than three times its base with and it should be constructed using the cement mortar specified for the zone.

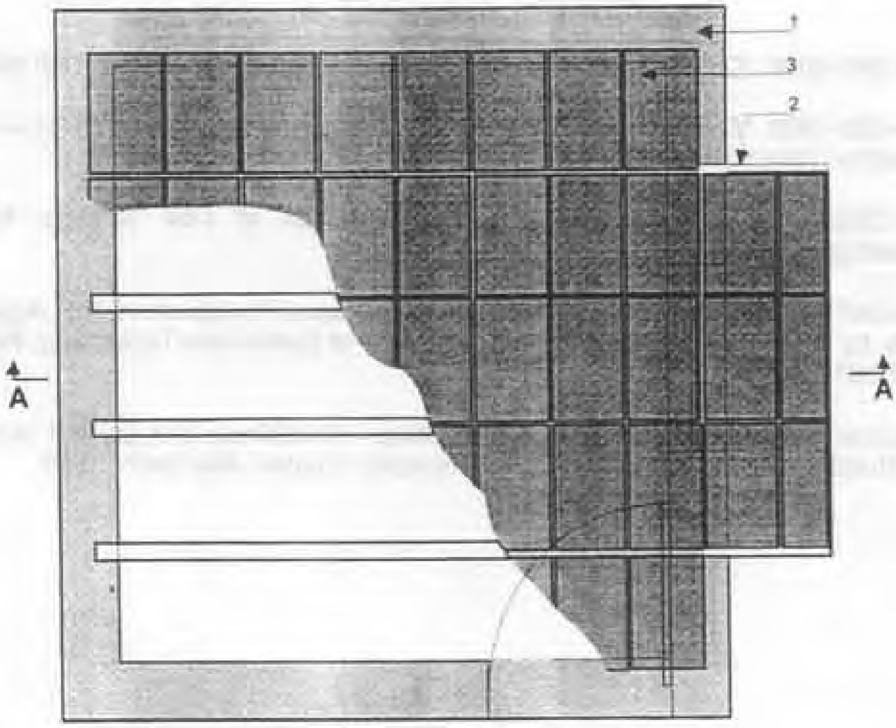
Alternatively, the parapet should be vertically reinforced, the reinforcement being anchored into the roof slab or in the main wall below the parapet.



(a) Details of Cross-section at xx

(b) Section showing connection with wall

Fig. 20B R.C. Joist – Plank – Screed system details



(a) Plan of roof or floor

1. Wall
2. Joist (Precast RC or Prefab Steel)
3. RC Plank
4. RC screed

(b) Section AA

Fig. 21B Roof/Floor plan using RC Joist – Plank – Screed

REFERENCES

1. IS:1893-2002 "*Criteria for Earthquake resistant Design of Structures*" (Fifth revision).

2. IS:4326-1993 "*Earthquake Resistant Design and Construction of Buildings – Code of Practice*" (Second revision).

3. IS:13828-1993 "Improving Earthquake Resistance of Low Strength Masonry Buildings- Guidelines".

4. "Guidelines for Earthquake Resistant Non-Engineered Construction" A.S. Arya, et al, pub. by IAEE, 1986, reprinted by Indian Society of Earthquake Technology, Roorkee-247 667.

5. "Improving Earthquake Resistance of Buildings – Guidelines, by Arya, A.S. et al., pub. by Building Materials and Technology Promotion Council, New Delhi, 1999.

PART C

Earthquake Resistant Construction of Stone Buildings

CONTENTS - PART C

1.C INTRODUCTION

These guidelines have been specially framed for the reconstruction of collapsed or severely damaged houses in the various affected Provinces of Afghanistan and also construction of new houses in these areas. The guidelines will also be helpful in earthquake resistant construction of houses in other parts of the country which fall in seismic Zones AB and C of the Seismic Zoning Map of Afghanistan.

2.C OBJECTIVES OF THE GUIDELINES

The main objective of these guidelines is to illustrate the earthquake resisting construction measures in accordance with the Seismic Zoning Map of Afghanistan using the building construction standards adopted in India, namely, IS: 4326, IS: 13827 and IS: 13828 of 1993.

According to Seismic Zoning Map of Afghanistan there are the following seismic zones (Fig. 9A):

Zone AB: MSK Intensity VIII or higher is probable to occur.
Zone C : MSK Intensity VII is probable here
Zone D: MSK Intensity VI is probable here.
Zone E: MSK Intensity V or lower is only considered probable.

The recommendations contained herein are based on these probable Intensities for the design of buildings according to the Codes. Reconstruction and new construction of buildings will be safe if it would be in accordance with the specified Intensities.

3.C SCOPE OF THE GUIDELINES

These guidelines cover those houses which are situated in the earthquake prone zones and whose bearing walls are built using coursed stone masonry and do not exceed 7.0 meters in length in any room and the number of storeys are no more than three. The roof can be flat or sloping. The earthquake resistant provisions are indicated for seismic Intensities MSK $\geq$ VIII, and VII as appropriate for the earthquake damage prone Zones AB, and C respectively. Construction of Rubble stone walls using mud mortar as well as cement mortars is dealt in this Guide. The earthquake resistant design principles as covered in Part A are made use of in working out the various design and construction details.

4.C OPTIONS FOR WALL TYPES

The following wall types are normally used in stone-building construction.

	Type of wall	*Seismic Safety Grading*
(i)	Random rubble stone masonry in mud mortar.	Sixth
(ii)	Courses rubble stone masonry in mud mortar.	Fifth
(iii)	Random rubble stone masonry in cement mortar	Third
(iv)	Coursed rubble stone masonry in cement mortar	Second
(v)	Dressed stone (Ashlar) masonry in mud mortar	Fourth
(vi)	Dressed (Ashlar) stone masonry in cement mortar.	First

From earthquake safety point of view, the above walls may be graded as shown against each. Unfortunately, their costs also vary more or less similarly except dressed stone masonry in mud may come second in order. In place of cement – sand mortar, appropriate mix of cement – lime – sand mortar may also be used if found economical and feasible.

Note: Dressed (Ashlar) stone masonry walls behave similar to other rectangular building units, such as bricks, and concrete blocks, and were dealt with in Part B of the Guidelines, hence not covered here.

5.C OPTIONS FOR ROOF AND FLOOR TYPES

There are three main type of roofs and floors adopted in houses using stone masonry in Afghanistan. These are

1) Wood logs supporting reeds or wooden planks, topped with earth fill
2) Sawn wood joists with wooden planks topped with earth fill
3) Masonry domes

There is no tradition of using sloping roofs with light covering such as burnt clay tiles or sheet roofing. The main reasons may be the extreme temperature conditions under which such light roofs will not provide the necessary comfort which is admirably provided by earthen roofs of various types as mentioned above. Therefore the appropriate options of roofs and floors may be as follows:

A. Flat Roof Types

(i) Wood joist/log type traditional system with improvement
(ii) RC joist replacing wood joists/logs
(iii) Reinforced concrete joists + Precast RC planks + RC screed + earth cover
(iv) Cast in situ RC slabs with earth cover for insulation

The roof should have adequate slope for free drainage of rain water.

B. Choice of Floor Types

The same systems as stated above will be suitable for floors also except that instead of thick earth insulation, the finishing may be done with thinner layer of brick tiles, clay mud or plain concrete.

6.C REQUIRED EARTHQUAKE SAFETY PROVISIONS

For the Seismic Zones AB, C & D (M.M. Intensity VIII or higher, Int. VII and Int. VI respectively) the following safety provisions are specified.

6.1.C Building Categorisation (as per IS: 4326-1993)

In accordance with the value of the design seismic coefficient (See Part A, 6.2.A), the Building Category may be taken as follows for selecting earthquake resistance features:

Table 1C : Building Categories

	Zone D	Zone C	Zone AB
Housing	B	C	D
Community Buildings	C	D	E

6.2.C Measures for Achieving Seismic Safety

6.2.1.C For all Building Categories **B** to **E**

In all seismic zones, the following measures should be adopted as per IS-4326 for masonry walls of all types.

(i) Control on length, height and the thickness of walls in a room.
(ii) Control on size and location of openings.
(iii) Control on material strength and quality of construction.

6.2.2.C Additional for all building categories **C** to **E**

(iv) Seismic band at plinth level (may be omitted if founded on rock or hard soil)
(v) Seismic band at door-window lintel level in all cases.

Where flat roof is adopted:

(vi) Seismic band at ceiling level of floors or roofs consisting of joisted roofs or jointed prefab elements.
(vii) Stiffening of prefab elements in roofs/floor where used (using peripheral seismic band and RC screed integrated together).

If and where sloping/pitched roof is used:

(viii) Seismic band at eave level of sloping roofs.
(ix) Seismic band at top of gable wall and ridge wall top.
(x) Bracing in roof structure of trussed as well as raftered roofs.

6.2.3.C Additional measures for 2-3 storeyed buildings of Category C and all buildings of Category D or E.

(xi) Seismic band or dowels at corners and T-junctions at window sill level.

(xii) Vertical steel reinforcing bars at jambs of doors and large windows.

Note: *The vertical reinforcement at jambs of small windows and ventilators (say 600 mm x 600 mm or less) may be omitted.*

7.C FOUNDATIONS

7.1.C New Foundations

7.1.1.C Rocky Ground

Weathered, jointed and fissured rock may be leveled by chiseling, in steps of about 150 mm and stepped strip footing built on it, with the foundation width of 600 mm for two storeyed houses. Boulder site may be leveled by removing small boulders but leaving large boulders in place. If the rock is massive, the surface should be roughened by chiseling and stepped-strip footing built on it. In all cases, the base concrete of sufficient thickness (with a minimum of 100 mm) should be used for leveling before starting the masonry.

7.1.2.C Soil Site

Use stepped-strip foundation with minimum depth of 750 mm below ground level and width of 700 mm (upto 2 storeyed houses), Fig. 1C. For each additional storey, increase width by 300 mm. The footing masonry should be brought in steps upto the plinth level.

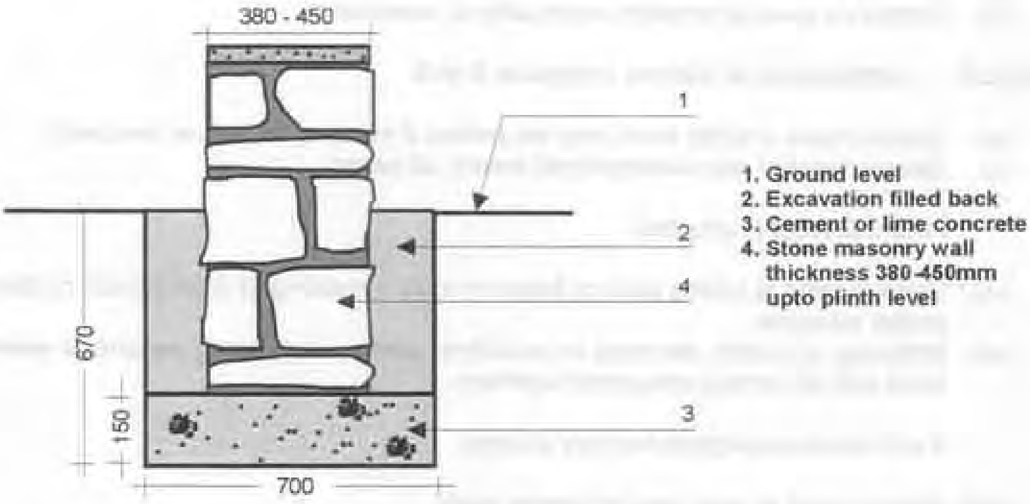


Fig. 1C Strip foundation on soil sites.

7.2.C Use of Existing Old Foundation

Houses of pre-damage dimensions and heights could be built on existing foundation constructed in stone laid in compacted sand or mud mortar. The existing foundation may be excavated to about 230 mm below ground level where base concrete 150 mm thick in 1:4:8 mix is to be cast on the existing lower part of the footing (Fig. 2C).

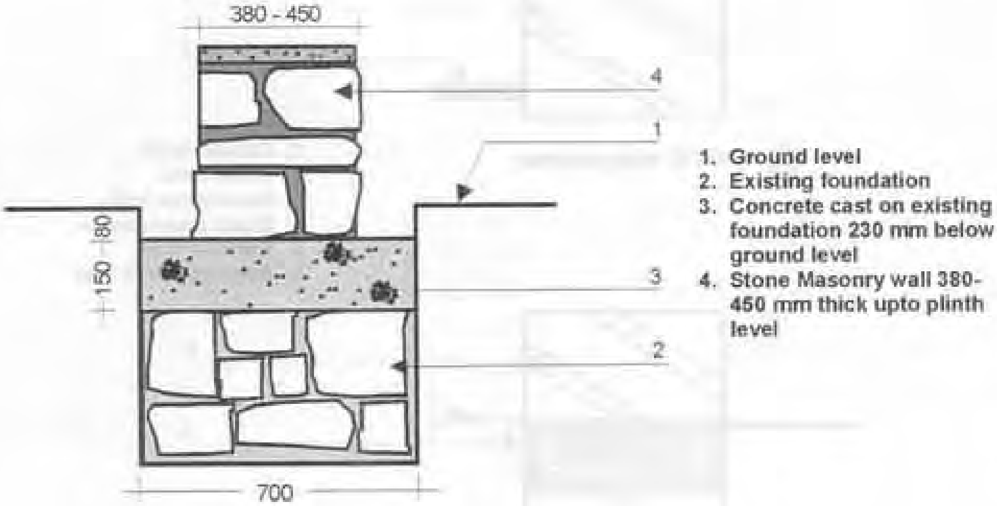


Fig. 2C Strip Footing on Existing Foundation.

8.C TREATMENT AT PLINTH LEVEL

This will depend on site-soil condition as follows:

a. Rocky Ground

The seismic band is not required. Use damp-proof course (D.P.C.) as usual on the strip foundation. It may be cement-sand mortar of 1:3 mix 25mm thick or 1:2:3 micro concrete 38mm thick, with damp proofing compound mixed in each case (See Fig. 3C).

b. Boulder or Soil Site

In each case, use RC seismic band of 75 to 100mm thickness (See Fig. 9C for detail of the band).

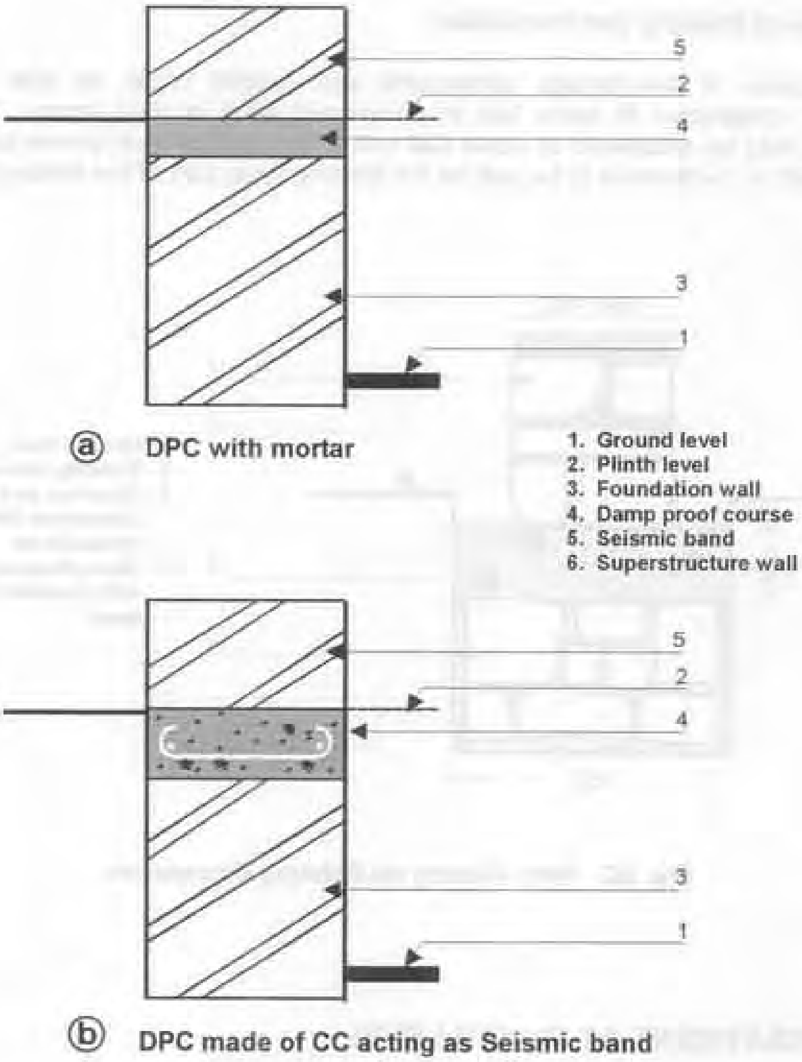


Fig. 3C DPC Alternatives

9.C STONE MASONRY WALLS IN MUD MORTAR

Stone masonry walls built using mud mortar and other details as given in the following paras, could be used for *housing only*, for reasons of affordability or non-availability of cement supply. Stone masonry in mud should not be used for community buildings such as schools, hospitals, mosques, etc.

9.1.C Construction Control

(i) The mortar should be clay mud of good quality.

(ii) The wall thickness 't' should preferably be kept 450mm, but not to be larger than 500mm. In any case, the stones of the inner and outer wythes should be interlocked with each other as far as possible.

(iii) The masonry should preferably be brought to courses at not more than 600 mm lift so as to achieve 'coursed rubble masonry'.

(iv) 'Through' stones of full length equal to wall thickness should be used in every 600 mm lift at not more than 1.2m apart horizontally (Fig. 4C).

(v) In place of 'through' stones, 'bonding elements' of concrete bars of 50mm x 50mm section with an 8mm dia rod placed centrally or solid concrete blocks of 150 x 150 x 'wall thickness size' may be used. (Fig. 4C). Alternatively, tree branches of 60 mm dia, or seasoned wooden battens of 50 mm x 50 mm size may be used as bonding element.

(vi) Long stones of 600 mm length or solid concrete blocks of 150 x 150 x 600 mm size should be used at wall corners and T-junctions every 600 mm height to connect the perpendicular walls effectively (Fig. 4C). Alternatively, branches of 65 mm dia, or seasoned wooden batten of 60 mm x 60 mm size may be used.

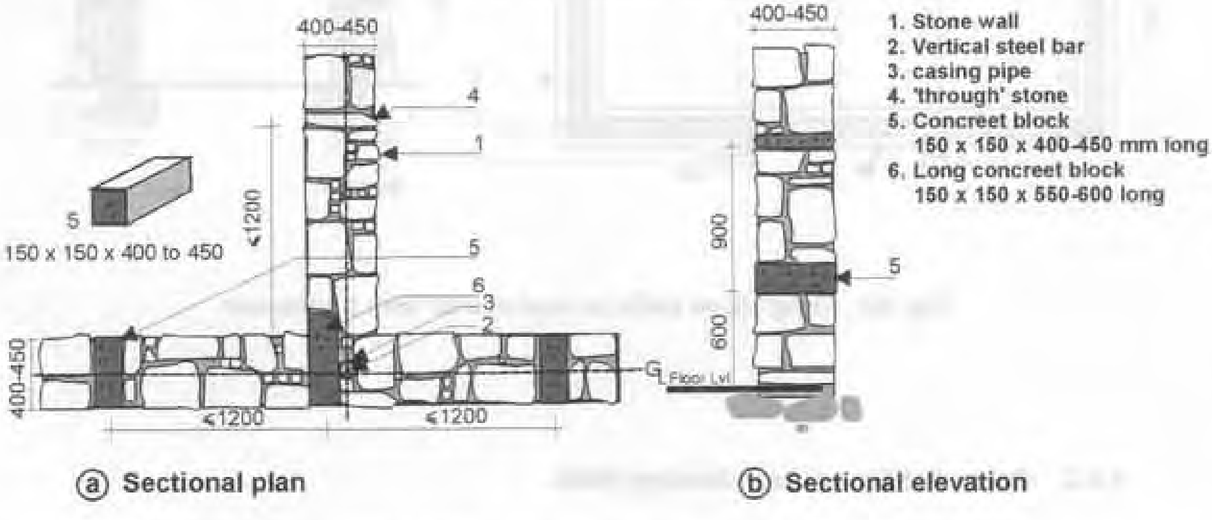


Fig. 4C 'Through' stone or bond elements in stone wall built in mud mortar

9.2.C Control on Wall Length and Building Height

Height of the coursed rubble masonry walls in mud mortar should be restricted, with storey height to be kept 2.7m maximum, and span of walls between cross walls to be limited to 5.0 m as follows:

In Zones C and D: preferably upto two storeys, but not more than three storeys in any case.

In Zone AB: preferably One storey but not more than two storeys in any case.

If walls longer than 5m are needed, pilasters or buttresses may be used at intermediate points not farther apart than 3.5m. The size of the pilaster or buttress be kept of uniform thickness with top width equal to the thickness of main wall 't' and the base width equal to t or one sixth of wall height. See Fig. 5C.

