GUIDELINES

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

AFGHANISTAN

June 2003

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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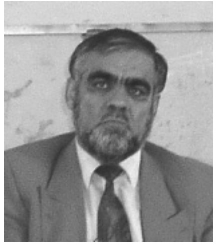


MESSAGE

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

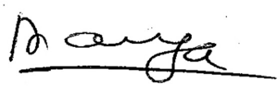
PART A: Earthquake Resistant Design of Buildings covers the principles of earthquake resistant design of buildings taking to account the seismic zones of Afghanistan. It also includes the detailing aspects of reinforced concrete buildings. This part will be used for providing training of the engineers 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.

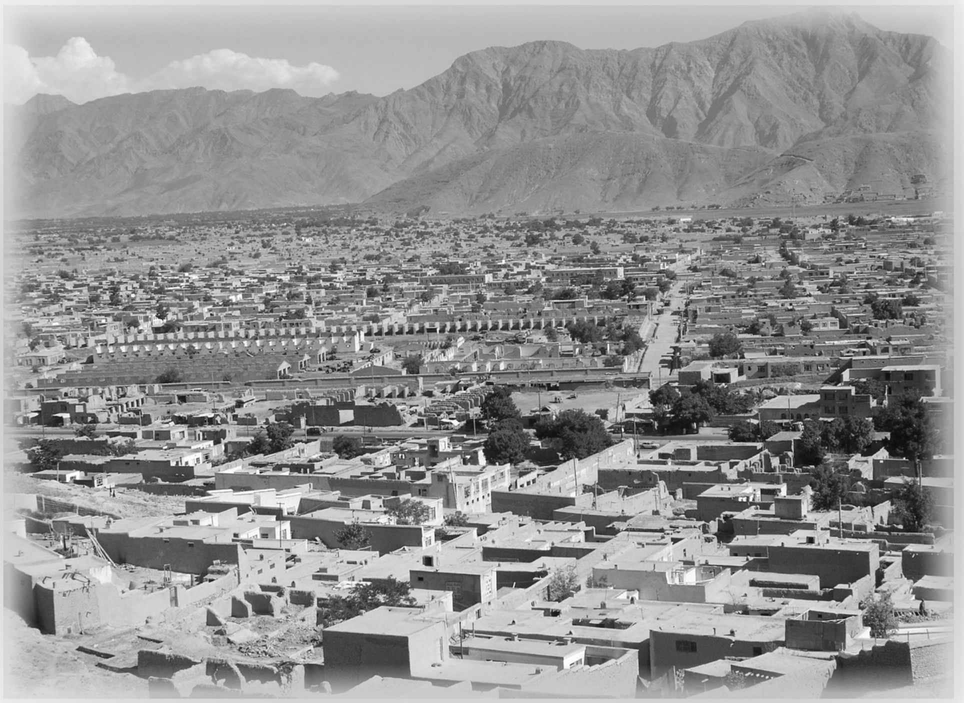
PART E: Earthquake Resistant Construction of Earthen Houses covers the earthquake resistant construction details of earthen houses taking into account the seismic zones of Afghanistan. This part will be useful for providing training of the engineers as well as masons, and help in improving the safety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



Anand S. Arya
Consultant

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).

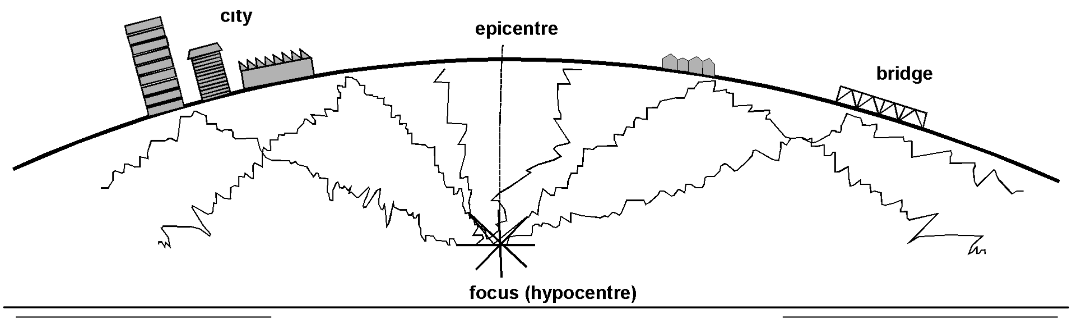


Fig. 1A Earthquake occurrence

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’.

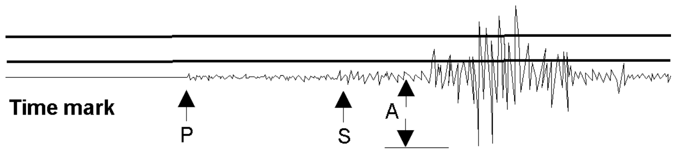


Fig. 2A A Typical earthquake record

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.