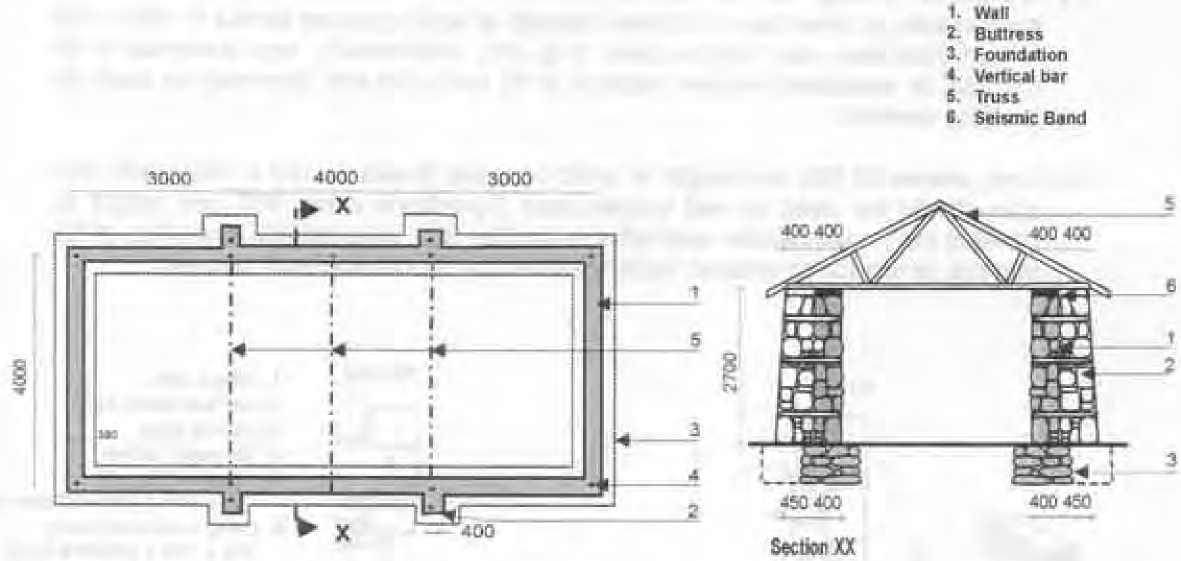


Fig. 5C Long stone walls in mud mortar with buttresses

9.3.C Control of Openings in Bearing Walls

For coursed rubble stone masonry built in mud mortar, the door and window opening may be located in the walls as follows (Fig. 6C).

Total length of openings in a wall = 0.33 of wall length in Category D and E and 0.42 in Category C buildings.

Distance of opening from inside corner: $b_5 \geq 600$ mm in Cat. D & E and 450 mm in Cat. C building

Pier width between consecutive openings ≥600mm

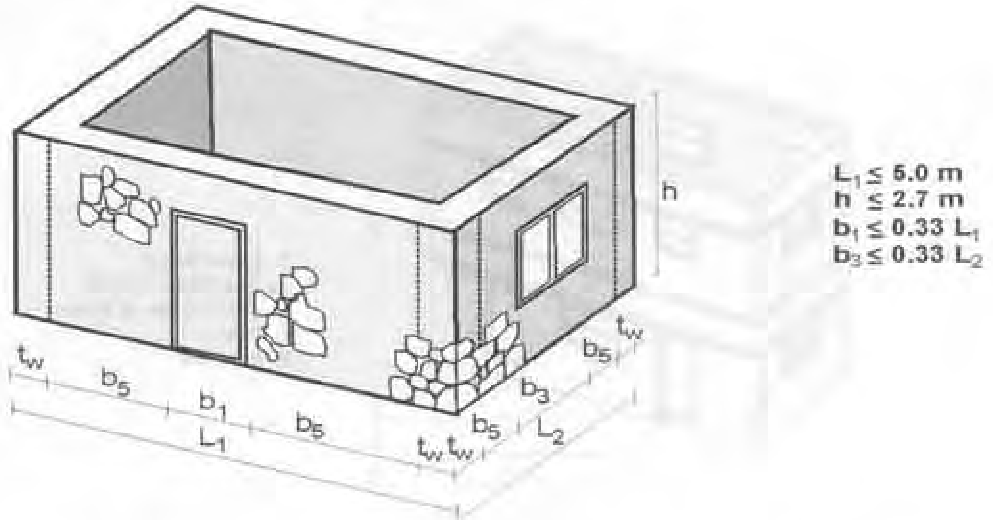


Fig. 6C Control on length, height and openings in stone walls built in mud mortar

9.4.C Seismic Bands

The overall arrangement of seismic reinforcing of masonry buildings is shown in Fig. 8C for buildings with flat roof and in Fig. 8C for building with sloping roof consisting of horizontal seismic brands and vertical bars. The seismic bands at various critical sections shall be as follows:

(i) Seismic bands at plinth, and lintel, ceiling levels in buildings with flat roof will be provided in all internal and external walls continuously without break in all storeys. Requirement of reinforcing bars in RC bands are given in Table 2C and the details of bands are shown in Fig. 9C.

(ii) In case of sloping roofs, triangular gable walls must be enclosed within eave level band and a band at the top of the gable wall. These bands must be made monolithic and continuous as shown in Fig. 10C.

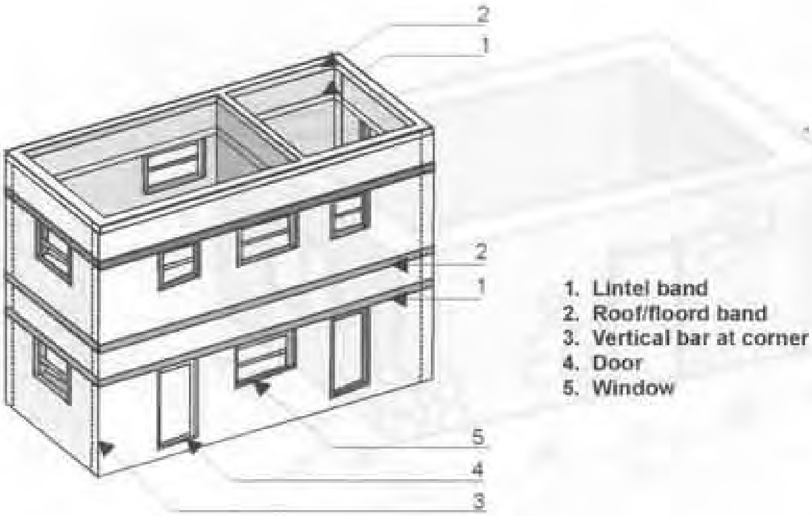


Fig. 7C Overall arrangement of earthquake resisting elements in double storeyed houses having flat roof (Roof not shown)

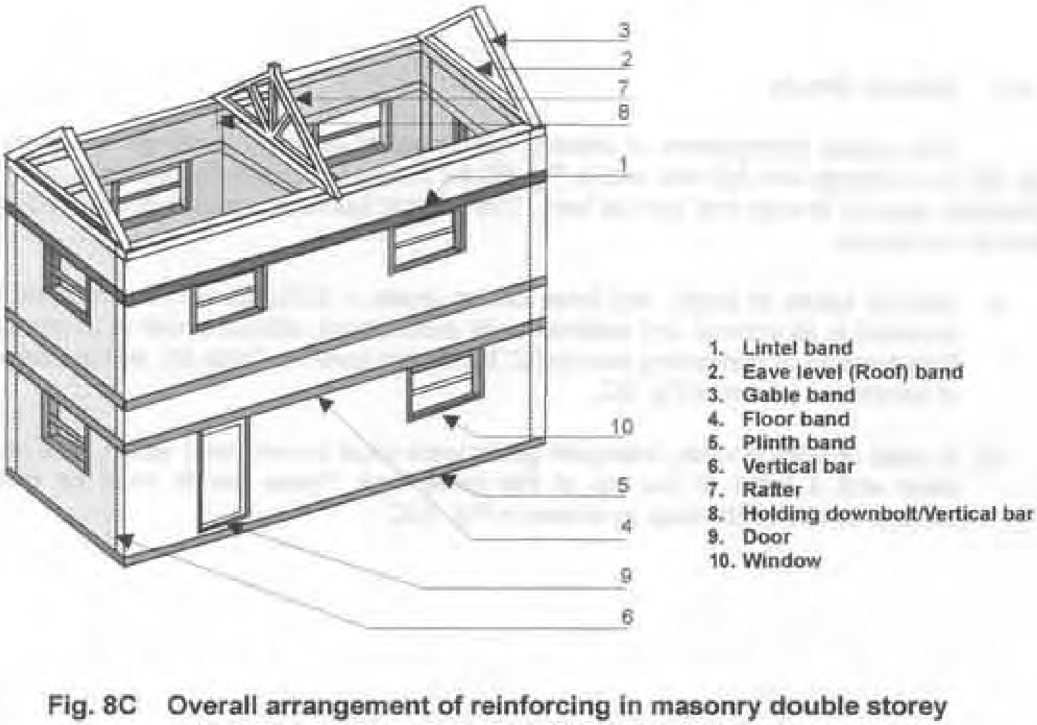


Fig. 8C Overall arrangement of reinforcing in masonry double storey building having pitched roof (Roof not shown)

Table 2C : Longitudinal Bars* in RC Bands (Stone Masonry in Mud or Cement Mortar)

Length of wall in room (m)	Reinforcing Bars in Building Categories							
	Cat. B		Cat. C		Cat. D		Cat. E	
	No	Dia (mm)	No	Dia (mm)	No	Dia (mm)	No	Dia (mm)
≤ 5	2	8	2	8	2	8	2	10
6	2	8	2	8	2	10	2	12
7	2	8	2	10	2	12	4	10

**High Strength Deformed (Tor) bars*

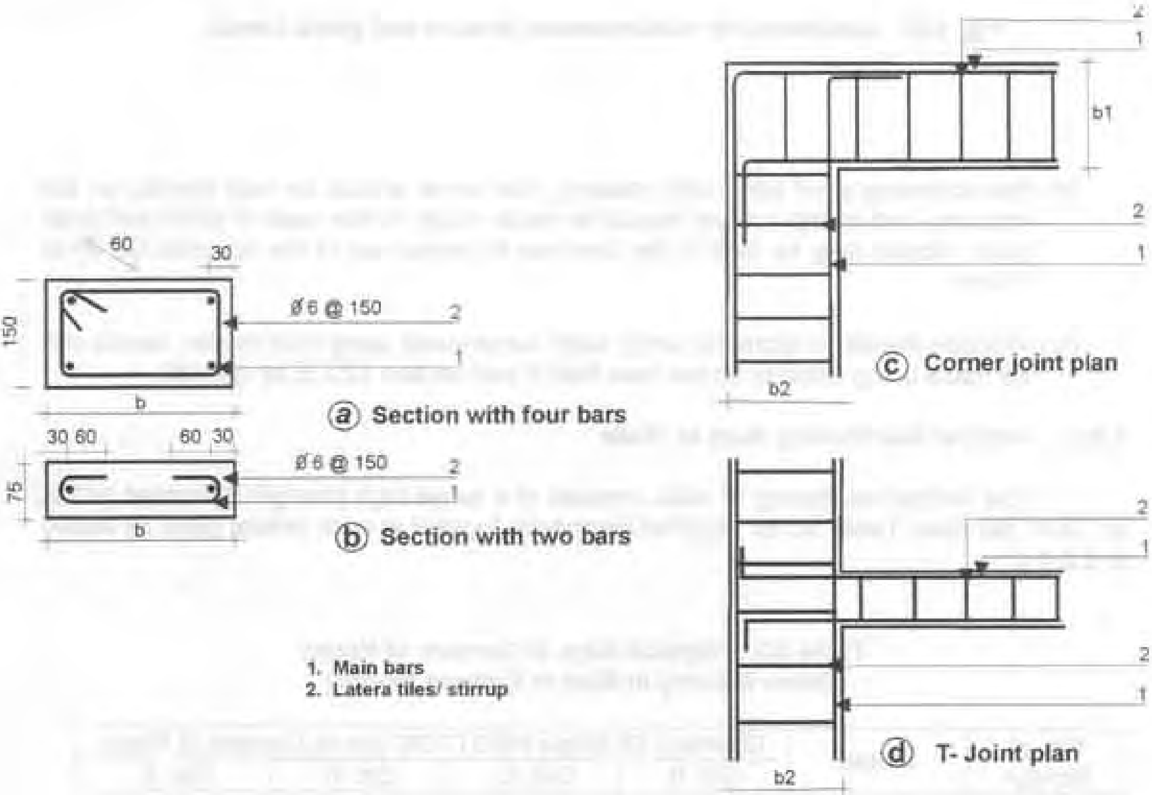


Fig. 9C Longitudinal Bars and links/stirrups in R.C. Bands

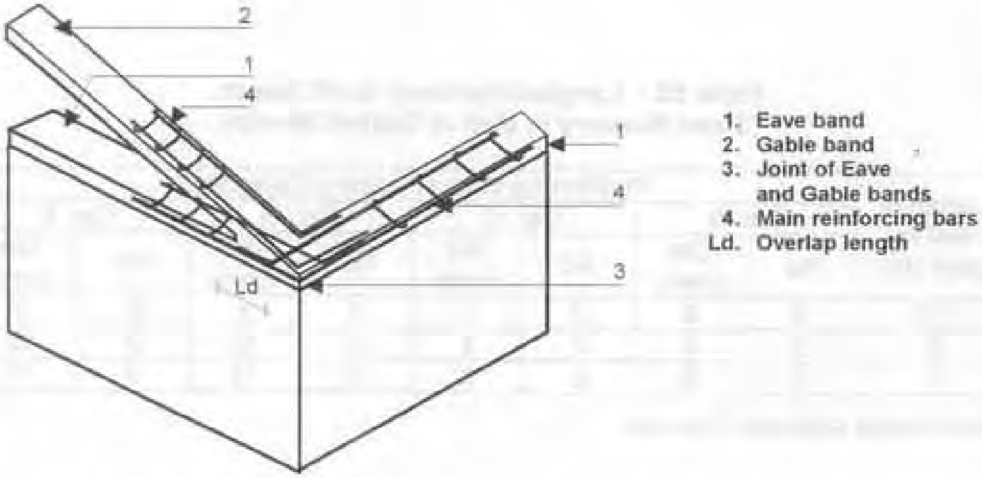


Fig. 10C Continuity of reinforcement in eave and gable bands.

(iii) For achieving good bond with masonry, the bands should be cast directly on the masonry and its top surface should be made rough. In the case of plinth and lintel band, stones may be cast in the concrete to project out of the concrete by 50 to 75mm.

(iv) *Wooden Bands*. In stone (or brick) walls constructed using *mud* mortar, bands can be made using wood or timber (see Part E sub-section 12.2.E for details).

9.5.C Vertical Reinforcing Bars in Walls

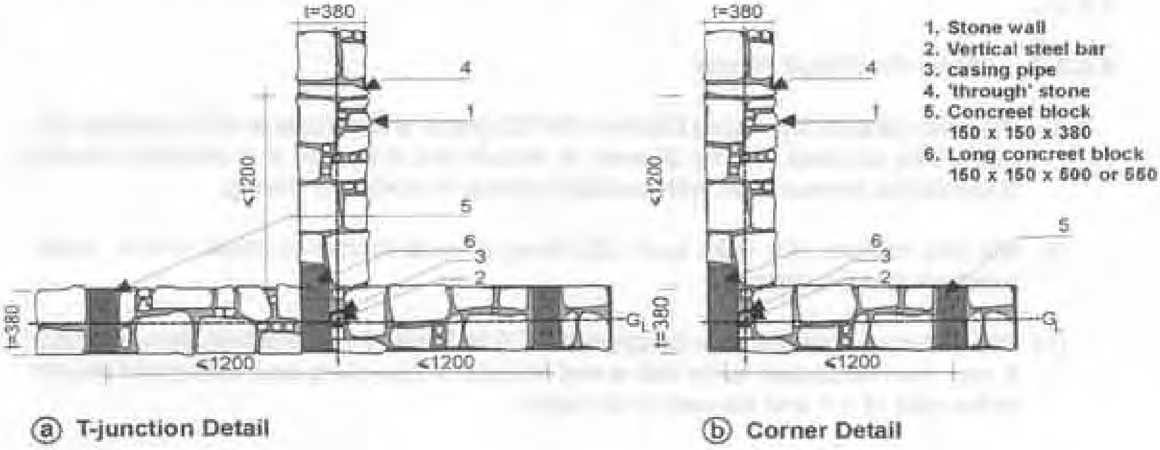
The vertical reinforcing of walls consists of a single high strength deformed (HSD) or 'TOR' bar (See Table 3C for required diameters) located at each critical point as stated in 6.2.3.C.

Table 3C : Vertical Bars at Corners of Room (Stone Msonry in Mud or Cement Mortar)

No. of Storeys	Storey	Diameter Of Single HSD (TOR) Bar at Corners of Room			
		Cat. B.	Cat. C.	Cat. D	Cat. E.
One	—	—	—	10	12
Two	Top	—	10	10	12
	Bottom	—	10	12	16
Three	Top	10	10	Three storeyed building, nor permitted in mud mortar	
	Middle	10	10		
	Bottom	10	12		

9.5.1.C Installation of Vertical Bars

For installations of vertical bars in stone masonry, use of PVC casing pipe of 100mm external dia, 600-750 mm long is recommended around which masonry be built to height 450-600mm (see Fig. 11C) and the pipe made loose by gently rotating. As the masonry hardens, the pipe is raised and the cavity filled with M20 concrete (nominal mix of 1:1.5:3) and fully compacted by rodding using 12mm dia and 600mm long bar.



t = 380 for cement mortar, 450 for mud mortar

Fig. 11C Installing vertical steel bars in stone masonry walls

9.5.2.C Keeping the Bar Vertical

Before casting the foundation, the vertical bars must be kept in correct in position horizontally and vertically. For this purpose tripods may be erected using bamboos or spare reinforcing bars (See Fig. 12C).

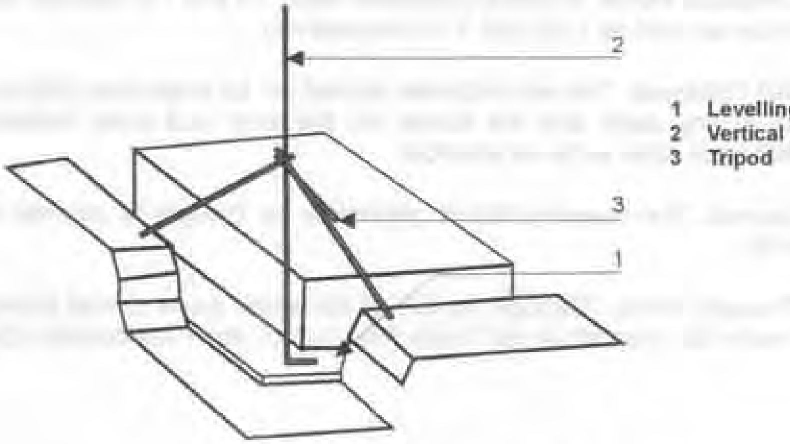


Fig. 12C Keeping the bar vertical

9.6.C Water Proofing

9.6.1.C For protection of external walls against damage by water

(i) Take out roof projection beyond the walls by about 300mm, and

(ii) Use cement-sand mortar pointing on external face of walls; *OR*

Use waterproof mud plaster on external face of walls, which may be done as per 9.6.2.C.

9.6.2.C Water Proof Mud Plaster

(i) Prepare cut-back by mixing bitumen 80/100 grade and kerosene oil in the ratio 5:1. For 1.8 kg cut-back, 1.5 kg bitumen is melted and is poured in a container having 300-millilitre kerosene oil, with constant stirring till complete mixing.

(ii) Mix this mixture with 0.03 cu.m (30 litres) of mud mortar to make it both, water repellent and fire resistant.

(iii) The waterproof plaster is to be applied in 20 to 25mm thickness and allowed to dry. It may then be coated twice with a wet mixture of cow-dung and waterproof plaster in the ratio of 1:1 and allowed to dry again.

10.C STONE MASONRY USING CEMENT MORTAR

Stone masonry using cement mortar and other details as set out in the following paras may be used for all building categories in the area.

10.1.C Construction Control

10.1.1.C *Mortar.* The mortar in superstructure masonry should be cement-sand (1:6 in zones C & D and 1:4 zone AB).

In the foundation masonry upto plinth, the mix 1:6 may be kept in all cases.

10.1.2.C *Composite Mortar.* In place of cement–sand 1:6 and 1:4 mortars, cement–lime–sand mortar may be used as 1:2:9 and 1:1:6 respectively.

10.1.3.C *Wall Thickness.* The wall thickness should not be larger than 380 mm (not more than 450 mm in any case) and the stones on the inner and outer wythes should be interlocked with each other as far as possible.

10.1.4.C *Coursed.* The masonry should preferably be brought to courses at not more than 600 mm lift.

10.1.5.C *'Through' Stone'* 'Through' stones of full length equal to wall thickness should be used in every 600 mm lift at not more than 1.2 m apart horizontally (Detail as per Fig.13C)

In place of 'through' stones, 'bonding elements' of concrete bars of 50mm x 50mm section with an 8 mm dia rod placed centrally or solid concrete blocks of 150 x 150 x walls thickness, can also be used.

10.1.6.C *Corner Stones.* Long stones of 500-600mm length should be used at wall corners and T-junctions of walls. Alternatively use of 150x150x(500 to 600) solid concrete blocks to connect the perpendicular walls effectively (Detail as per Fig.13C).

10.2.C Control on Wall Length and Building Height

10.2.1.C Height

The height of the coursed-rubble masonry walls in cement mortar should be restricted as follows:

(i) *For Categories C and D* : Three storeys with flat roof or two storey plus attic.

(ii) *For Categories D and E* : Two storeys with flat roof or one storeys plus attic for pitched roof.

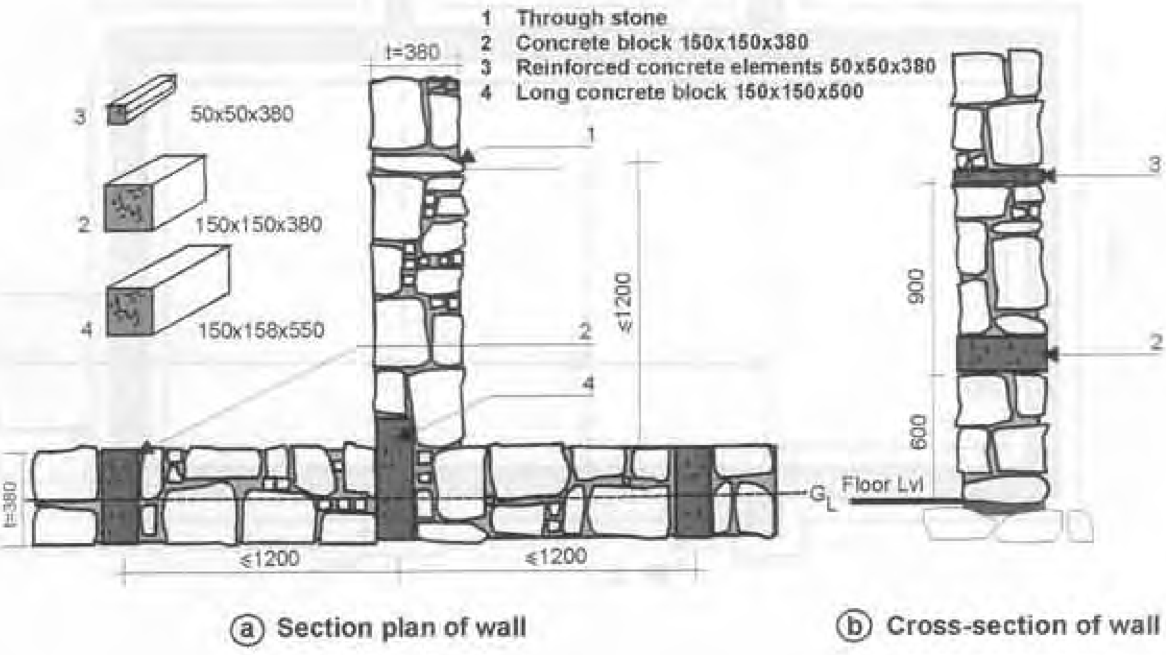
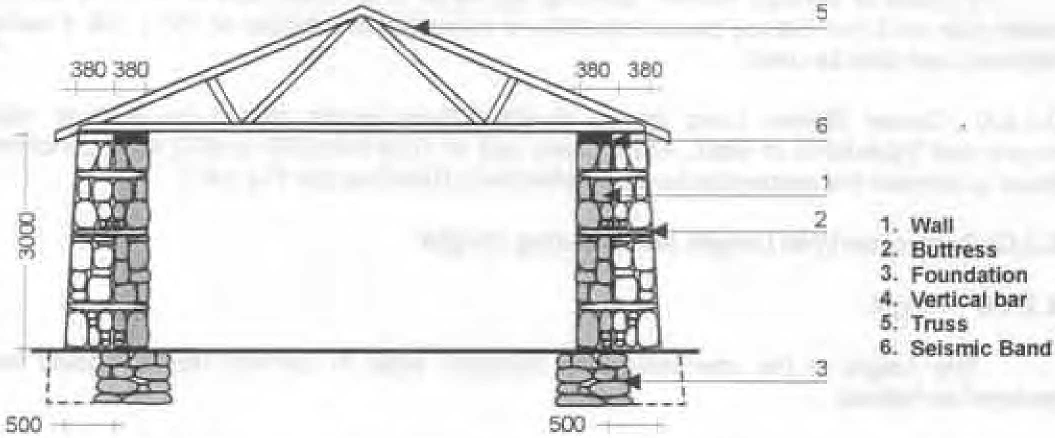


Fig. 13C 'Through' stones and bond elements (element mortar)

The storey height to be kept 3.2m maximum, and span of walls between cross walls to be limited to 7.0m. If rooms longer than 7m are needed, buttresses may be used at intermediate points not farther apart than 5.0m. The size of the buttress be kept of uniform thickness with top width equal to the thickness of main wall and the base width equal to one sixth of wall height. (See Fig. 14C for arrangement of pilasters or buttresses).



Section XX

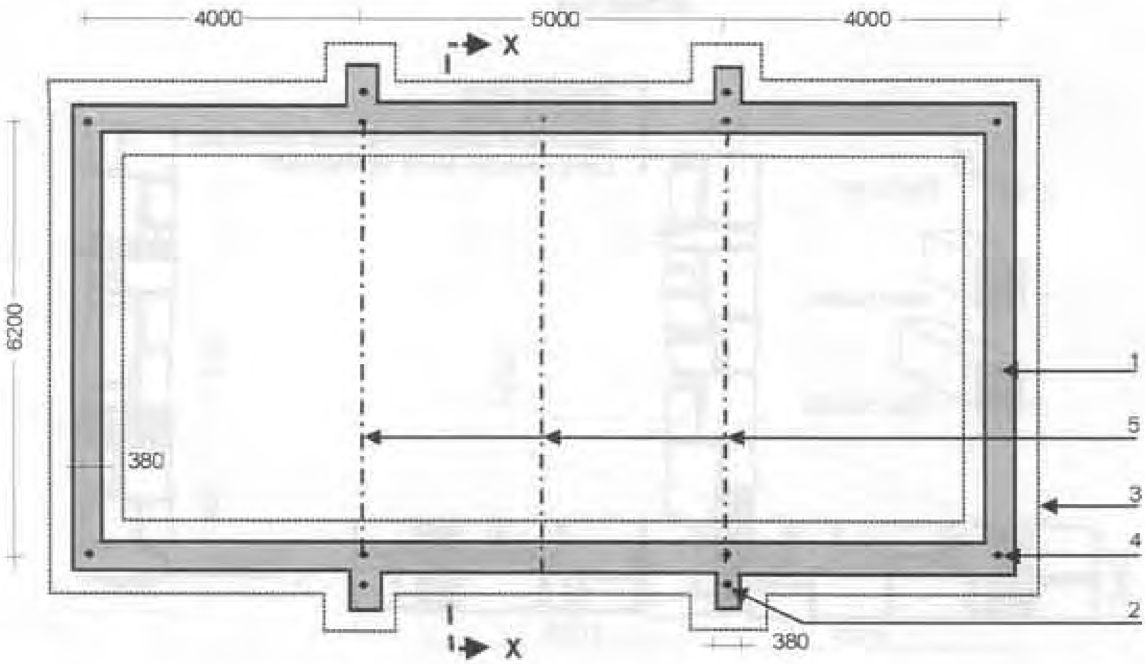


Fig. 14C Long walls with buttresses (cement mortar)

10.3.C Control of Openings in Bearing Walls

For stone masonry built in cement mortar and brought to courses, the door and window openings should be controlled as follows: (Fig. 15C).

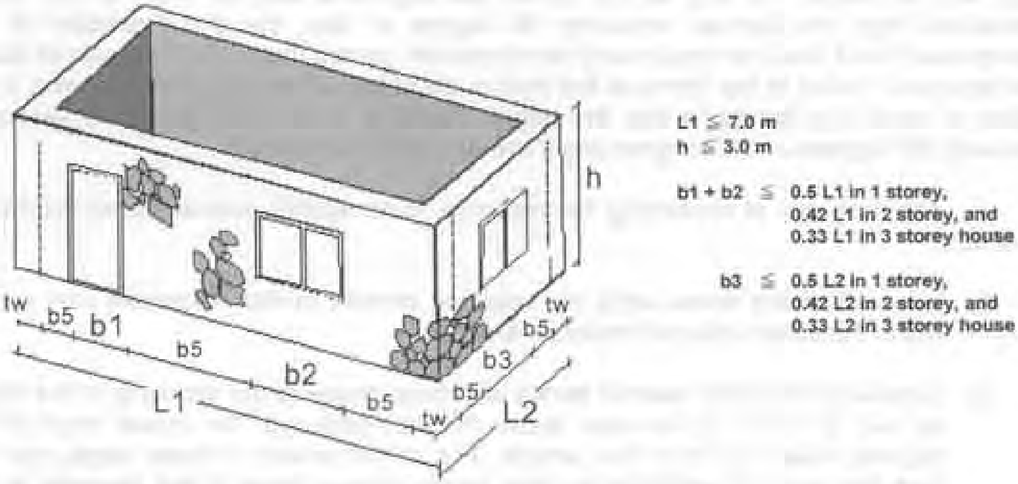


Fig. 15C Control on length, height and openings of wall (cement mortar)

Ratio of total length of openings in a wall to length of the wall in a room should not exceed 0.5 in single storeyed, 0.42 in 2-storeyed and 0.33 in 3 storeyed buildings.

Distance of opening from inside corner	≥	450mm
Pier width between consecutive openings	≥	600mm

10.4.C Seismic Bands

The seismic bands at various critical sections should be as provided in sub-para 9.4.C (Figs. 9C, 10C).

10.5.C Vertical Reinforcement

The vertical bars to be provided at corners of rooms and the jambs of large openings should be as specified in 9.5.C (See Figs. 11C, 12C).

11.C FLOORS AND ROOF

The construction of floors and roofs with earthquake resisting features as described in Part B Section 13.B will be suitable for use in stone masonry buildings.

12.C MASONRY DOME

The masonry domes are usually made of Hemispherical or segmental shape, which could cover large column free spaces. In most cases the domes are without any opening but some times an opening of cylindrical shape is created near the crown with a cover at the top, and vents on the sides. This is called the 'lantern' which permits entry of light and ventilation. So long as the domes are segmental with the angle of the radius measured from the vertical remaining 50 degree or less, the dome remains in the compression and does not require any reinforcement, except that a *hoop* capable of taking the horizontal thrust of the dome at the bottom periphery will be required. However if the dome is made fully hemispherical, the edges becoming vertical, the portion of the dome between 50 degrees and 90 degree angle comes under hoop tension.

The best way of reinforcing the masonry dome against seismic forces will be as follows:

(i) to construct the dome using the specified cement mortar *or* cement lime mortar mix in the construction of masonry, and

(ii) to provide horizontal seismic bands of circular shape at the springing of the dome as well as every six courses above the springing upto the critical angle of 50 degrees measured from the vertical. The reinforcement in these bands may be kept the same as specified for lintel bands of span equal to the diameter of the dome.

13.C PARAPETS

The suggestions given in Part B, Section 14B may be followed.

PART D

Repair, Restoration and Seismic Retrofitting of Masonry Buildings

CONTENTS - PART D

1.D INTRODUCTION

In the last twelve years, Afghanistan has suffered severe to moderate building damages from three earthquakes in 1991, 1998 and 2002 which killed in all, more than 10,000 persons, in several villages. Besides, thousands of buildings have been damaged during two decades of civil strife in the country. Whereas there is need for reconstruction of collapsed or severely damaged buildings, repairing and retrofitting of moderately damaged buildings will be a time saving and economical option instead of their demolition and reconstruction.

People are killed or badly injured during strong ground shaking in stone masonry buildings in villages as well as in towns because of the following contributing factors:

a) poorly constructed buildings, collapsing either totally or partially;
b) walls collapsing within narrow streets, burying people escaping into them;
c) untied roofs and cantilevers falling onto people;
d) free standing high boundary walls, parapets and balconies falling due to the sever shaking.

Many times, buildings which are standing in damaged condition with cracks of minor to major width and extent, are repaired superficially, that is, with cosmetic repairs. When this is done, these buildings will remain very vulnerable to severe damage in future earthquakes due to the hidden cracks in the walls.

The purpose of these guidelines is to address the issues of repair, restoration and seismic retrofitting of various types of *masonry buildings*.

2.D OBJECTIVES AND SCOPE

These guidelines have the following objectives;

(i) To indicate appropriate methods of repair and restoration taking into account the building type and the type of damage.
(ii) To recommend methods of seismic strengthening to upgrade the strength of the buildings in line with the requirements of the seismic-zoning map of Afghanistan (See Part A) and Earthquake Resistance Codes of India (IS : 4326-1993) and (IS:13828-1993).

The retrofitting measures are worked out here for safety of existing damaged or undamaged buildings in future MSK Intensity occurrences in the various seismic zones.

The masonry buildings will include: Walls of brickwork, random rubble stone masonry and cut stone masonry whether used for housing or community buildings.

3.D CATEGORISATION OF DAMAGE

As specified usually in the MSK Intensity scale, five Grades of damage are recognized and named as G1 to G5; G1 referring to very slight damage without loss of structural strength and G5 referring to complete collapse of the building (See Table 2A in Part A). Description of these Grades of damage as applicable to masonry buildings is presented in Table 1D for ready reference. So far as repair, restoration of structural strength and seismic strengthening to meet the codal requirements are concerned, Grades G1 to G3 are most relevant, since buildings or parts thereof subjected to Grades G4 and G5 in most cases have to be demolished and rebuilt.

4.D CONCEPTS OF REPAIR, RESTORATION AND RETROFITTING

There is a need to distinguish between the terms *repair*, *restoration* and *strengthening* as described below:

4.1.D Repair

It consists of *actions taken for patching up superficial defects*, re-plastering walls, repairing doors and windows and services such as the following:

i) Patching up of defects as cracks and fall of plaster and re-plastering if needed.
ii) Repairing doors, windows and replacement of glass panes.

Table 1D : Damage Grades*

	Category	Walls *	Roof / Floors
0	No Damage	No Damage	No Damage
G1	Slight Non-Structural Damage	Thin cracks in plaster, falling of plaster bits in limited parts.	Thin cracks in small areas, tiles only slightly disturbed.
G2	Slight Structural Damage	Small cracks in walls, falling of plaster in large areas : damage to non-structural parts like *chhajjas*, parapets.	Small cracks in slabs/ A.C. sheets; tiles disturbed in about 10% area; minor damage in under-structure of sloping roof.
G3	Moderate Structural Damage	Large and deep cracks in walls; widespread cracking of walls, columns and piers; or collaps of one wall. The load carrying capacity of structure is partially reduced.	Large cracks inslabs; some AC sheets, broken; upto 25% tiles disturbed/fallen moderate damage to understructure of sloping roofs.
G4	Severe Structural Damage	Gaps occur in walls; two or more inner or outer walls collapse; Approximately fifty percent of the main structural elements fail. The building takes a dangerous state.	Floors badly cracked, part may fall; under- structure of sloping roof heavily damaged, part may fall; tiles badly affected & fallen.
G5	Collapse	A large part or whole of the building collapses.	A large part or whole floor and roof collapse or hang precariously.

* *Based on I.A.E.E. Guidelines, further developed through observations in earthquakes in India, by Dr. A.S. Arya, Professor Emeritus, Deptt. of Earthquake Engineering, Indian Institute of Technology, Roorkee, Roorkee.*

iii) Checking and repairing electrical connections, gas connections, plumbing, heating, ventilation etc.
iv) Rebuilding non-structural walls, chimneys, boundary walls.
v) Relaying cracked flooring at ground level and roofing sheets or tiles.
vi) Redecoration work (White or colour washing etc.)

It would be seen that *the repairing work carried out as above does not add any strength to the structure.*

4.2.D Restoration

This includes *actions taken for restoring the lost strength of structural elements of the building.* This is done by making the columns, piers, beams and walls at least as strong as originally provided as follows:

i) Removal of portions of cracked masonry walls and piers, and rebuilding them in richer mortar. Use of non-shrinking mortar will be preferable.
ii) Addition of reinforcing mesh on both faces of the cracked wall, holding it to the wall through spikes or bolts and then covering it suitably with micro-concrete or 1:3 cement -coarse sand plaster.
iii) Injecting neat cement slurry or epoxy like material, which is strong in tension, into the cracks in walls, columns, beams etc.

If the structural restoration is properly executed, the structure will be as strong as before the earthquake. It is also possible to strengthen a structure to take increased vertical loading, if required.

4.3.D Seismic Strengthening (Retrofitting)

It will involve *actions for upgrading the seismic resistance of an existing building so that it becomes safer under the occurrence of probable future earthquakes.*

The seismic behaviour of existing buildings is affected by their original structural inadequacies, material degradation due to aging and alterations carried out during use over time. The complete replacement of such buildings in a given area is just not possible due to a number of social, cultural and financial problems. Therefore, seismic strengthening of existing undamaged or damaged buildings is a definite requirement. Seismic strengthening *including* structural restoration and cosmetic repairs may some times cost upto 25 to 30 per cent of the cost of rebuilding although usually it may not exceed 12 to 15 per cent. Hence justification of strengthening work must be fully considered from cost point of view. The main items of seismic strengthening could be some or all of the following actions:

i) Modification of roofs,
ii) Substitution or strengthening of floors,
iii) Modification in the building plan,
iv) Strengthening of walls including provision of horizontal and vertical bands or belts, introduction of 'through' or header stones in thick stone walls, and injection grouting etc.,
v) Adding to the sections of beams and columns by casing or jacketing etc.,
vi) Adding shear walls or diagonal bracings,
vii) Strengthening of foundations if found necessary (but very difficult and expensive).

5.D ASSESSMENT OF DAMAGE

The buildings to the restored and repaired should be thoroughly surveyed and various damages should be recorded on scaled drawings. The width and length of each damage needs to the record to as to estimate the required materials and labour for restoration and repair properly.

It should also be assessed if during the process of restoration, some of the service lines will need to be disturbed, and their temporary bypassing may be needed. The expenses should be included in the estimates.

6.D USUAL DAMAGE TYPES IN MASONRY BUILDINGS

The types of damage generally observed in various masonry buildings during the earthquake are listed in Table 2D. Alongside, the actions to be taken for restoration of the lost strength are also suggested. Details of each such action are described in the following paragraphs.

Table 2D : Types of Damage in Masonry Buildings

	Damage Observed		Action for Restoration
a)	Different types of cracks seen in masonry walls i. Vertical cracks ii. Inclined cracks iii. Cracks at the corners or T-junctions, and separation of the cross-walls	i,ii. iii.	Cracks to be fully filled using appropriate grout or mortar. Cracks at the corners or T-junctions to be filled as above but before that the walls at right angles to be connected using ferro-cement corner plates.
b)	At some places, occurrence of many cracks close together in the walls, OR tilting of some wall portions out of plumb after Separation, OR bulging of stone wall after delamination, OR falling of some wall portions.	b)	This type of cracked, fallen, tilted or bulged wall portion to be reconstructed using mortar, richer than originally used, after partial partial demolition of wall as required.
c)	Shifting of roofing joists or rafters OR falling down and being broken	c)	The covering tiles to be removed for further work and the joints/logs/rafters to be properly positioned.

7.D METHODOLOGY FOR GROUTING OF CRACKS

For grouting of cracks in any masonry wall, the *grout* has to be chosen appropriately to suit the mortar used in the masonry.

For masonry done in cement-sand or lime mortars, the grout may consist of cement slurry made from *Non-shrink* cement and water in the ratio of 1:1 by volume.

For masonry in mud mortar, the grout may be made using *non-shrink* cement + sandy soil + fine sand mix in the proportions in 1:1:3 with enough water to make it into slurry. The soil and sand will be sieved through 0.5 mm sieve.