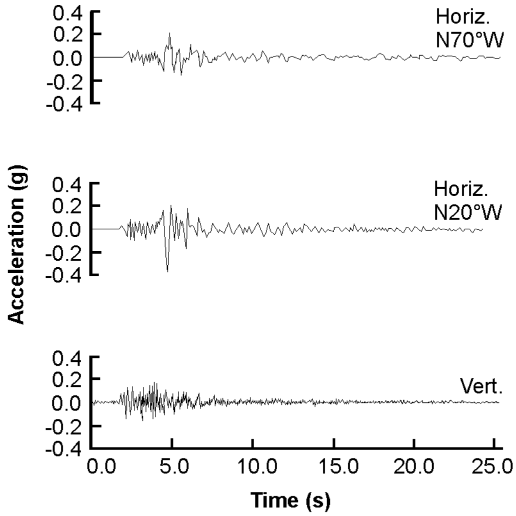


Fig. 3A Accelerograms of earthquake recorded at Gopeshwar during Chamoli (India) Earthquake in March 29, 1999 (Peak value = 0.35g)

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:

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

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.

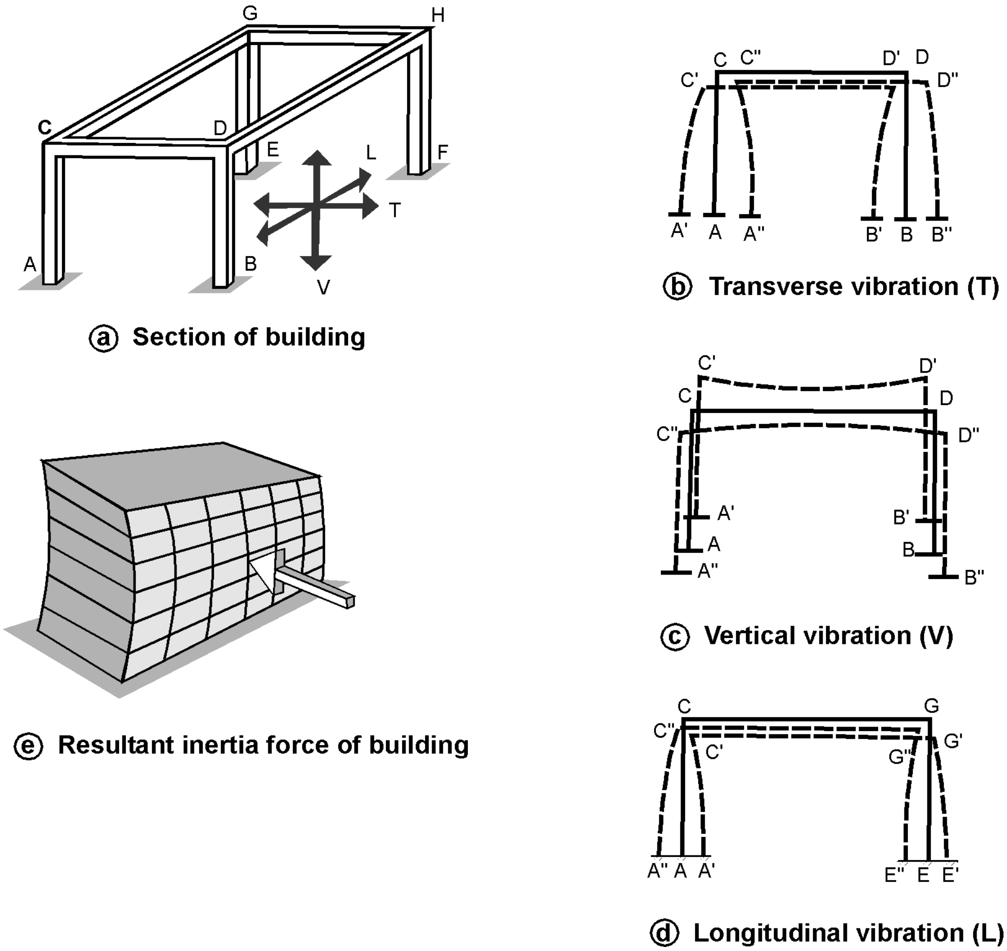
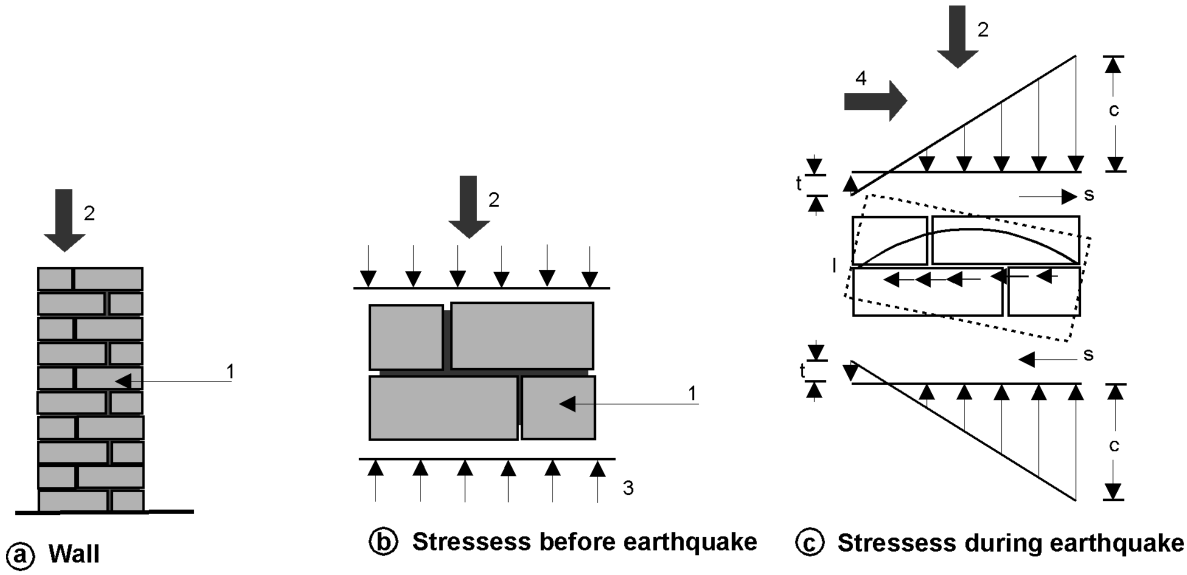


Fig. 4A Seismic vibration of a building and resulting earthquake forces

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.*



1. **Wall element**
2. **Vertical load from above the wall element**
3. **reaction from below**
4. **earthquake force**

c compressive stress
t tensile stress
s shearing stress

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.

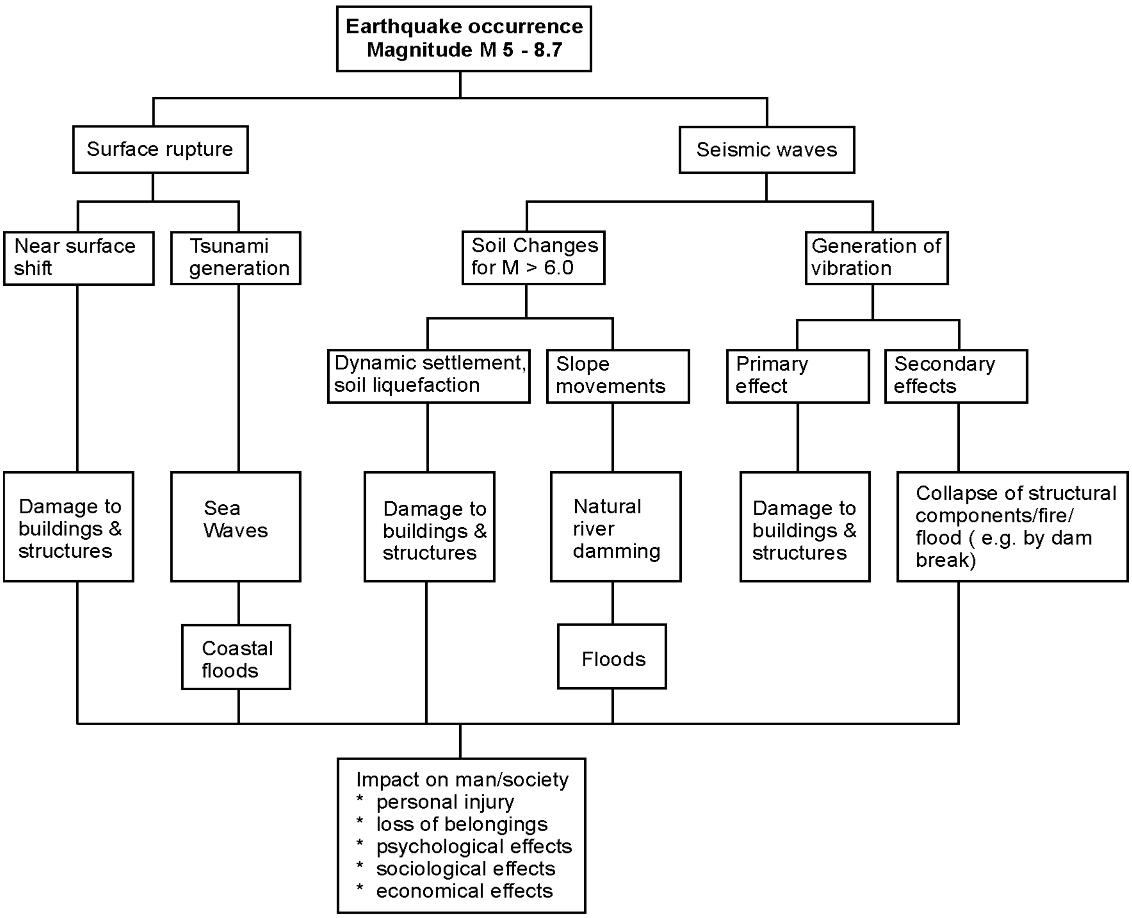


Fig. 6A Possible overall effects of earthquake hazards *(Source UNDRO)*

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.