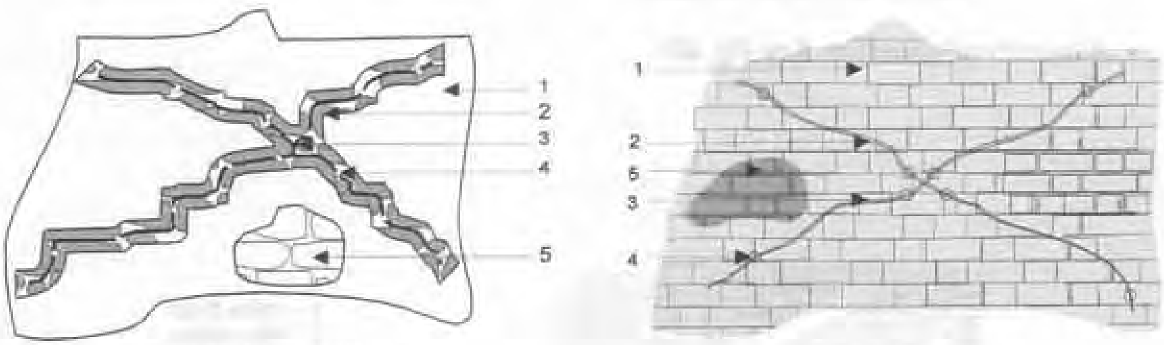
7.1.D Minor and medium cracks (crack width 0.5 mm to 5.0 mm)

Material/equipment required

(i) Plastic / Aluminium nipples of 12 mm dia (30 to 40 mm long).
(ii) Appropriate grout to be chosen.
(iii) Polyster putty or 1:3 cement sand mortar for sealing of the cracks.
(iv) Compressor for injecting the slurry or a container at a height of 1.2 to 1.5 m above the cracks with flexible hose pipe for flow of grout by gravity.

Procedure: See Fig. 1D

Step-1 Remove the plaster in the vicinity of crack exposing the cracked bare masonry.
Step-2 Make the shape of crack in the V-shape by chiselling out.
Step-3 Fix the grouting nipples in the V-groove on the faces of the wall at spacing of 150-200 mm c/c.
Step-4 Clean the crack with the Compressed air through nipples to ensure that the fine and loose material inside the cracked masonry has been removed.
Step-5 Seal the crack on both faces of the wall with polyster putty or cement mortar 1:3 (1-cement: 3-coarse sand) and allow to gain strength.
Step-6 Inject water starting with nipple fixed at higher level and moving down so that the dust inside the cracks is washed off and masonry is saturated with water. (Water injection should *not* be done in the case of mud mortar masonry).
Step-7 Start injecting the grout from lower most nipple till it comes out from the next higher nipple and then move to next higher nipple.
Step-8 After injection grouting through all the nipples is complected, replaster the surface and finish the same.



(a) **Stone wall** (b) **Brick wall**

1- Plaster
2- Plaster removed and cracks cleaned
3- Cracks sealed with mortar or putty
4- Grout ports
5- Plaster fallen to be done again

Fig. 1D Filling grout in cracks

7.2.D Major crack (crack width more than 5.0 mm)

Grout for masonry in cement or lime mortar may consist of non-shrink cement + sand in 1:3 proportion

Grout for masonry in mud may be kept as non shrink cement + sandy soil + sand in 1:1:3 proportion (soil and sand will be sieved through 1 mm sieve)

Material/equipment required for grouting

(i) Plastic/Aluminium nipples of 12 mm dia (30 to 40 mm long)
(ii) Polyester putty or 1:3 cement-sand mortar for sealing of cracks.
(iii) Appropriate Grout
(iv) Compressor for injecting the slurry.

Procedure:

Step-1 Remove the plaster in the vicinity of crack exposing the cracked bare masonry.
Step-2 Make the shape of crack in the V-shape by chiseling out.
Step-3 Clean the crack with compressed air.
Step-4 Fix the grouting nipples in the V-groove in both faces of the wall at spacing of 150-200 mm c/c.
Step-5 Clean the crack with the compressed air through nipples to ensure that the fine and loose material inside the cracked masonry has been removed.
Step-6 Seal the crack on both the faces of the wall with polyester putty or cement mortar 1:3 (1-cement:3-coarse sand) and allowed to gain strength.
Sept-7 Inject water starting with nipples fixed at higher level and moving down so that the dust inside the crack is washed off and masonry is saturated with water. (Water *not* to be injected in mud mortar masonry)
Step-8 Start injecting the grout from lower most nipple till the slurry comes out from the next higher nipple and then move to next higher nipple.
Step-9 After injection grouting through all the nipples is completed, replaster the surface and finish the same.

Alternative Procedure: See Fig. 2D

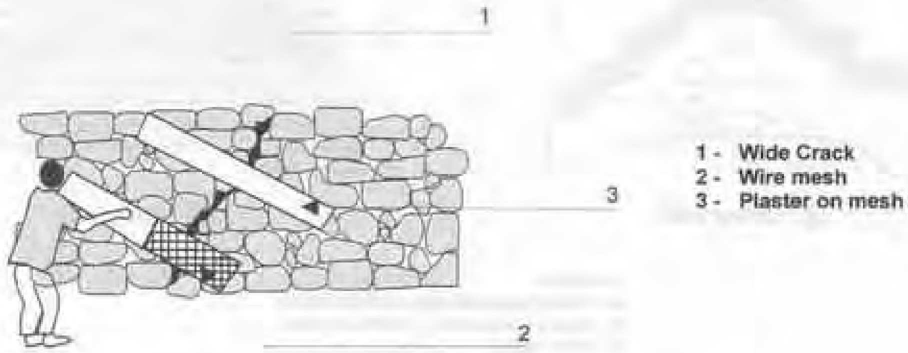


Fig. 2D Fixing mesh across wide cracks

Material required for ferrocement plate covering

(v) Galvanised steel wire fabric (16 to 14 gauge i.e. 1.5 to 2.03mm dia wire) with 25 mm x 25 mm mesh size.

(vi) Galvanised steel clamping rod of 3.15 mm dia, or 5 mm dia 150 mm long wire nails.

Step-1 Remove the plaster in the vicinity of crack exposing the cracked bare masonry.

Step-2 Make the shape of crack in the V-shape by chiseling out.

Step-3 Clean the crack with compressed air.

Step-4 Fill the crack with cement mortar 1:3+water (1-non shrink cement : 3 sand : necessary water) from both sides as deep as feasible.

Step-5 Provide wire mesh on both the faces of wall after removal of plaster in the region of repair to a width of 150 mm on each side of the crack.

Step-6 Clamp the mesh with the wall using clamps or wire nails at the spacing of 300 mm c/c.

Step-7 Plaster the meshed area with cement sand mortar of 1:3, covering the mesh by a minimum of 12 mm.

8.D INSTALLING FERRO-CEMENT PLATES AT THE CORNERS

After filling the cracks as in 7.D, use galvanized weld-mesh 'g14' (2.0mm wires @25x25mm mesh) over a length of 500-600 mm on each side of the crack both inside and outside of the room in a depth of 300mm at windows sill on about 900 mm height above the floor (Fig. 3D) and another one at lintel level or about 2 m above the floor. But if horizontal seismic belt is to be provided at the lintel level, the second mesh is not required.

The steps to be taken for installing the meshes are given in 17.D.

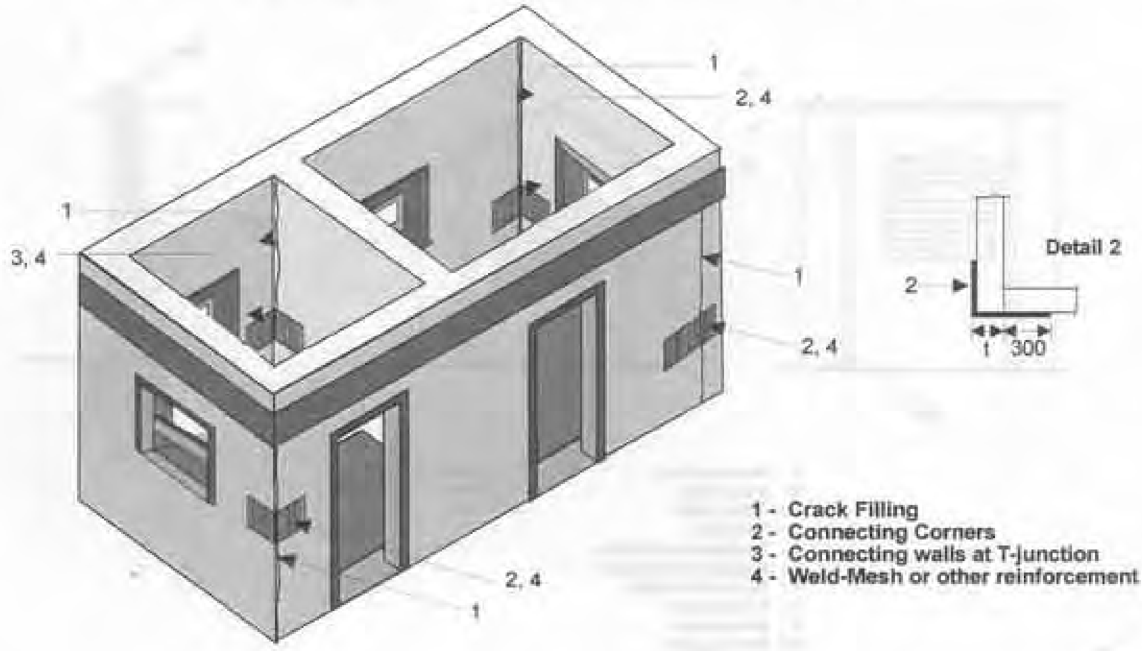


Fig. 3D Connection of cracked walls at corners and junctions

9.D REBUILDING PORTIONS OF THE WALL

(i) Generally the random stone walls are seen to be 450-600 mm thick, built by two wythes vertically (Fig. 4Da). During an earthquake, the wythes get separated and either one or both get bulged (Fig. 4Db) which even fall away under further vibrations (Fig. 4Dc). For preventing such delamination, it is necessary to use 'through' stones or RCC elements. These should be installed while rebuilding the wall (Fig. 4Df).

(ii) Where portions of wall require rebuilding, the roof resting on the wall should first be supported by wooden struts, (Fig. 4Dd,e). Then the damaged portion of the wall should be dismantled. The new portion of the wall should be constructed using cement-sand mortar of 1:6 cement-sand mortar in walls built originally in weak mortar, but using 1:4 mix for walls originally built in cement mortar.

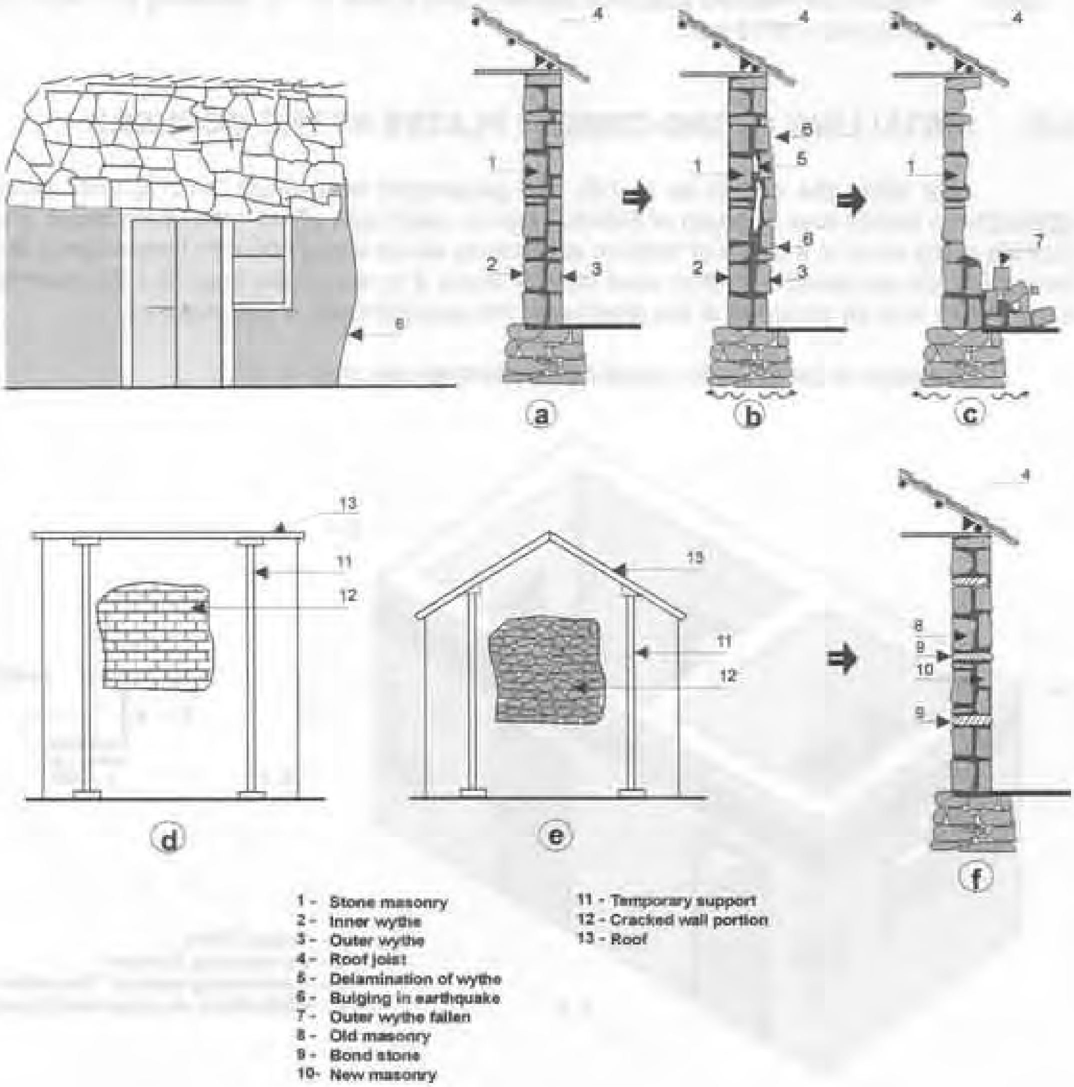


Fig. 4D Rebuilding part of wall

10.D EARTHQUAKE RESISTANT RETROFITTING OF BUILDINGS

For achieving safety of buildings against collapse in a future severe earthquake, the following retrofitting actions are recommanded. The amount and placing of the retrofitting element depends upon the seismic zone, the importance of the building and the stiffness of the base soil. The Categorisation of Buildings is given in Table 3D. This Categorisation is in line with IS : 1893 - 2002 where the maximum response in short period range is taken as uniform for all soils. Housing falls under Ordinary buildings. The community buildings are considered under Important buildings.

Table 3D : Simplified Building Categories in the Seismic

	Zone D	Zone C	Zone AB
Housing	B	C	D
Community Buildings	C	D	E

i) Check length, height and thickness of walls and modify to conform to recommendation given in Part B for Rectangular Unit Masonry Buildings and Part C for Stone Masonry Buildings.
ii) Check the positions and sizes of openings in masonry walls and modify as required, or provide reinforcement (See Parts B & C).
iii) If there are no 'through' stones in thick stone walls, then provide RC headers by making 'through' hole by removing the stones in opposite wythes, inserting an iron link and filling the hole with concrete.
iv) Provide seismic belt below roof and above door/window lintel level. For this use weld mesh reinforcement.
v) Provide vertical reinforcement at the corners and T-junction of walls, either using bars or ferro-cement with weld-mesh reinforcement.
vi) Modify the roof structure by providing additional bracing elements and fix it to the seismic band/belt.

11.D CONTROL ON LENGTH, HEIGHT, THICKNESS OF WALLS

a) *R.R Stone Masonary.*

The wall length should not exceed 5m between cross walls in case of mud mortar and 7m in cement mortar case. If length exceeds these, provide internal wall at a spacing not farther than 4m in mud mortar and 5 m in cement mortar case (See Fig. 5D). The thickness of new wall should not exceed 400mm. The wall height should not exceed 2.7m in mud mortar and 3.2m in cement mortar (see Table 4D).

b) *Rectangular Unit Masonry in cement mortar.*

The wall length should not exceed 35 t and the height should not exceed 15 t where t = thickness of wall. See Table 4D. In case of longer room, external pilasters/battresses may be added as shown in Fig. 5D(b).

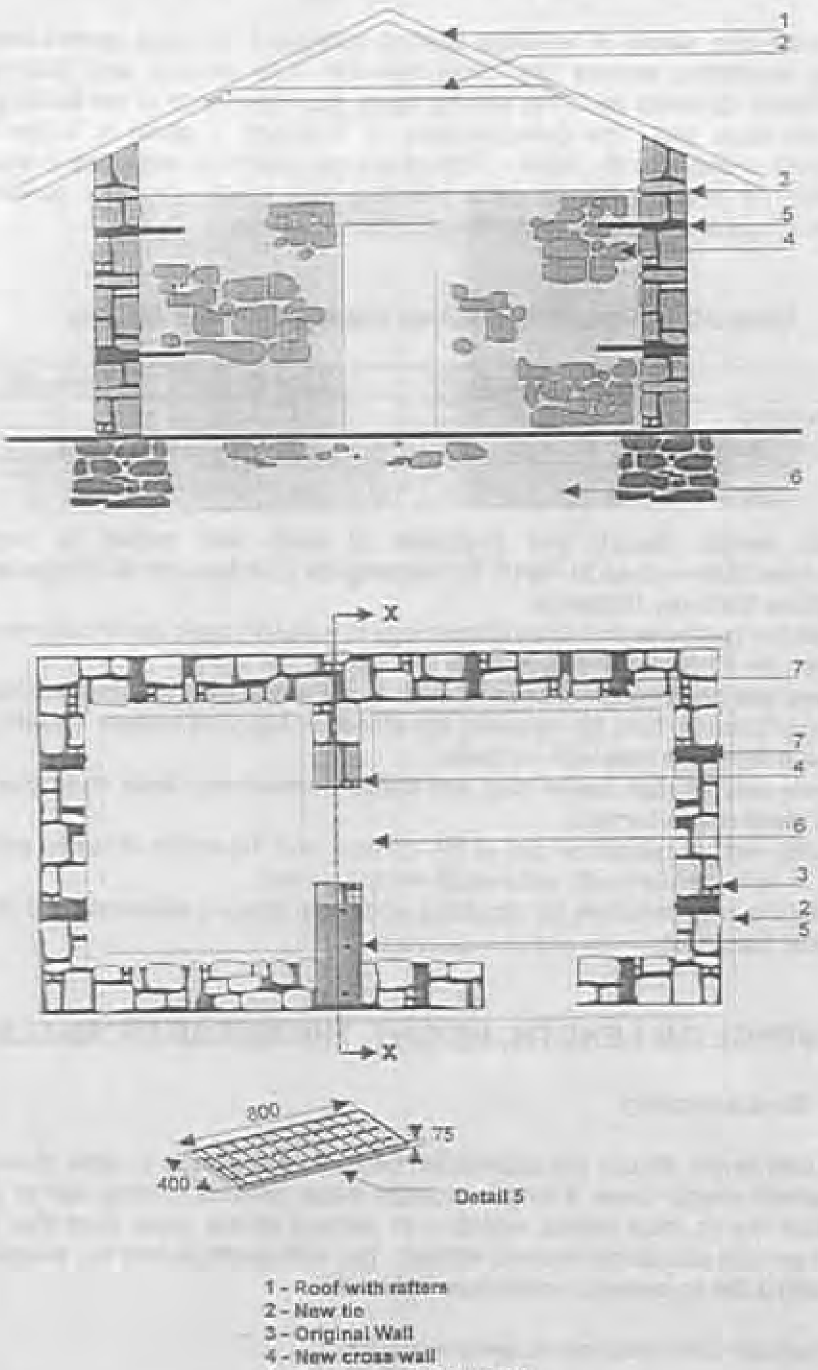


Fig. 5D(a) Introducing New Internal Wall

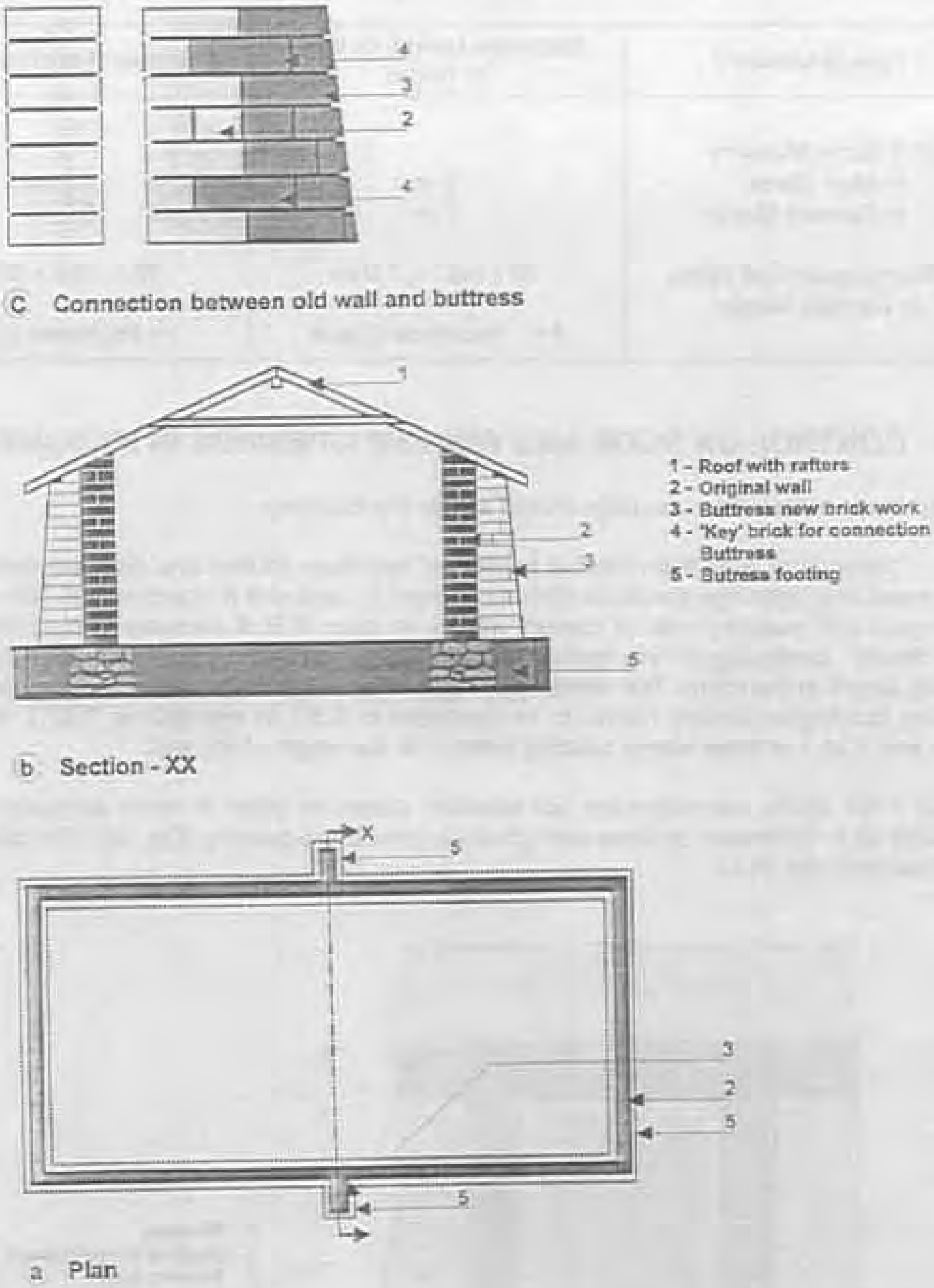


Fig. 5D(b) Adding Pilasters/Buttresses to Long Walls

Table 4D : Control on Length, Height & Thickness of Walls

Type of Masonry	Maximum Length of Walls in Room	Maximum Height of Storey
(a) R R Stone Masonry - in Mud Mortar - in Cement Mortar	 5 m 7 m	 1.7 m 3.2 m
(b) Rectangular Unit Walls - in Cement Mortar	35 t but $\leq$ 7.0 m t = thickness of wall	15 t but $\leq$ 3.5m t = thickness of wall