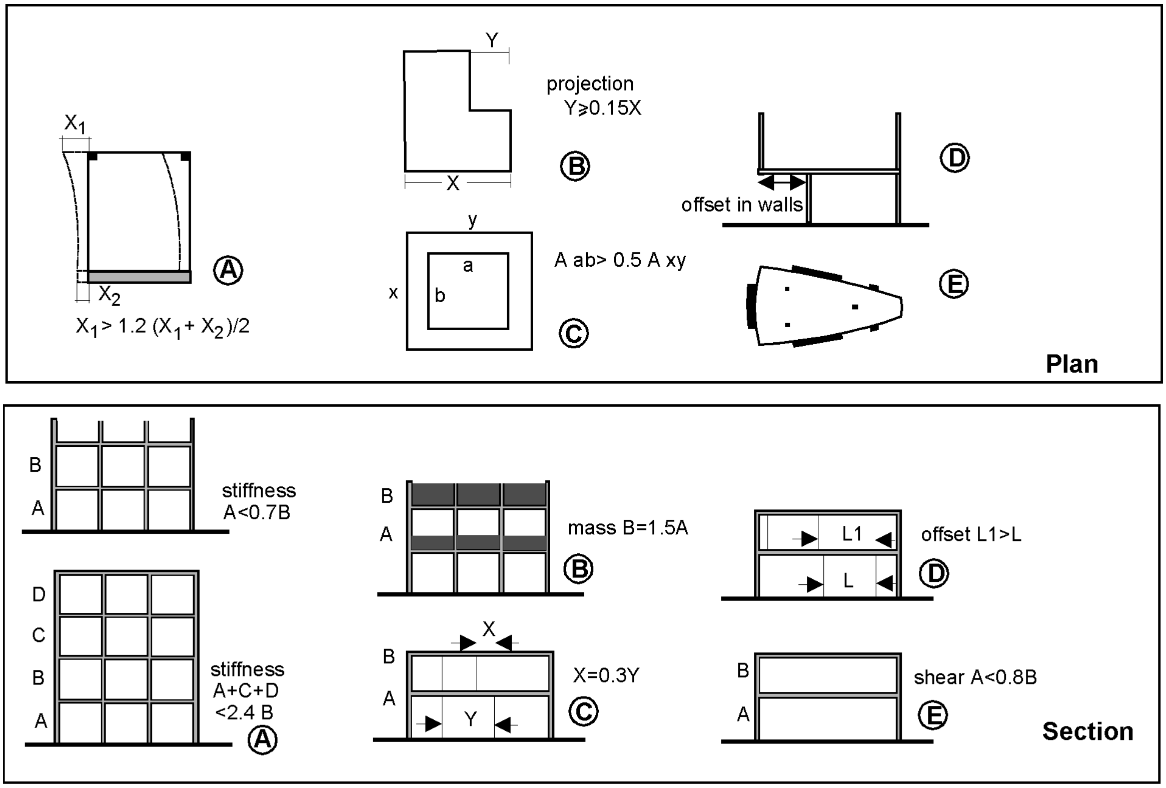


Fig. 7A Configuration irregularities
(Source: Uniform building code of USA, 1988)

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.

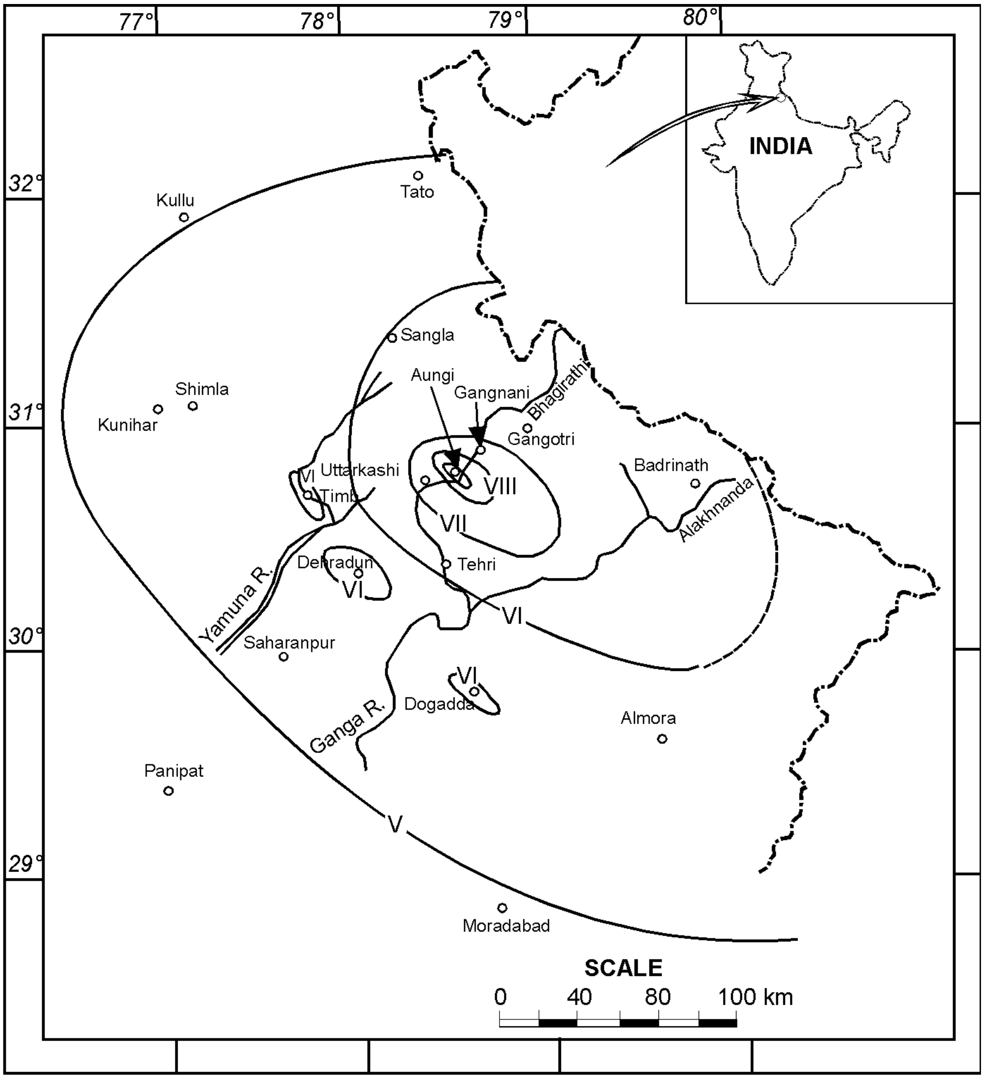


Fig. 8A Isoseismic of Uttarkashi Oct. 20, 1991 earthquake

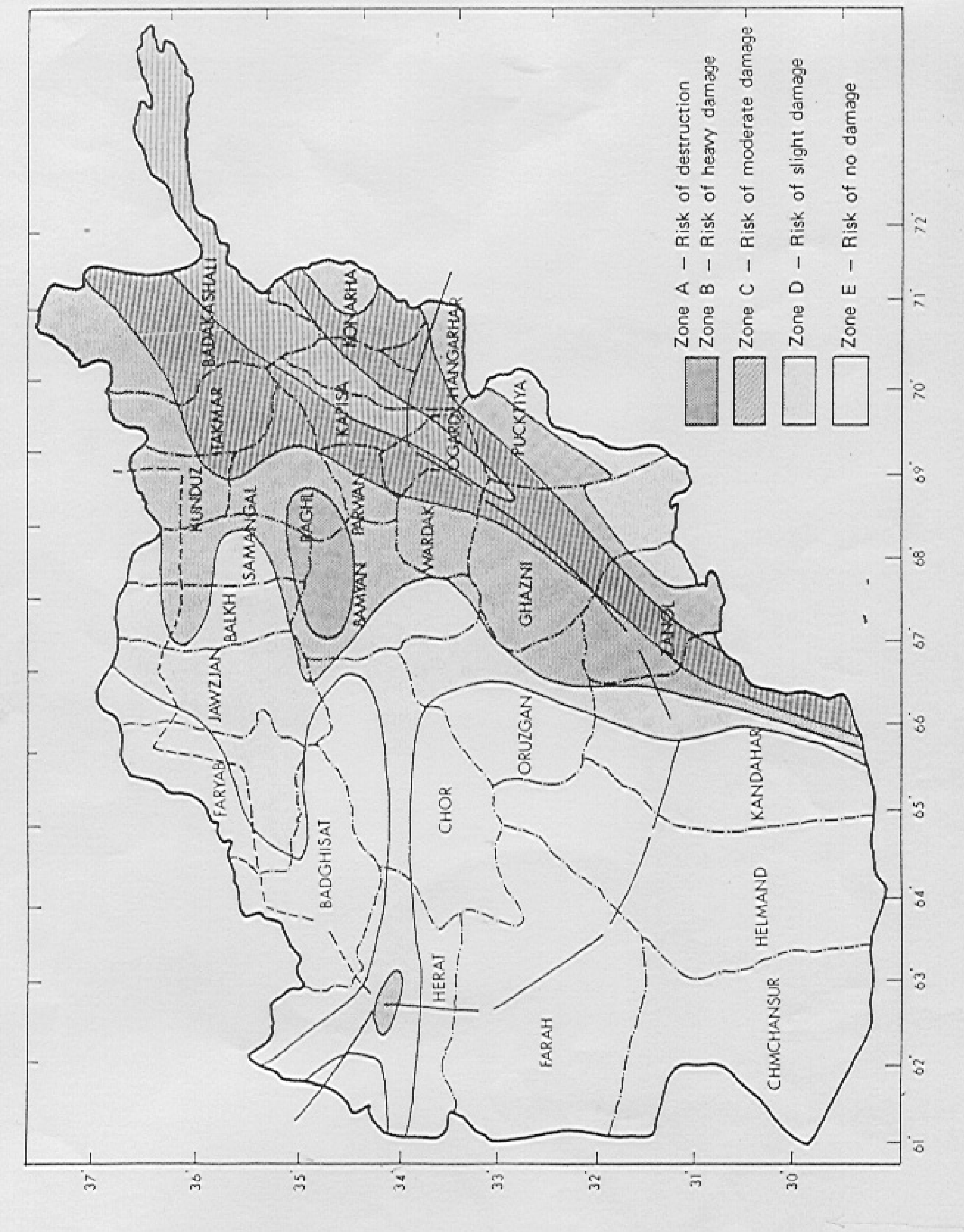


Fig. 9A Seismic Zones of Afghanistan
(Source: A.S. Arya, UNESCO Bangkok Report, 1973)