12.D CONTROL ON DOOR AND WINDOW OPENINGS IN MASONRY

i) Door and window openings should satisfy the following :

Distance of jamb from internal corner not less than 450mm and distance between two consecutive openings should be 600mm or more in case of R R masonry and 560mm in rectangular unit masonry both in cement mortar. In case of R R masonry in mud mortar, there should preferably be only one door or window in one wall not exceeding one-third of the wall lenght in the room. The combined length of openings in a wall of rectangular unit masonry building in cement mortar to be restricted to 0.5 L in one storey, 0.42 L in two storey and 0.33 L in three storey building where L is the length of the wall.

ii) If the above conditions are not satisfied, action be taken to close an opening or reduce its size. Otherwise, provide strengthening around the opening (Fig. 6D). For detail of reinforcement, see 16.D.

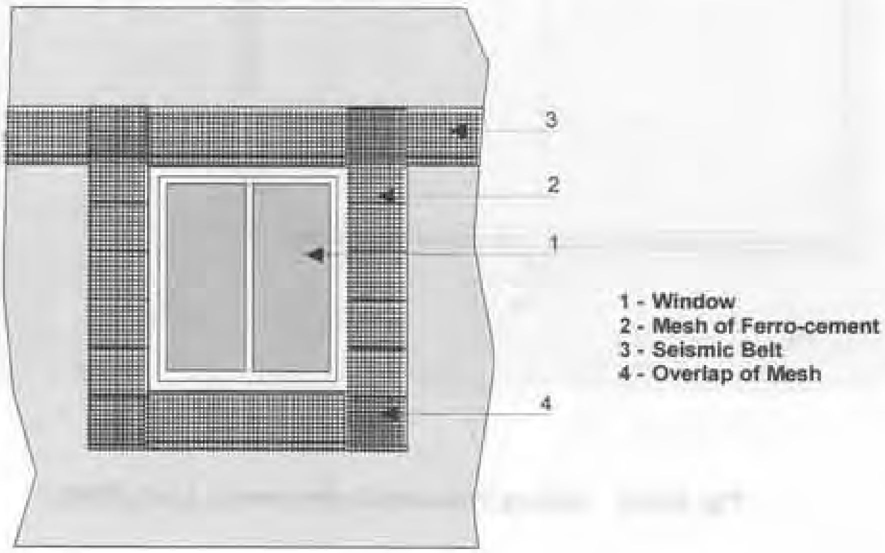
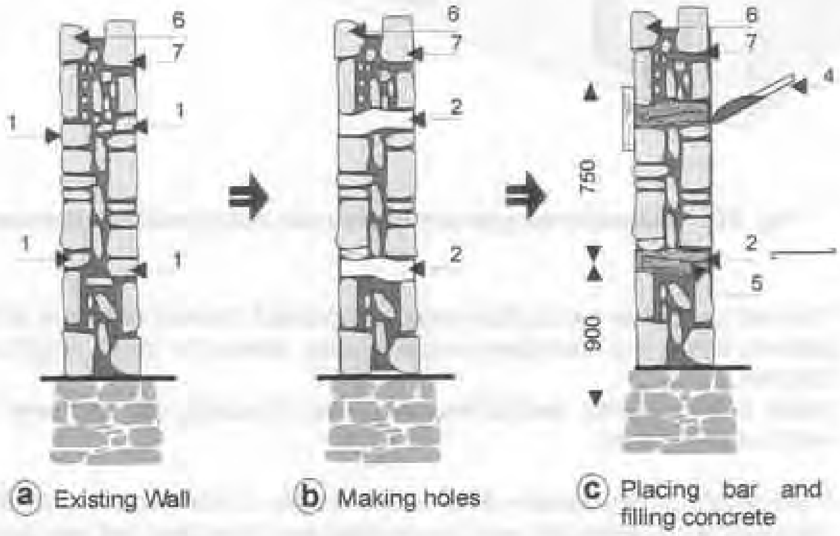


Fig. 6D Reinforcing around opening

13.D MAKING 'THROUGH' BOND ELEMENTS IN R.R. STONE WALL

a) Select points where 'through' stones will be installed at horizontal and vertical distance of about one meter apart, with 50cm horizontal stagger.
b) Remove the plaster from the surface exposing the stones. Remove the mortar around the stone to sufficient depth gently, not violently, so as to expose the stone on all sides.
c) Loosen the stone by means of gentle pushes side ways and up and down by means of a small crowbar, so that the other stones of the walls are not disturbed. Pull out the stone slowly, holding it by both hands.
d) Remove inner material gradually so that a 75mm size hole can be made in the wall. Bigger hole is not needed.
e) Locate position of the opposite stone on the other face of the wall by gentle tapping in the hole. Remove the identified stone slowly by same gentle process.
f) The hole so made through the wall may be bigger in size on both faces and narrower inside resembling a dumbbell shape. This is good. It does not matter if the hole is inclined instead of being horizontal.
g) Place concrete of 1:2:4 mix to fill half the depth of the hole from both sides and place 8mm dia hooked mild steel bar in the hole and fill the hole completely.
h) Cure for minimum 10 days by sprinkling water on the exposed surfaces on both sides.



1 – Stones removed to make through holes
2 – Holes
3 – Hooked Bar
4 – Chute for pouring concrete
5 – Filled concrete
6 – Internal wythe
7 – External wythe

Fig. 7D Providing R.C. 'through' elements for 'stitching' stone wythes

14.D PROVIDING HORIZONTAL SEISMIC BELTS

14.1.D Seismic Belt Locations

i) Seismic belts are to be provided on all walls on both the faces (i) just above lintels of door and window openings and (ii) just below floor or roof.

Note : *On small wall lengths in a room (less than 5m) seismic band only on the outside face will suffice. In this case these should be connected by ties going across the rooms (see Fig. 8D).*

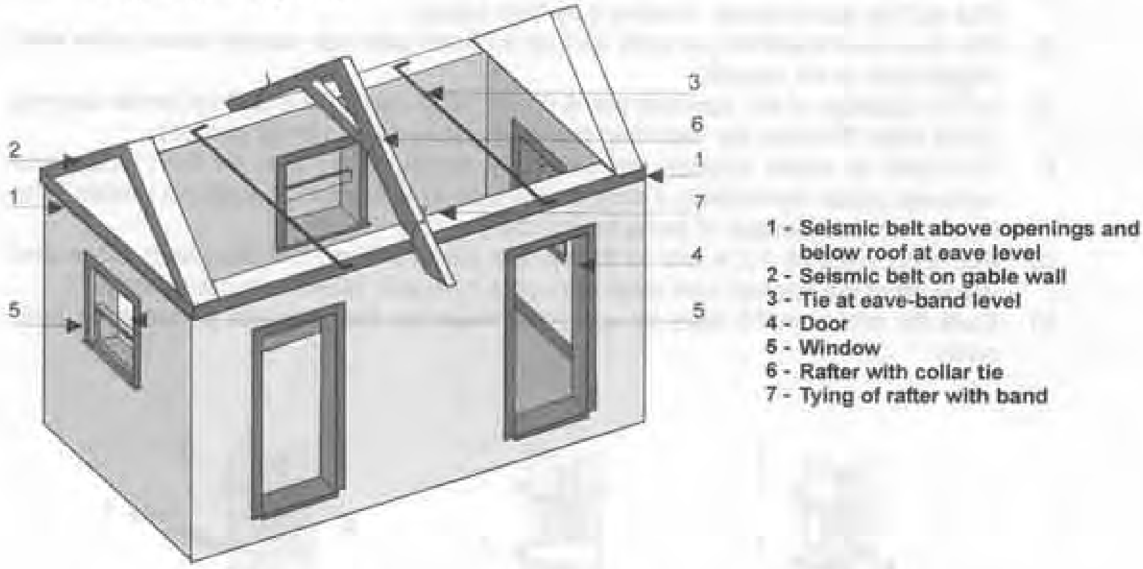


Fig. 8D Overall arrangement of seismic belts (roofing removed)

ii) The belt just below roof or floor may be omitted if the roof or floor is of RCC slab.

iii) Seismic belt is not necessary at plinth level, unless the plinth height is more than 900 mm.

iv) Install similar seismic belt at the eave level of sloping roof and near top of gable wall, below the roof.

Note: *If the height of ceiling/eave level above the top of door in less than 900 mm, only the ceiling/eave level belt may be provided and lintel level belt may be omitted.*

14.2.D Description of reinforcement in belt

The reinforcement may be of mesh types as suggested in Table 5D or any other mesh of equivalent longitudinal wires. For example in Cat. **D** building with room length of 6 m, MW 21 weld mesh (with long wires 5 of 4.5 mm dia spaced at 75 mm apart; cross wires of 3.15 mm dia placed at 300 mm apart) can be used, the height of the belt being kept as 375 mm.

Note: *Weld mesh has to be provided continuously. If splicing is required, there should be minimum overlap of 300mm.*

Table 5D : Mesh Reinforcement in Seismic Belts in Various Building Categories

Length of Wall M	Cat. B			Cat. C			Cat. D & E		
	Gauge	N	H	Gauge	N	H	Gauge	N	H
≤5.0	g13	8	225	g13	9	250	g13	10	275
6.0	g13	9	250	g13	10	275	g13 +2 bars of 6 ϕ	10	275
7.0	g13	10	275	g13 +2bars of 6 ϕ	10	275	g13 +3 bars of 6 ϕ	10	275
8.0	g13 +2 bars of 6 ϕ	10	275	g13 +3 bars of 6 ϕ	10	275	g13 +4 bars of 6 ϕ	10	275

1. Gauge: g13 = 2.34 mm dia of wire.
2. N = Number of main longitudinal wires in the belt at spacing of 25 mm. Additional longitudinal bars will be 6 mm dia mild steel tied to mesh at 150 mm c/c.
3. H = Height of belt on wall in micro-concrete, mm.
4. The transverse wires in the mesh could be spaced upto 150 mm.
5. The mesh should be galvanized to save from corrosion.

15.D VERTICAL SEISMIC BELT AT CORNERS

Vertical reinforcing is required at the corners of rooms and junctions of walls as per Table 6D. Alternatively MW21 weld mesh of equivalent longitudinal area could also be used. The width of this belt on each side of the corner has to be kept 25mm extra to the width of the mesh.

This reinforcement should be started 300mm below the plinth level and continued into the roof/eave level horizontal band. (See Fig. 9D).

Notes regarding Table 6D

1. Gauge 13 (2.34 mm dia galvanized mesh with 20 mm spacing of wires) shall be used. Additional longitudinal bar will be one T8 mm dia HSD tied to mesh at 150 mm c/c
2. Single bar, if used, shall be HSD or TOR type, if two bars be used in a T-junction, the diameter can be as follws. For One of T10 or T12 take 2 of T8, and for One of T16 take 2 of T12
3. N = Number of longitudinal wires in the mesh, T' represents HSD or TOR.
4. B = Width of the micro concrete belt, on each wall meeting at the corner or T-junction.
5. The transverse wires in the mesh could be at a spacing up to 150 mm.

16.D SEISMIC BELTS AROUND DOOR/WINDOW OPENINGS

The jambs and piers between window and door openings require vertical reinforcement in the following situations:

i) In category **D** and **E** buildings for resistance against earthquake forces.
ii) For restoring the strength of the piers in any building category when badly damaged in an earthquake.

The following mesh reinforcement is recommended to be used for covering the jamb area on both sides of an opening or for covering the pier between the consecutive openings.

i) *In Cat.D & E buildings*

Mesh of gauge 10 with 10 wires in vertical direction spaced at 25 mm in a belt width of 280 mm.

ii) *In Cat. C buildings*

Mesh of gauge 12 with 9 wires in vertical directon spaced at 25 mm in a belt width of 250 mm.

Table 6D : Vertical Bar or Mesh Reinforcement in Vertical Belt at Corners of Rooms

No. of Storeys	Storeys	Cat. B			Cat. C			Cat. D & E		
		Single Bar.mm	Mesh		Single Bar. mm	Mesh		Single Bar. mm	Mesh	
			N	B		N	B		N	B
One	One	-	-	-	-	-	-	10	20	500
Two	Top	-	-	-	-	-	-	10	20	500
	Bottom	-	-	-	-	-	-	12	28	700
Three	Top	-	-	-	10	20	500	10	20	500
	Middle	-	-	-	10	20	500	12	28	700
	Bottom	-	-	-	12	28	700	12	28	700

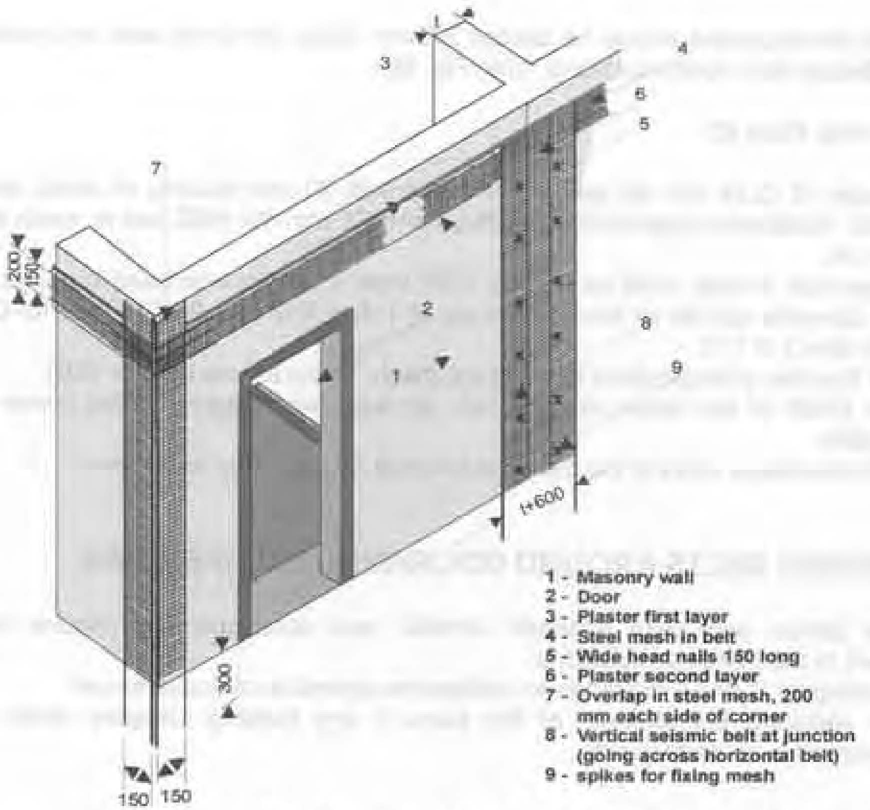


Fig. 9D Vertical seismic belts at corner and junction

17.D METHOD OF FIXING SEISMIC BELTS

The reinforcement specified in 8.D, 14.D, 15.D and 16.D is to be finally attached to the stone wall by nails or connectors and cement mortar. For this purpose either 1:3 cement-coarse sand mortar or micro-concrete 1:1.5:3 is used. It is applied in two layers like plaster as described below.

Steps to construct the Belt:

Step-1 Remove plaster in the height of the belt.
Step-2 Rake out mortar joints to 12-15 mm depth.
Step-3 Clean the surface and wet it with water.
Step-4 Apply neat cement slurry and apply first coat of 12 mm thickness. Roughen its surface after initial set.
Step-5 Fix the mesh with 150 mm long nails at about 300 mm apart while plaster is still green.
Step-6 Apply second coat of plaster of 16 mm thickness.

Note :

1. *The mesh should be continuous with 200mm overlap at the corner or elsehere.*
2. *Using galvanized binding wire, tie up the roof rafters with the nails of the eave level belt before applying the plaster over the mesh.*
3. *In brick and Bela stone walls, it will be easy to drill or chisel out holes of 75 mm dia. In that case, instead of the nails, use 3 mm galvanized mild steel wires through the holes to hold and clamp the longitudinal wires every 450 mm c/c.*

18.D PROVIDING VERTICAL REINFORCEMENT AT CORNERS, JUNCTIONS OF WALLS

The vertical reinforcement consisting of TOR bar as per Table 6D or equivlent shall be provided on the inside corner of room starting from 750 mm below the ground floor going upto the roof slab, passing through each middle floor through holes made in the slabs. (See Fig.10D) The reinforcement will be connected to the walls by using L shape dowels of 8 mm TOR bar, the vertical leg of 400 mm length firmly tied to the vertical reinforcement bars and the horizontal leg of minimum 150 mm length embedded in the walls through 75 mm dia. holes drilled in the wall into which the 8 mm dia. leg of the dowel will be grouted using non-hrink cement cum polymer grout. Such dowels will be provided, first one just above plinth level and then at about every 1 m distance apart. The corner reinforcement will be covered with 1:3 cement mortar or 1:1.5:3 micro concrete fully bonded with the walls giving a minimum cover of 15 mm on the bar.

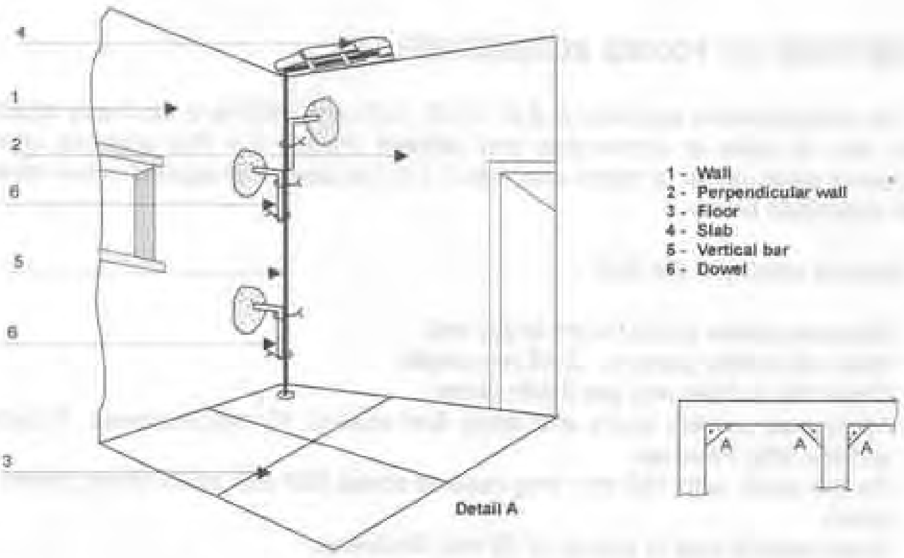


Fig. 10D Vertical bar at inside corner

19.D STIFFENING THE FLAT WOODEN FLOOR/ROOF

Many of the damaged houses have flat floor or roof made of wood logs or timber joists covered with wooden planks and earth. For making such roof/floor rigid, long planks 100mm wide and 25 mm thick should be nailed at both ends of the logs/joists from below. Additionally, similar planks or galvanized metal strips 1.5 mm thick 50 mm wide should be nailed diagonally also. See Fig. 11D.