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,

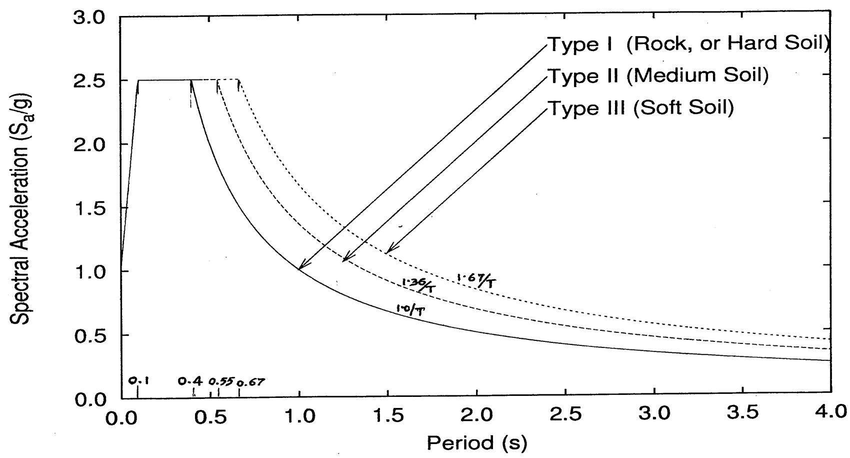


Fig. 10A Design Earthquake Average Acceleration Spectra

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:

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

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

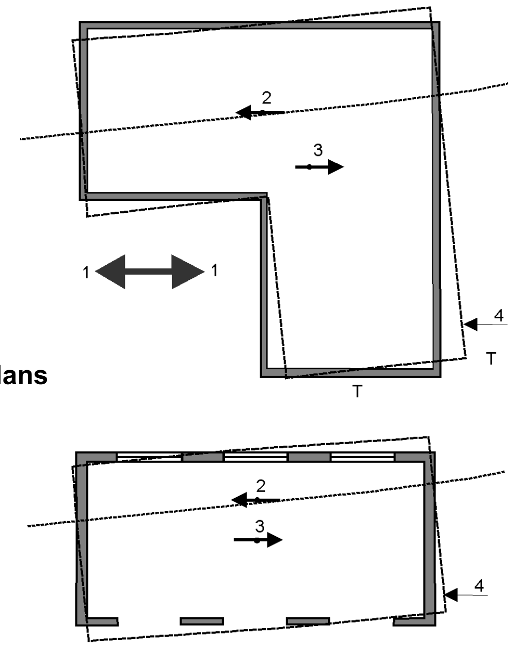
Analysis of building frames for the lateral earthquake loads could be carried out by a number of methods, e.g. (a) some approximate methods based on statical equilibrium making the frame statically determinate by a number of assumptions, such as pier analysis for masonry buildings (b) some more accurate 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.

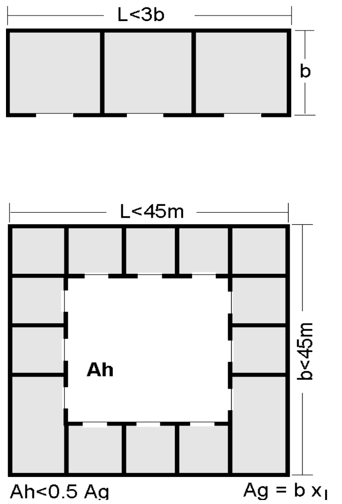
(iii) Suspended ceiling should preferably be avoided. Where necessary, it should be light, adequately framed and securely connected.

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).



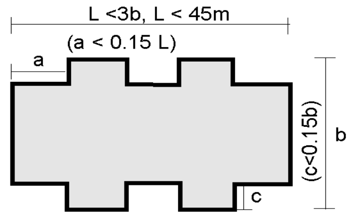


Fig. 12A Building Plan Guidelines

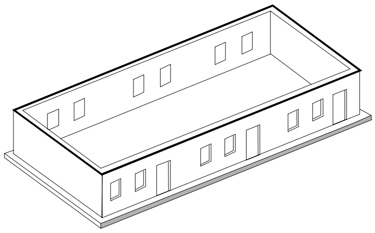
(b) Long Buildings

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).

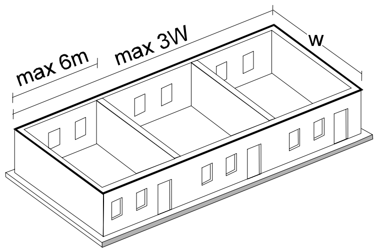
(c) Separation of Wings

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.

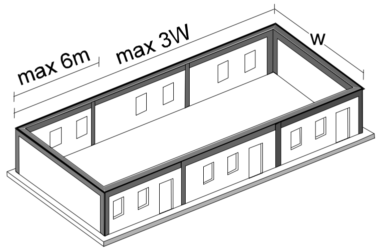
Note: Single houses normally have small projections causing unsymmetry. These should preferably be limited as shown in Fig. 12A.



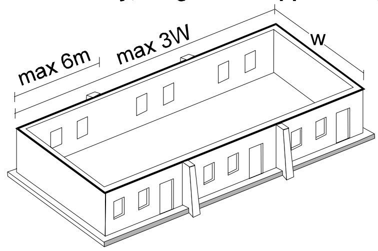
ⓐ Unsatisfactory; long unsupported walls



ⓑ 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.

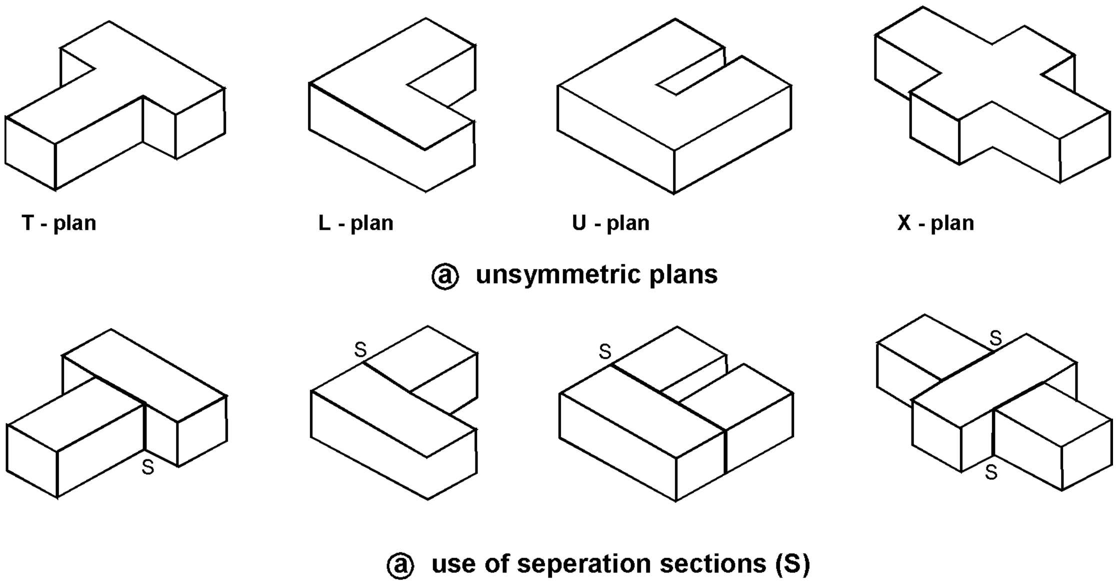


Fig. 14A Architectural Planning of Large Buildings

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.

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* 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.

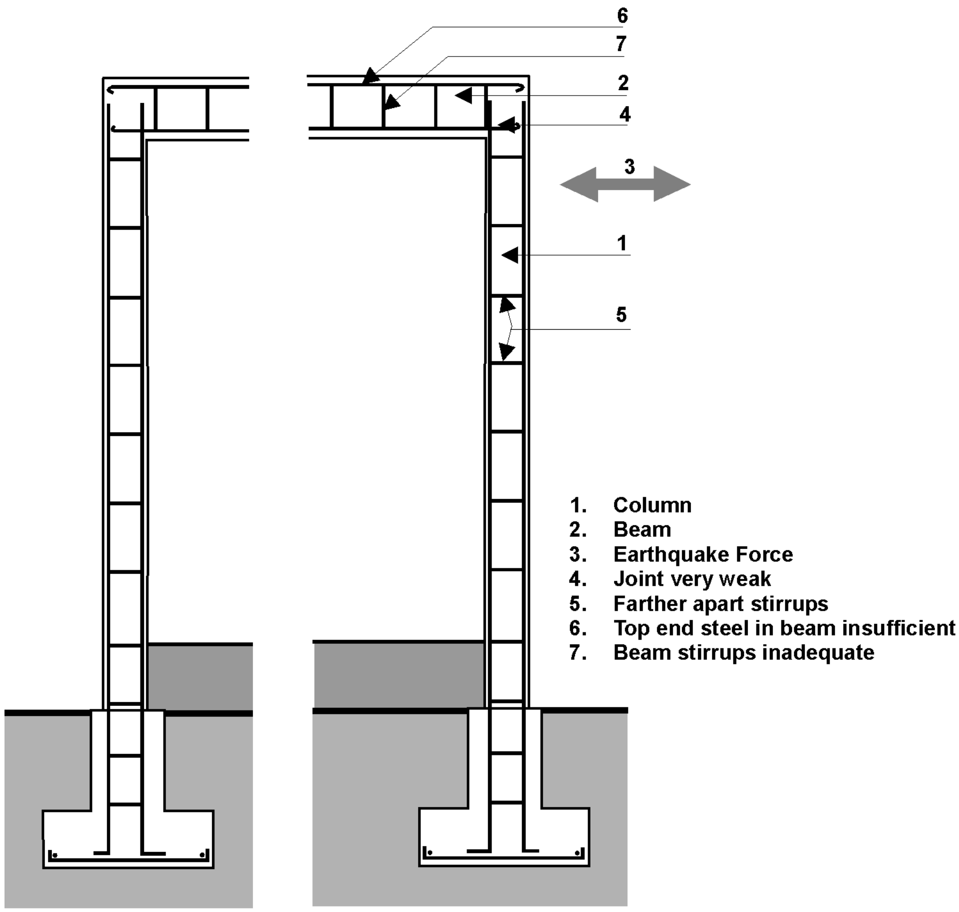
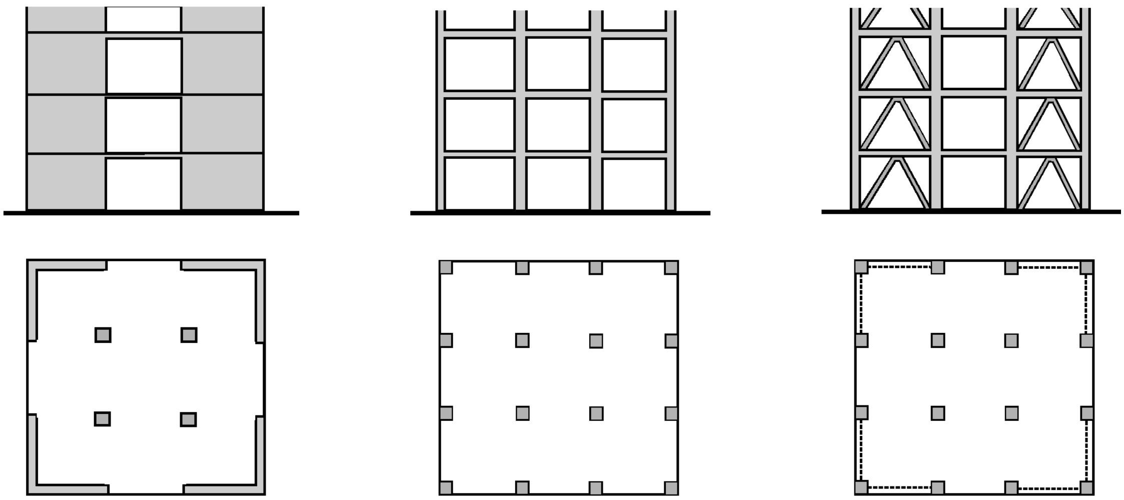