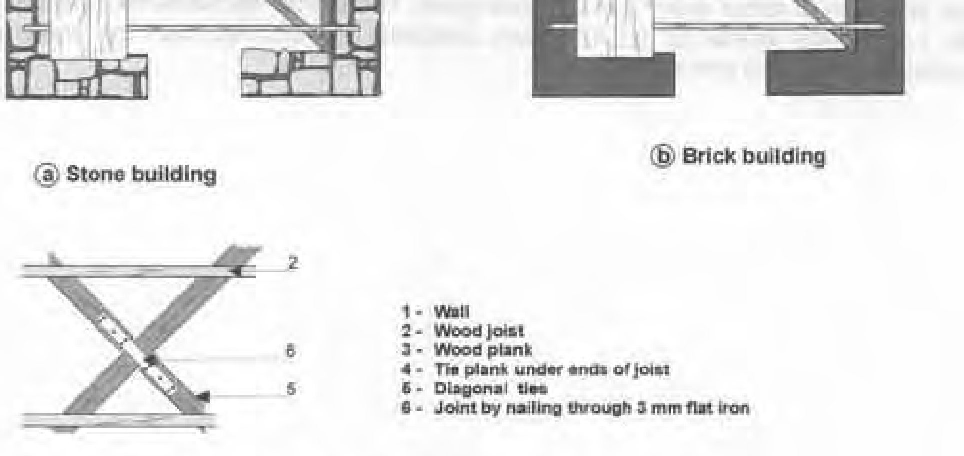


Fig. 11D Stiffening flat wooden floor/roof

20.D STIFFNING THE SLOPING ROOFS STRUCTURE

Most of the sloping roof are usually made of rafters, purlins with covering of burnt clay tiles or corrugated galvanized iron (CGI) sheets or asbestos – cement (AC) sheets on top. In Afghanistan sloping roofs on reinforced concrete slabs are also some times used. Such roofs push the walls outward during earthquakes. For stiffening such roofs, the rafters should be tied with the seismic belt as in Note under 17.D, and the opposite rafters, on both sides of the ridge need to be connected near about mid-height of the roof through cross ties nailed to the rafters (See Fig. 12D). The important point in retrofitting is the provision of seismic belts just below eave level and the gable level.

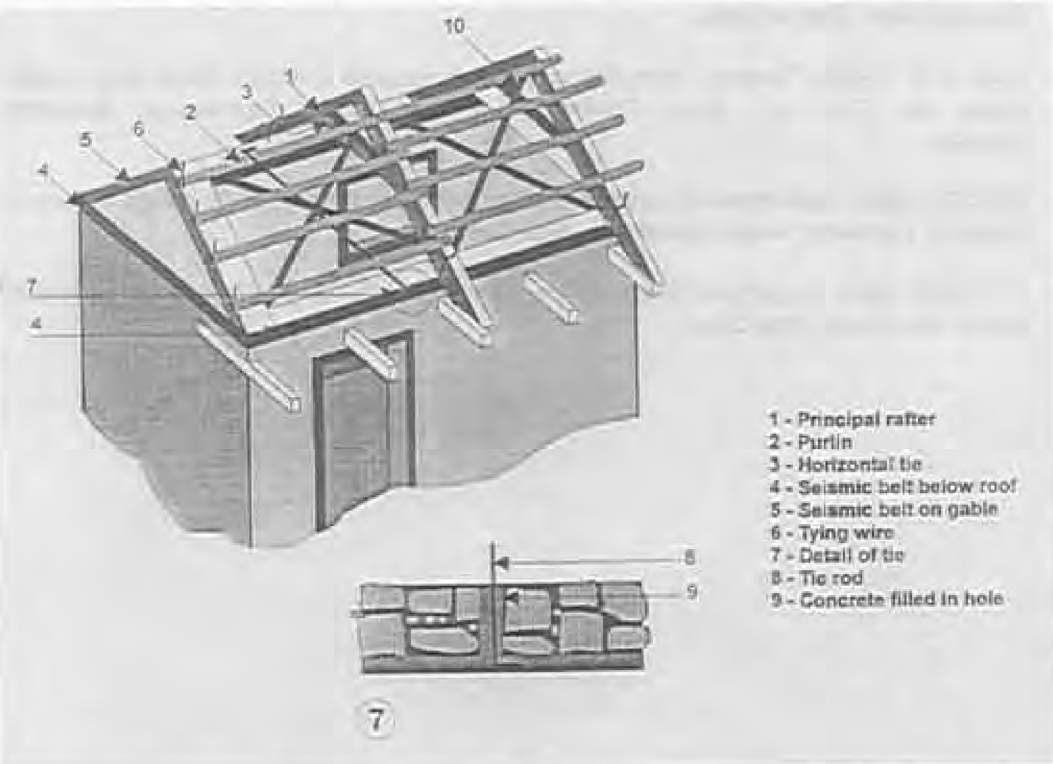


Fig. 12D Stiffening of sloping roof structure

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PART E

Earthquake Resistant Construction of Earthen Houses

CONTENTS – PART E

1.E INTRODUCTION

The local situation of house types in Afghanistan as covered in Part A of these Guidelines is briefly stated below:

Main types of house constructions use Sun-dried brick or Adobe walls with wooden roof, and Sun-dried brick with Dome. Mud is the main construction material. In Afghanistan 95% of construction is with mud. Only in urban areas, contemporary modern building materials are used.

One complete house is on a plot of approximate size of 500 sq.m. with two rooms and one passage. Mostly front portion of house is of L shape and is located in one corner of plot. Opposite to the L shaped house, two rooms and other utility spaces like bathing, washing space, etc. are constructed. Some time on contour site, house is with a basement room. This basement room is mostly used for storing fodder and agriculture produce. Usually the house has a compound wall with height ranging from 2.5 m to 3.5 m.

Built up area of houses ranges from 60 to 100 sq.m. Due to thick walls, the usable carpet area of a house is considerably less than the plinth area.

In rural areas, construction of 'ground plus one' house is a normal practice. New construction is normally only the ground floor and future extension is usually to build the first floor instead of horizontal expansion.

Sun Dried Brick (Adobe)

In Pastun the Sun dried Brick is called Khiste–Kham. Different sizes of the mud brick are available i.e. 20 cm x 10cm x 5 to 6 m, 38 cm x 38 cm x 8 cm and 25 cm x 12 cm x 6 cm. Mud bricks are easily available and used in construction activity almost all over the country.

Mud mortar is used for mud brick masonry. Quality of masonry is average. Two layers of burnt brick are put on the wall once the wall is raised to full height to prevent washing of the mud in rains. Sometime the burnt bricks are replaced with grass or wooden planks to prevent the mud from washing out in rains.

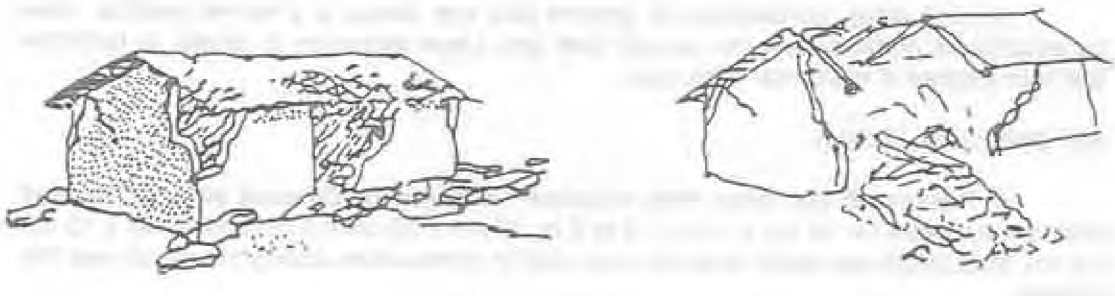
Stack wall (Pakhsa Wall)

Stack walls are made out of mud locally available without any additives. The mud is mixed with water, puddled and left for 24 hours. With this preparation, mud lumps are made and stacked in order to construct a mud wall. The wall is constructed in layers and each layer has a thickness of 70 to 80 cm and layer height of 70 to 80 cm. One layer is put in a day and the next is put on the dried up layer the next day. Sometimes a stone or sun dried bricks is inserted at the edges and the junctions between two layers of stacked wall. A locally made tool known as Paksha Taras is used to dress the wall. The final finish of the wall is done with mud plaster. The mud plaster is made out of mud, water and rice or wheat husk. No scaffold is used for constructing the wall. Usually the mason sits on the wall itself while constructing. Normally the brick masonry work is also executed in the similar fashion. As in Adobe walls, two layers of burnt brick are put on top once the wall is raised to full height to prevent washing of the mud in rains or grass or wooden planks are used for rain protection of the mud.

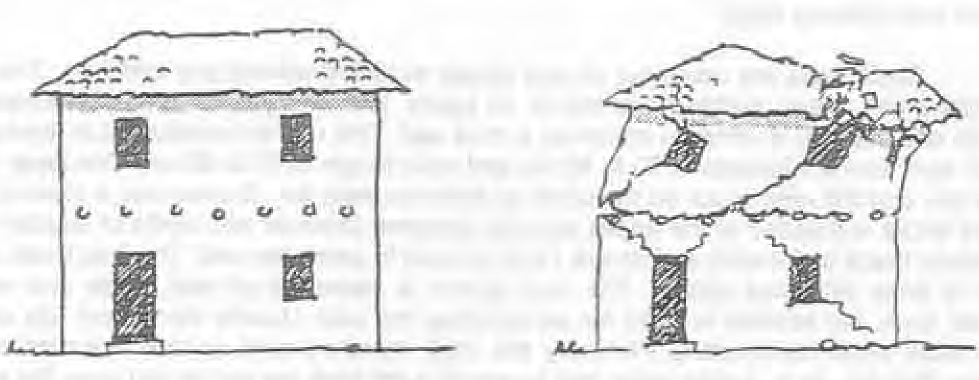
It is known that 95% of the construction in Afghanistan is with mud and construction with mud is part and parcel of Afghanistan culture. In all construction activity in the near future, mud is likely to remain the main constituent as the most affordable. So whatever Code/ Guidelines is developed, must deal with mud Construction for construction activity in Afghanistan.

2.E TYPICAL DAMAGE AND COLLAPSE OF EARTHEN BUILDINGS

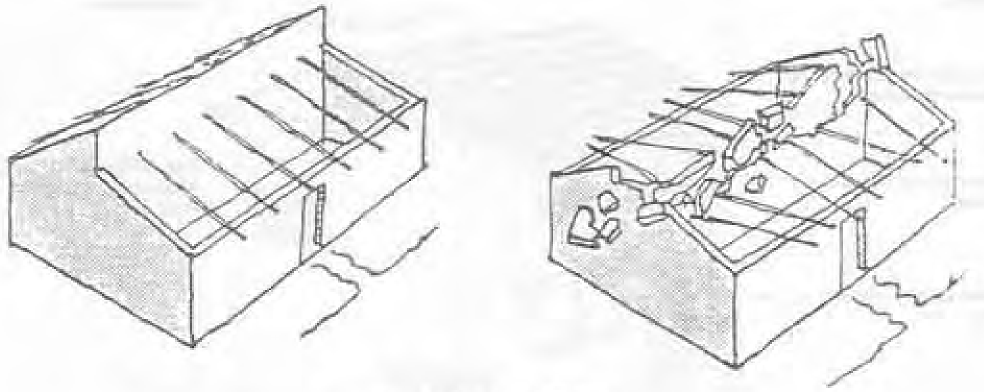
Earthquake experience shows that earthen buildings may be cracked at MSK Intensity VI, wide cracks and even partial collapse may occur at MSK VII and collapses are widespread under MSK VIII. Damage is always much more severe in two storeyed buildings than in one storeyed ones. Some typical damages are sketched in Fig. 1E. However, single storeyed houses with flat roofs constructed in good clay have been found to be undamaged in Intensity VIII zone whereas at the same location two storeyed houses were completely ruined. The main causes of failure of earthen buildings in earthquakes are graphically summarized in Fig. 2E.



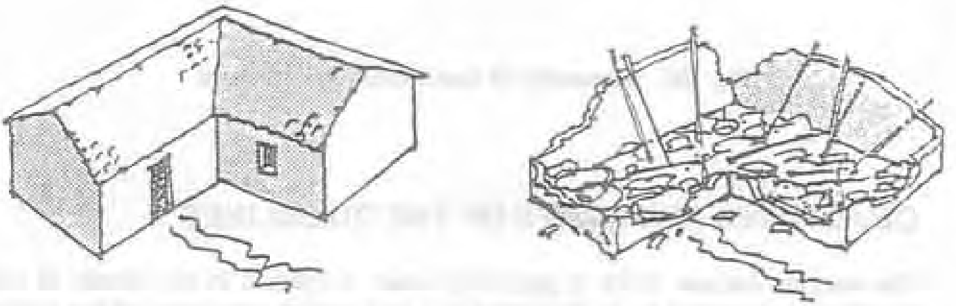
a) Corner Failure and out of Plane Collapse of Walls



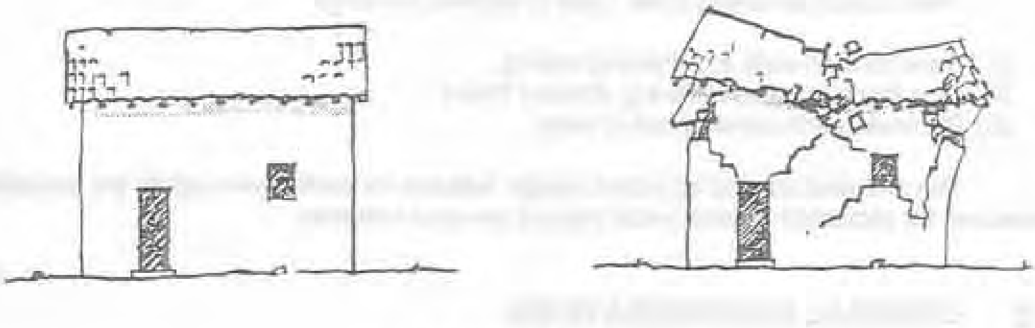
b) Two Storey House Damage/Collapse



c) Split Level Roof



d) L Shaped Building



e) High – Walled Houses

Fig. 1E Some Typical Damages in Earthen Houses

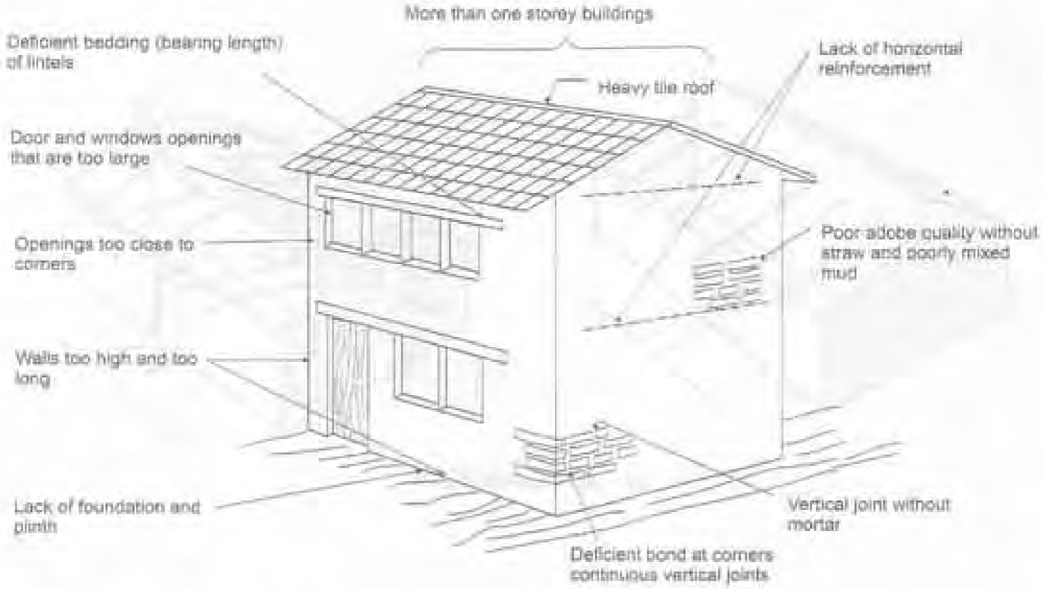


Fig. 2E Summary of main causes of failure

3.E OBJECTIVES AND SCOPE OF THE GUIDELINES

The earthen houses suffer a great deal when subjected to the effects of water in rains or floods and impacted by earthquakes due to inherent weakness of the material in tension and shear. The main object of this Guidelines is to indicate such simple and affordable improvements in construction and addition of earthquake resisting elements which will make the earthen buildings safe against probable maximum earthquake intensities in various seismic regions of Afghanistan (See Fig. 9A).

The Guidelines covers three types of earthen buildings

(i) Hand formed walls e.g. Paksha walling
(ii) Clay block (Adobe) walls e.g. Khishte Kham
(iii) Rammed earth construction of walls

The architectural and structural design features for earthquake safety are included. Measures for protection against water ingress are also indicated.

4.E GENERAL CONSIDERATIONS

4.1.E For the safety of earthen houses, appropriate precautions must be taken against the actions of rain and flood waters, and earthquakes. Minimum precautions are recommended herein.

4.2.E Whereas dry clay block is hard and strong in compression and shear, water penetration will make it soft and weak, the reduction in strength could be as much as 80 to 90 percent. Hence, once built, ingress of moisture in the walls must be prevented by the protective measures such as roof projection and water proof plastering.

4.3.E The recommendations made here are low-cost and do not include the use of stabilizers, which though effective in increasing the strength and water-resistance of the clay units or walls are quite costly. Where feasible lime-stabilized compacted clay blocks or cement-stabilized sandy soil blocks may be used with compatible mortars.

4.4.E Lightness

Since the earthquake force is a function of mass, the building should be as light as possible, consistent with structural safety and functional requirements. Therefore the walls and roof should be made as thin as found adequate for thermal comfort.

4.5.E Height

Experience in Intensity areas of MSK VIII has shown the high vulnerability of two-storeyed houses, hence only one storey construction should *preferably* be adopted in seismic zones A, B. Use of vertical tensile elements will be essential in two storey houses for earthquake safety.

4.6.E Shape of Building

For better earthquake resistance, the building should have a simple rectangular plan and be symmetrical, as far as possible. The load bearing walls should run continuously in both directions. Large houses may have an inner courtyard for light and ventilation with proper drainage outlets, instead of having projections giving rise to L, T and U shape plans.

5.E CONSTRUCTION OF EARTHEN WALLS

Earthen walls may be constructed in the following three ways.

5.1.E Hand–formed in layers using mud-lumps to form walls (as Pakhsa walling)

5.2.E Built by using sun-dried blocks or *Adobe*, which are moulded and compacted and laid in courses using clay mud as mortar.

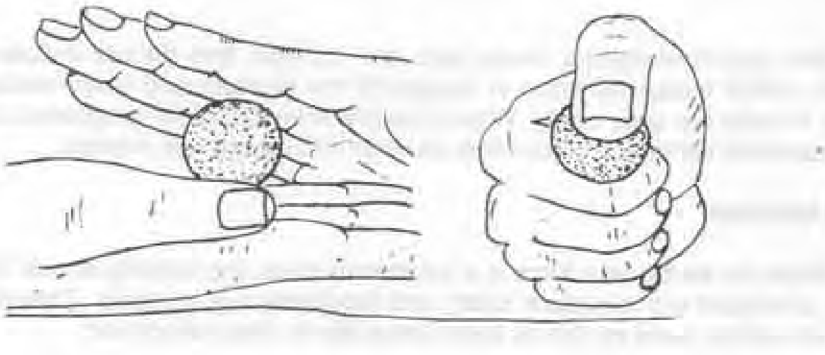
5.3.E Built by using rammed earth in which moist soil is filled between wall forms and compacted manually or mechanically.

6.E SUITABILITY OF SOIL

The following qualitative tests may be used for determining the suitability of a soil for earthen construction.

6.1.E Dry Strength Test

Five or six small balls of soil of approximately 2 cm in diameter are made. Once they are dry (after 48 hours), each ball is crushed between the forefinger and the thumb. If they are strong enough that none of them breaks, the soil has enough clay to be used in the Adobe construction. (see Fig. 3E).



(I)Making the ball *(II) Crushing the ball*

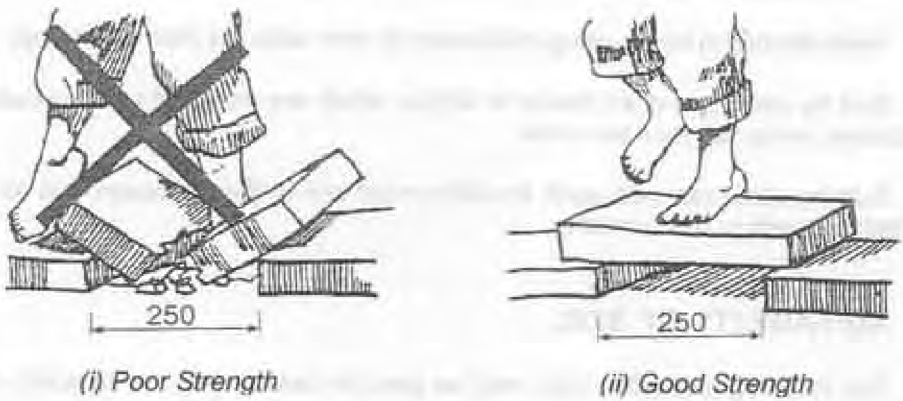
Fig. 3E Dry Ball Strength Test for Soil

Note: *If some of the balls break, the soil is not considered to be adequate because it does not have enough clay and should be discarded.*

6.2.E Strength Test of Adobe

The strength of adobe may be qualitatively ascertained as follows:

After 4 weeks of sun drying the adobe, it should be strong enough to support in bending the weight of a person 60 – 70 kg (see Fig. 4E). If it breaks, more clay and fibrous material is required to be added. Quantatively, the compressive strength may be determined by testing 100 mm cubes of clay after completely drying them. A minimum value of 1.2 N/mm^2 (12 kg/cm^2) will be desirable.



(i) Poor Strength *(ii) Good Strength*

Fig. 4E Field Testing of Adobe Strength

7.E HAND-FORMED LAYERED CONSTRUCTION

7.1.E Walls built by hand forming are usually the weakest of all earthen walls, since enough moisture for full dispersion of clay is not usually employed, and fissures also develop horizontally and vertically. Use of straw is recommended in the clay (in the proportion 1:1 by volume), so as to impart strength and reduction of fissures.

7.2.E The quality of construction will improve if the clay-water-straw mixture was kneaded daily and allowed *to sleep for 7 days* (minimum 3 days) before use in walls so that thorough dispersion of moisture in clay and decomposition of straw into fibres takes place.

7.3.E The area of the lower layer should be moistened well before adding the new layer so as to minimize the horizontal fissures at the joints.

8.E BLOCK OR ADOBE CONSTRUCTION

8.1.E Suitable soil should be used for making the blocks, by using uniform size of moulds, after keeping the soil-water mix for 24 hours. The blocks should be allowed to dry out side of the moulds so as to allow 'free' shrinkage without developing fissures.

8.2.E Block sizes are not standardized yet and various sizes are used in the world.

Three sizes of Adobe are commonly used in Afghanistan:

(i) 200 x 100 x 60 brick size
(ii) 380 x 380 x 80 square block
(iii) 250 x 120 x 60 rectangular

The following sizes of blocks are recommended for making 380 mm thick walls, which are considered adequate for strength, stability and thermal comfort.

***Rectangular* : 380 mm x 250 mm x 110 mm (Overlap of about 125 mm)**
***Square* : 380 mm x 380 mm x 110 mm (Overlap of about 190 mm)**

Note: *Thickness less than 100 mm may not be used for achieving adequate flexural strength.*

The square type block will be better for stronger construction in view of less vertical joints between units and better breaking of vertical joints.

8.3.E The mud 'mortar' used to join the blocks together should be of the same soil as used in making blocks. However, to make it non-shrinking, straw in the ratio 1:1, by volume of soil, should be mixed. The wet mix should be kneaded and allowed to rest for 7 days (minimum 3 days) before use. The lower layer of adobes should be moistened before the 'mortar' is laid. Also, the surface of the adobes to be laid should be moistened for a few minutes before the adobe is laid. If the mortar is seen to fissure on drying, some sand could be added to the mixture.

8.4.E The usual good principles of bonds in masonry should be adopted for construction of adobe walls, that is:

a) all courses should be laid level,
b) the vertical joints should be broken between the consecutive courses by overlap of adobes and should be fully filled with mortar (see Fig. 5E), and
c) The perpendicular joints between walls should be made in such a way that through vertical joint is avoided (see Fig. 5E).

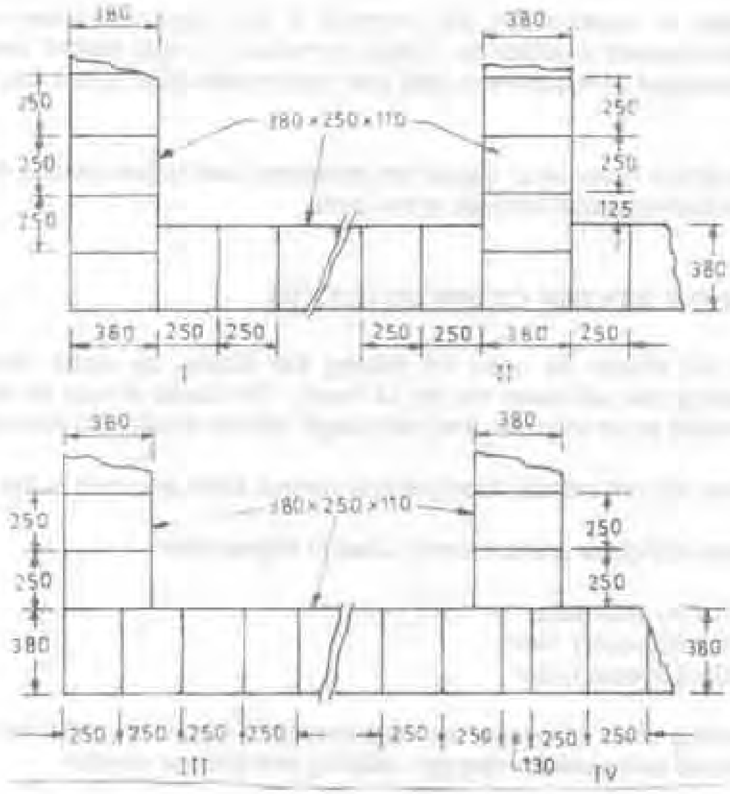


Fig. 5E Adobe Laying for Proper Bond in Wall

9.E RAMMED EARTH CONSTRUCTION

9.1.E To construct walls, in this method, moist soil is poured in long wooden forms of the walls and compacted to achieve the desired density. The soil suitable for rammed earth construction will generally have less clay than that used for making Adobes. The moisture content should be kept less but close to optimum moisture content determined by Proctor Compaction Test. Simple penetrometer may be as compaction monitoring device.

9.2.E To control shrinkage fissures on drying, prior testing may be required for determining the quantity of sand to be added to the clayey soil, based on the moisture, the layering and the amount of compaction to be used in the construction.

9.3.E The soil should be placed in layers of about 100 mm thickness and fully compacted, then water should be sprinkled on the compacted layer before placing the next layer of 100 mm. The total height of this block achieved this way may be kept 500 to 800 mm. Before starting the new block, sufficient water should be poured on the completed layer to ensure its connection with the new layer.

9.4.E Higher compaction leads to higher strength but up to a limit only. Compaction should be standardized. The following procedure is recommended:

> *Give 50 strokes per 1000 cm² of wall area using a wooden mallet of about 8 to 10kg weight.*

9.5.E Small amount of straw, in the ratio of not more than one-fourth of the volume of soil-water mixture, may be used in the soil for fissure control.

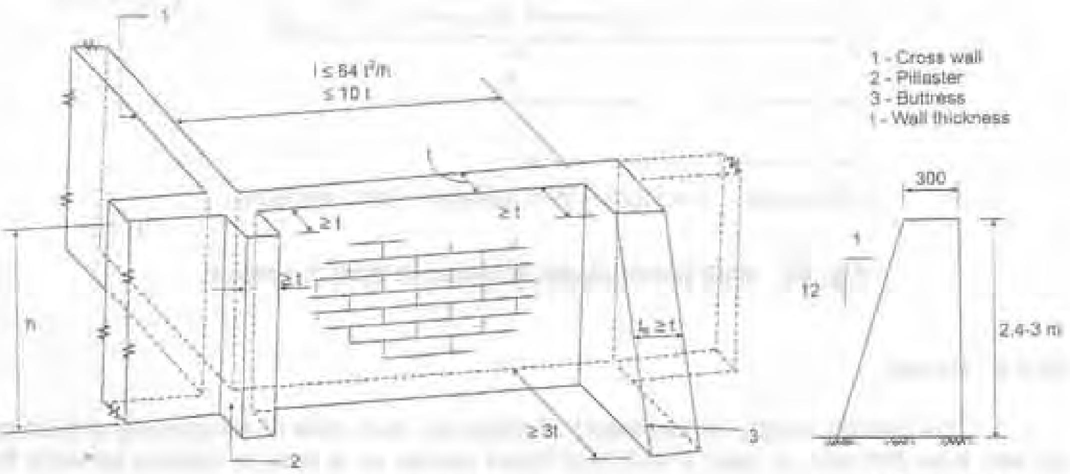
10.E WALLS IN SEISMIC ZONES AB AND C

10.1.E Height

The height of the Adobe building should preferably be restricted to one storey only in seismic zones AB and to two storeys in other zones. Important building ($I \geq 1.5$) as for community gathering, school, etc. should not be constructed with earthen walls in seismic zones AB and restricted to only one storey in other zones.

10.2.E Length of Wall

The length of a wall, between two consecutive walls at right angles to it, should not be greater than 10 times the wall thickness t, nor greater than 64 t^2/h where h is the height of wall (see Fig. 6E). When a longer wall is required, the wall should be strengthened by intermediate vertical buttresses (see Fig. 6E).



(a) Cross walls and buttresses (b) Tapered wall

Fig. 6E Length, Height and Thickness of Earthen Walls

10.3.E Thickness of Wall

Hand-formed walls could preferably be made tapering upwards, keeping the minimum thickness 300 mm at top and increasing it with a batter of 1:12 at bottom (see Fig. 6Eb). The thickness of Adobe walls may be kept 380 mm uniform in one storey and two storeyed houses.

10.4.E Openings in Walls

The width of an opening should not be greater than 1.20 m (see Fig. 7E).

The distance between an outside corner and the opening should be not less than 1.20 m.

The sum of the widths of openings in a wall should not exceed 1/3 of the total wall length in seismic zone AB and 2/5 in zones C and D.

10.5.E Providing outside pilasters at all corners and junctions of wall are recommended as these increase the seismic stability of the buildings a great deal (see Fig. 7E).

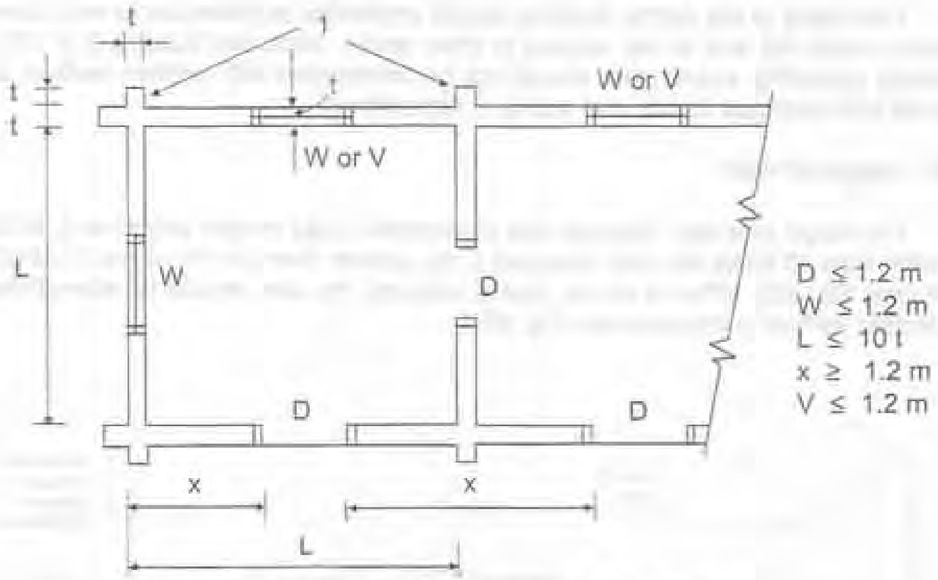


Fig. 7E Wall Dimensions, Pilaster at Wall Junctions

10.6.E Lintels

The bearing length (embedment) of lintels on each side of an opening should not be less than 300 mm. In case a floor/roof beam comes on a door or window opening the lintel should be strengthened (See Fig. 8E).

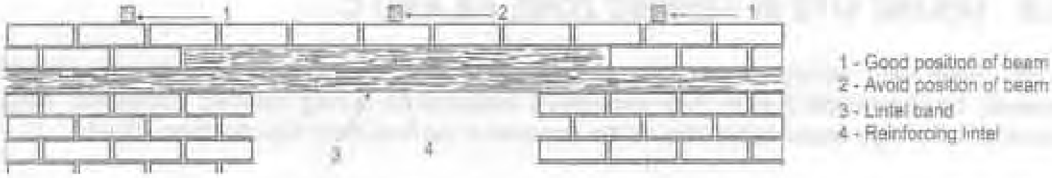


Fig. 8E Strengthening of Lintels

10.7.E Adequate Configuration of Earthen Buildings

Taking the various planning measures into account, a configuration of earthen buildings, which will be suitable in seismic zones, is shown in Fig. 9E. Here a sloping roof is sketched, but could be replaced with a flat roof as commonly adopted in Afghanistan, using a wall plate under the wood longs or joists.

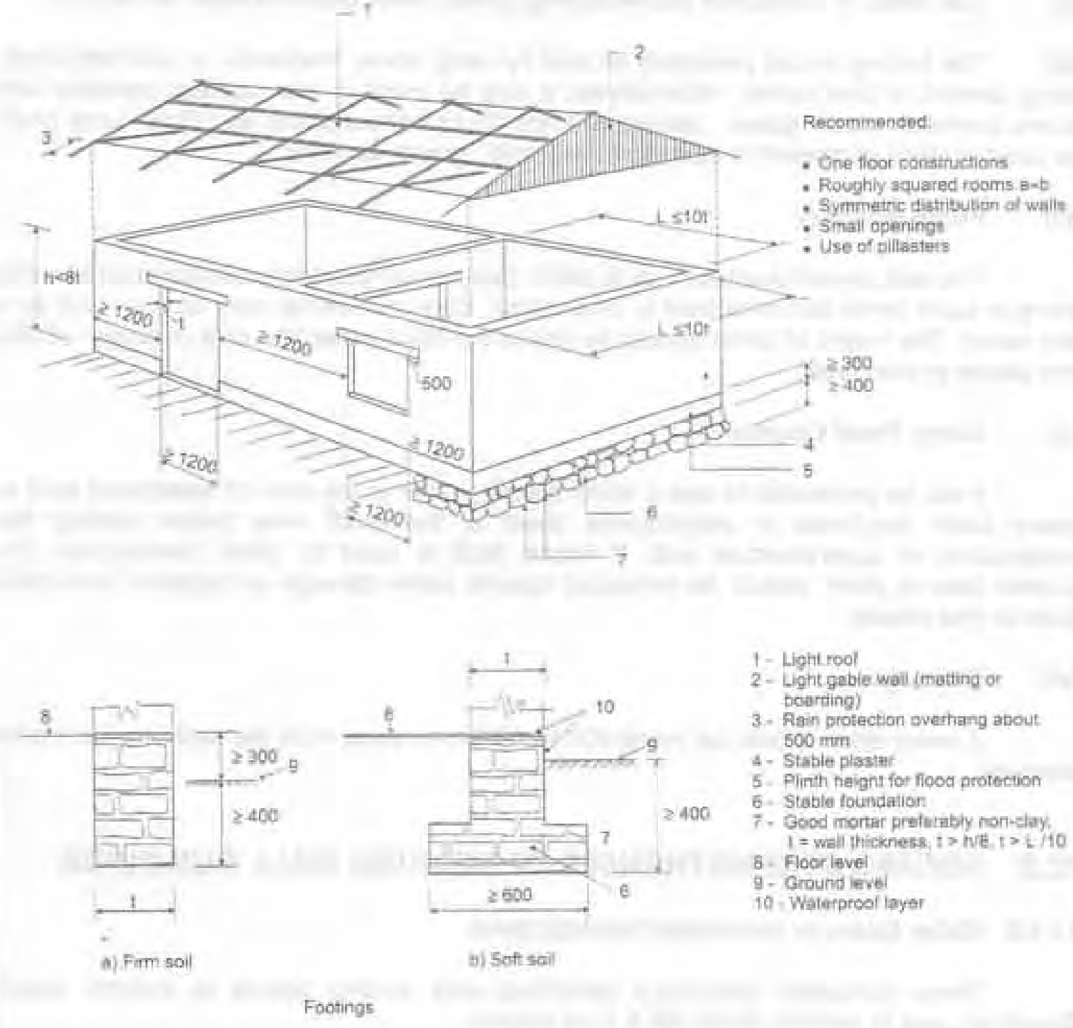


Fig. 9E Adequate Configuration of Earthen Buildings

11.E HOUSE SITE IN SEISMIC ZONE AB AND C

11.1E Sites with sandy loose soils, poorly compacted clays, and fill materials should generally be discarded due to their excessive settlements during seismic vibrations. Also, sites with very high water table should be avoided to be free from liquefaction effects.

11.2.E Site should be above high flood level or the ground shall be raised to this effect.

11.3.E Foundation

(i) Width of strip footings of the walls may be kept as follows:

i)	One storey on firm soil	-	500 mm
ii)	2 storeys on firm soil	-	600 mm
iii)	One storey on soft soil	-	600 mm
iv)	2 storeys on soft soil	-	700 mm

(ii) The depth of foundation below existing ground level should at least be 500 mm.

(iii) The footing should preferably be built by using stone, fired brick, or concrete block, using cement or lime mortar. Alternatively, it may be made in lean cement concrete with plums (cement : sand : gravel : stones as 1:4:6:10) or without plums as 1:5:10. Lime could be used in place of cement in the ratio lime : sand : gravel as 1:4:8.

(iv) Plinth Masonry

The wall above foundation up to plinth level should preferably be constructed using stone or burnt bricks laid in cement or lime mortar. *Clay mud mortar may be used only as a last resort.* The height of plinth should be above the flood water line or a minimum of 300 mm above ground level.

(v) Damp Proof Course

It will be preferable to use a water-proofing layer in the form of waterproof mud or heavy black polythene or polyethylene sheet at the plinth level before starting the construction of superstructure wall. If Adobe itself is used for plinth construction, the outside face of plinth should be protected against water-damage by suitable burnt-brick facia or lime plaster.

(vi) Drainage

A water drain should be made 900 to 1200 mm away from the wall to save it from seepage.

12.E SEISMIC STRENGTHENING OF BEARING WALL BUILDINGS

12.1.E Collar Beam or Horizontal Seismic Band

Three horizontal continuous reinforcing and binding beams or *seismic bands* should be used in seismic zones AB & C as follows:

(i) Plinth Band.

Where stone or burnt-brick plinth is constructed, a reinforced concrete *band* may be used (see Fig. 10E). In that case, separate Damp proof course will not be necessary.

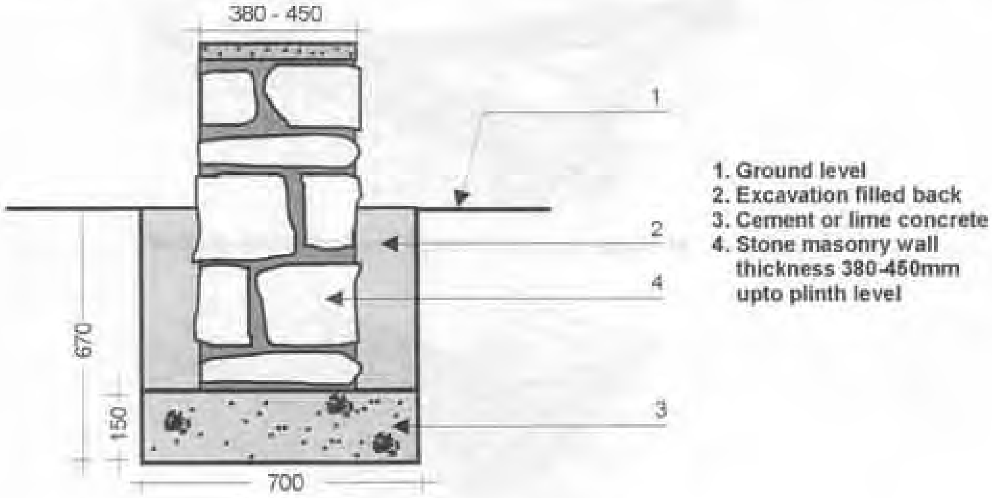


Fig. 10E Strip foundation on Soil sites

Such plinth band will not be necessary in a building founded on *hard* soil.

(ii) Lintel Band

This wooden band will be provided coinciding with lintels of door and window openings.

(iii) Ceiling Band

This band will be provided just below the roof or floor. This will also serve as wall plate for supporting the floor/roof wood logs or joists, which should be nailed/spiked to this band for ensuring their stability during earthquakes.

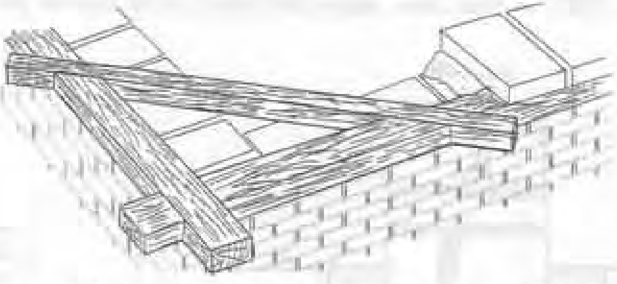
Note: *1. Where the height of wall is not more than 2.5 m, the lintel band can be avoided, but the lintels should be connected to the roof band (see Fig. 12E).*
2. Only one such band below the roof and floor each may be used in Zone D.

12.2.E Details of Bands

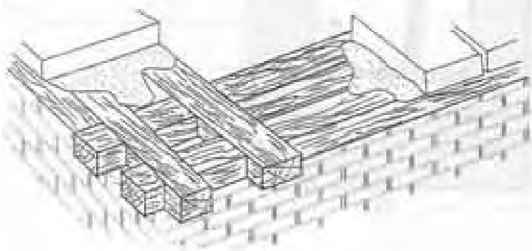
The bands in earthen walls and walls made of stone or burned bricks laid in mud mortar could be in the following forms:

(i) Unfinished rough cut or sawn (50 x 125 mm in section) lumber in single pieces provided with diagonal members for bracing at corners (see Fig. 11Ea).
(ii) Unfinished circular sawn into halves (from 90-100 mm dia log) or fully sawn (75 x 38 mm in section) lumber in two pieces placed in parallel with halved joints at corners and junctions of walls (see Figs. 11Eb and 11Ec). The longitudinal pieces

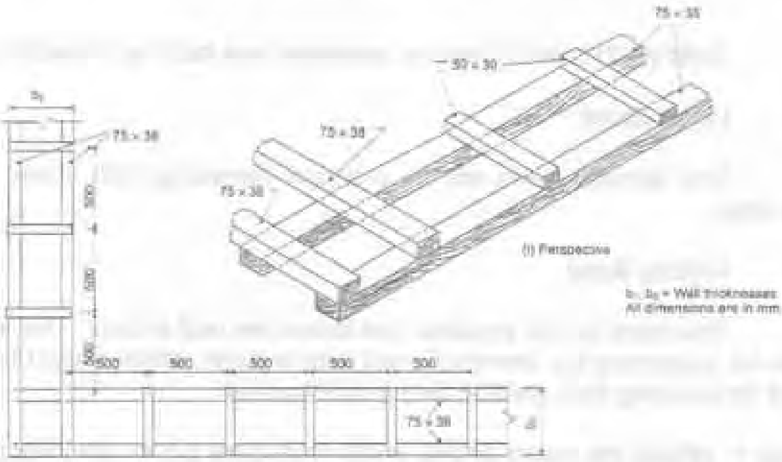
will be braced by cross pieces 50x30, (or circular halves, 60 mm dia) with nailed joints.



a) Rough cut lumber in single piece with corner diagonal



b) Rough cut lumbers in parallel



c) Details of timber seismic bands

Fig. 11E Wood Bands at Lintel and Ceiling Levels

Alternatively, bamboos in ladder form may be used as seismic bands.

In each case, the lengthening joint in the elements shall be made using framed joints with overlapping strips or iron-straps with sufficient nails/screws to ensure the strength of the original lumber or bamboo at the joint.

Note: *For durability over long life, the wood should be well seasoned and preserved against termite attack by appropriate chemical treatment.*

12.3.E Pilasters and Buttresses

Where pilasters or buttresses are used, as recommended earlier at corners and T-junctions, the collar beam or band should cover the buttresses as well, as shown in Fig. 12E. Use of diagonal struts at corners will further stiffen the collar beam.

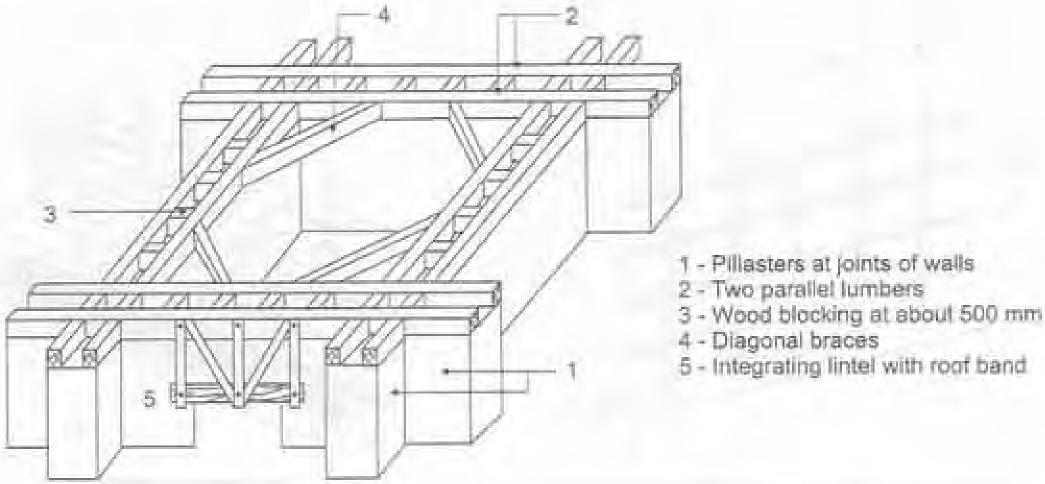


Fig. 12E Seismic Band Using Timber on Pilastered Walls

12.4.E Dowels/Bands at Window Sill Level

In the severe seismic zone AB and all *important* (I = 1.5) buildings, a seismic band should be provided at window sill level going through all the walls except at door locations. Alternatively, dowels may be provided at all corners and T-junctions of walls as shown in Fig. 13E.

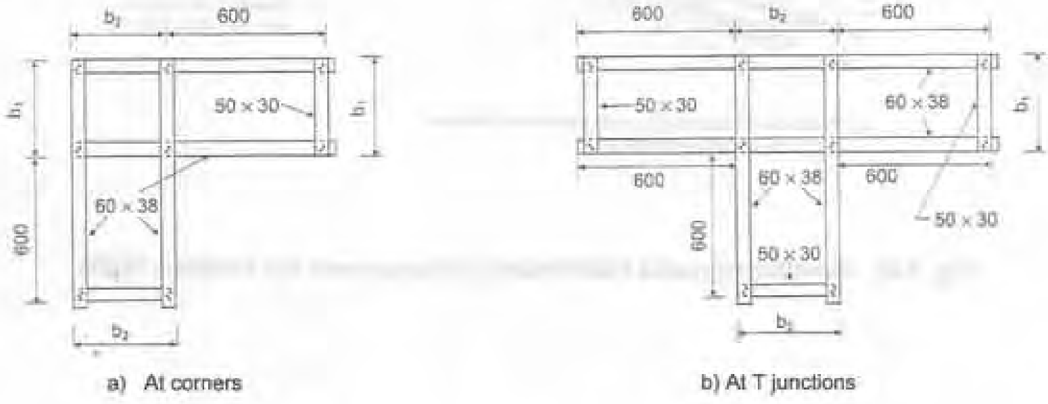
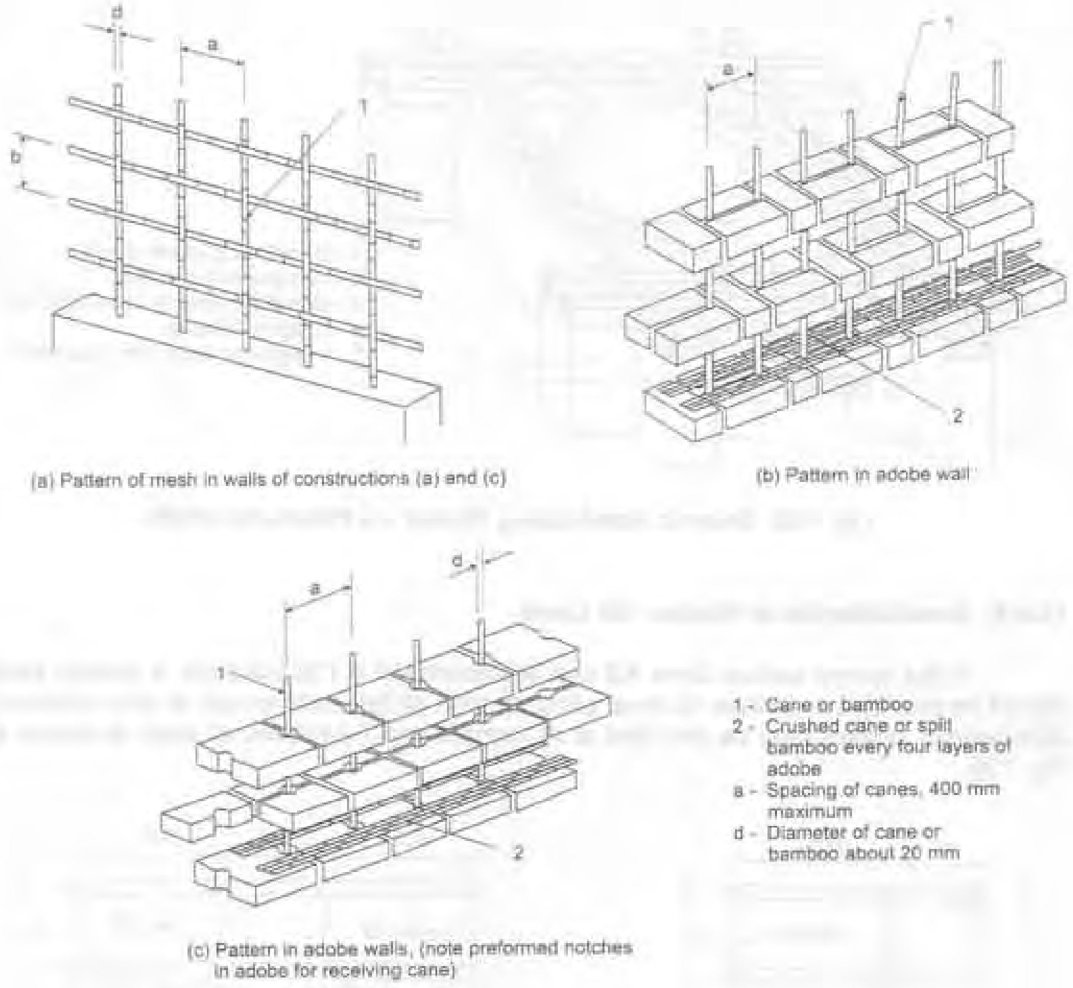


Fig. 13E Wooden Dowels at window sill level

12.5.E Vertical Reinforcement in Walls

In the highest seismic zone AB, mesh form of reinforcing embedded in the walls is recommended. Here the whole walls are reinforced by a mesh of canes or bamboos as shown in Fig. 14E alongwith the collar beams or seismic band which may in this case be made from canes or bamboos themselves. The vertical canes must be tied to the horizontal bamboos as well as the collar beams at lintel and the ceiling levels.



(a) Pattern of mesh in walls of constructions (a) and (c)

(b) Pattern in adobe wall

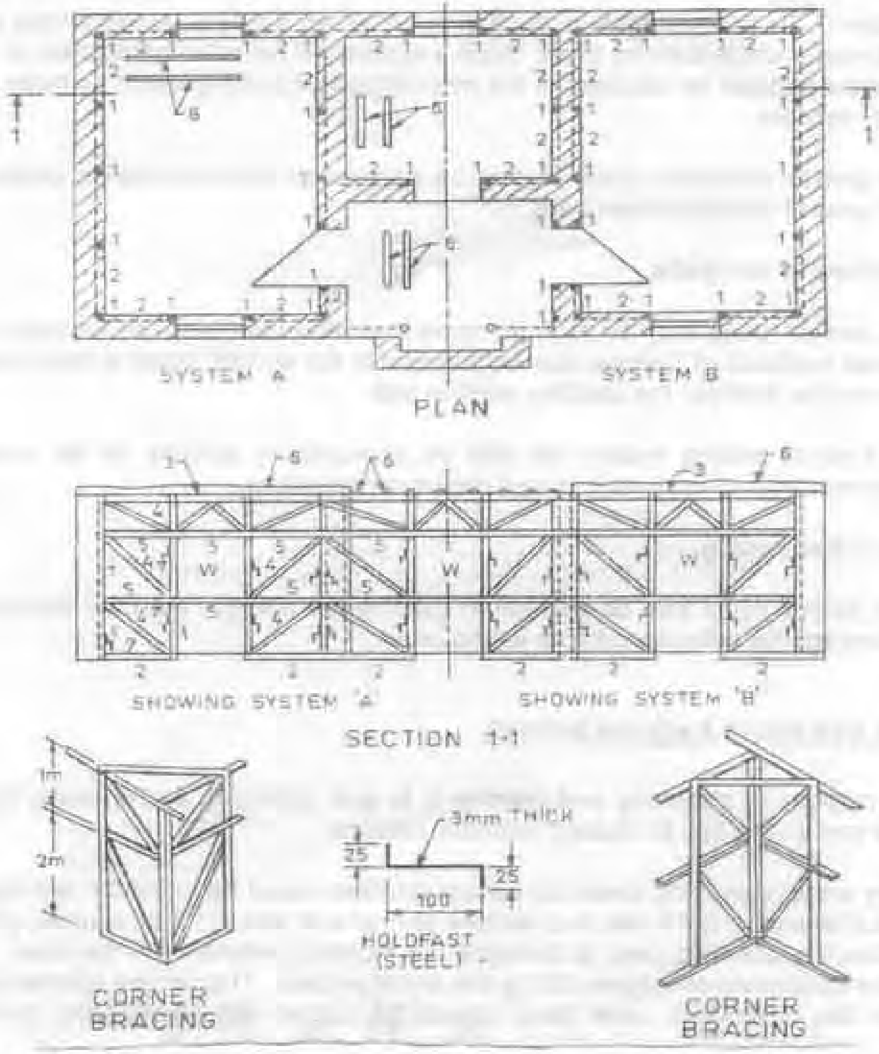
(c) Pattern in adobe walls, (note preformed notches in adobe for receiving cane)

Fig. 14E Best Earthquake Reinforcing Arrangement for Earthen Walls

13.E BRACING AND BRACED FRAMES

For achieving adequate seismic resistance in Zones AB, it will be desirable to provide diagonal bracing members in the planes of walls as well as horizontally at the floors and roofs. This can be done by using heavier wood logs vertically and lighter wood logs or bamboos horizontally and diagonally, with nailing between the framing members at the ends and intermediate points of intersection, before constructing the hand-formed mud walls or laying the Adobes within the panels. Long nails (minimum 150 mm long), minimum two, should be used for connections.

In using the braced frame method, the following three systems can be adopted:(Fig. 15E)



Minimum Dimensions

1.- Column 100 x 75 or 100 ϕ   2 – Sill 100 x 75   3 – Beam 100 x 100 or 75 ϕ   4 – Diagonal 100 x 50*

*5 – Strut 100 x 50   6 – Ceiling beam 75 x 125 or 100 ϕ   *Corner 100 x 100   7 – Hold fast*

Joints – Use 6 gauge nails 75 mm long minimum 2 from each face through iron sheet gussets, minimum 1 mm thickness or straps of 2 mm thickness

All dimensions in millimeters

Fig. 15E Braced Wood Frames for Adobe and other Masonry walls in mud mortar

13.1.E *System A* – The whole building plan may be framed as one piece and the external walls built keeping the wooden frame at the inner face of external walls and the internal walls built keeping the frame on one of its faces (preferably on the bed room side). Such a frame will have the advantage of redundancy, and use of less number of columns. But the frame can be subjected to tensional stresses under the earthquake motions.

13.2.E *System B* – Each room may be framed individually, thus the external walls will have the frame only on their inner face, the internal walls will have the frames on both faces, preventing the fall of the inner wall either way. This system will have the advantage of permitting any plan shape without the problem of torsion of the frames and much greater safety of cross walls. It will, however, consume more timber since all frames on the inner walls will be doubled.

13.3.E *System C* – In the third system, the frames of system B may be joined across walls making it a stronger whole building frame. Such a system will have the advantages of both A and B systems and can be adopted for the more important buildings such as those built for community services.

As a general guidance, system A may be adopted for near symmetrical plans and system B for general unsymmetrical plans.

13.4.E Holdfasts to the Walls

The earthen walls may be kept no more than 400 mm thick. To improve their behaviour, steel holdfasts of Z-shape may be screwed to the wooden posts at least one for each triangle and be built into the cladding earthen wall.

13.5.E The internal bracing system will also be appropriately suitable for the seismic safety of random rubble or brick work in mud mortar constructions.

13.6.E Use in Retrofitting

Such frames could also be inserted in existing low strength masonry houses for retrofitting them against collapse in future earthquakes.

14.E PLASTERING AND PAINTING

The purpose of plastering and painting is to give protection and durability to the walls and the roof, in addition to obvious aesthetic reasons.

14.1.E In dry areas, plastering based on natural additives could be formed in two layers. The first one of about 12 to 15 mm, is a mixture of mud and straw (1:1 in volume), plus a natural additive like cowdung used to increase the moisture resistance of the mud, thus preventing the occurrence of fissures during the drying process. The second and last layer is made with fine mud which when dried, should be rubbed with small, hard, rounded pebbles.

14.2.E In wet areas, the walls should be covered with waterproof mud plaster. To obtain this, the following procedure may be followed:

"*Cut-back* should be prepared by mixing bitumen 80/100 grade and kerosene oil in the ratio 5:1. For 1.8 kg *cut-back*, 1.5 kg bitumen is melted and is poured in a container having 300 millilitres kerosens oil, with constant stirring, till complete mixing. This mixture can now be missed with 30 litres of mud mortar to make it both, water repellent and fire resistant.

14.3.E For improving water resistance of roof, the waterproof plaster may be applied on top surfaces of the roof, 20 to 25 mm thick, and allowed to dry. It may then be coated twice with a wet mixture of cowdung and waterproof plaster in the ratio of 1:1, and allowed to dry again.

14.4.E The exterior of walls after plastering may be suitably painted using a water-insoluble paint or washed with water solutions of lime or cement or gypsum.

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3. IS: 13827-1993 "*Improving Earthquake Resistance of Earthen Buildings - Guidelines*".

4. "*Guidelines for Earthquake Resistant Non-Engineered Construction*" A.S. Arya, et al, pub. by IAEE, 1986, reprinted by Indian Society of Earthquake Technology, Roorkee-247 667.

5. "*Improving Earthquake Resistance of Buildings – Guidelines*", by Arya, A.S. et al., pub. by Building Materials and Technology Promotion Council, New Delhi, 1999.

APPENDIX 1

Photos of Current Building Conditions in Afghanistan

APPENDIX 2

Photos of Damages of Building in Naharin Earthquake of 2002

APPENDIX 3

Photos of UNCRD-MUDH Training Programme in Kabul

APPENDIX 4

Photos of Shake Table Testing in Kabul

About UNCRD

The United Nations Centre for Regional Development (UNCRD) was founded in 1971 in Nagoya, under an agreement between the United Nations and the Government of Japan. UNCRD has been striving to achieve the following objectives:

- Serve as a training and research centre,
- Provide advisory services
- Promote global knowledge-sharing, and
- Encourage international cooperation among nations, regions, and organizations.

In 1999, the UNCRD Disaster Management Planning Hyogo Office was established in Kobe, where the Great Hanshin-Awaji Earthquake had claimed the lives of more than 6,000 people in 1995. The Hyogo Office focuses on various disaster management initiatives through multi-lateral collaboration at an international level while utilizing the momentum created during the UN IDNDR 1990-99 (United Nations International Decade for Natural Disaster Reduction). It promotes effective disaster mitigation, focusing on key elements of self-help, cooperation, and education through activities such as: (a) research projects; (b) training and capacity-building; (c) a series of international workshops; and (d) advisory services.

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