Fig. 15A Commonly constructed post-beam form

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.



Shear walls **Moment Resistant Frames** **Braced Frames**

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:

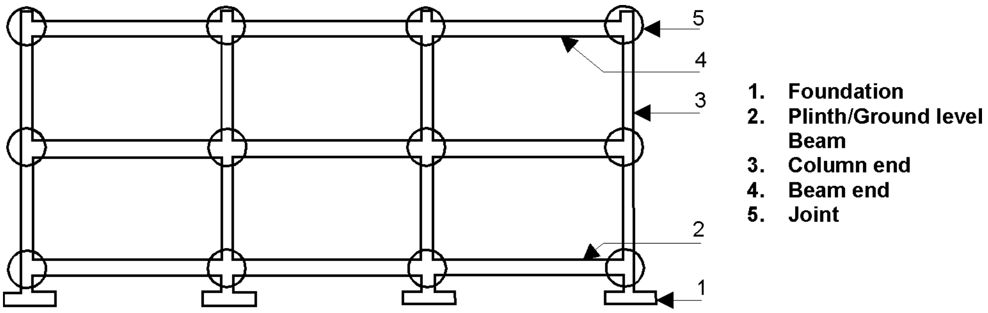


Fig. 17A Critical sections of frames

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

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

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

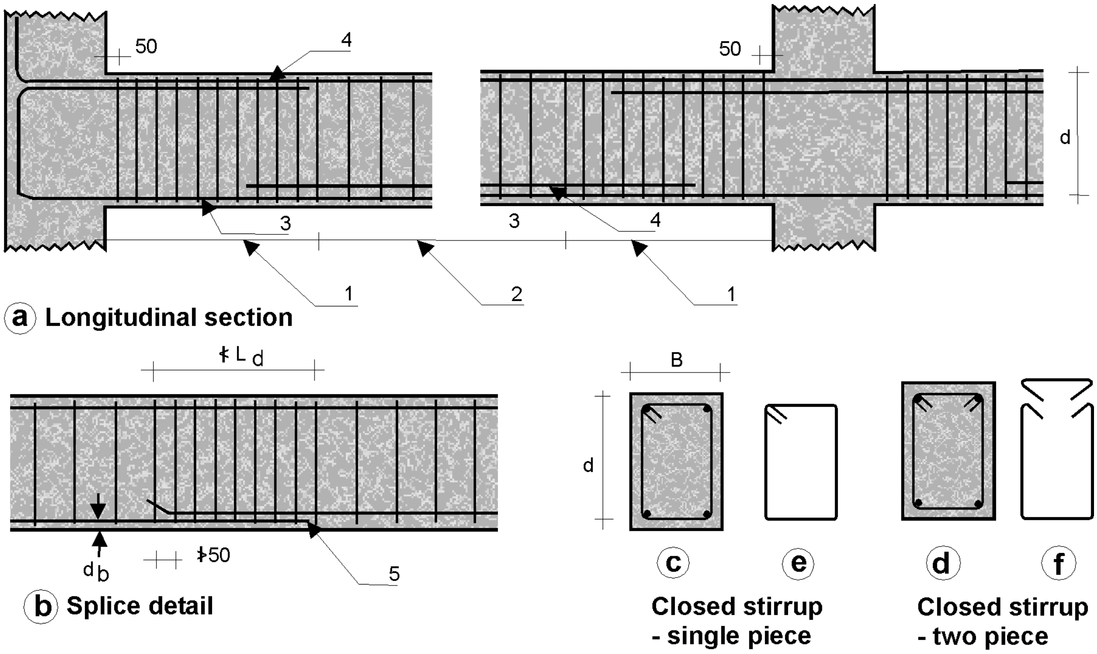
iii. The beams should have at least two bars satisfying the minimum reinforcement criterion on top as well as bottom face throughout the length of the beam with full bond length anchorage in the end columns, and continuity in the adjacent spans. Other bars coming into the joint should be anchored or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



1 Hoop spacing ≤ d/4
2 Hoop spacing ≤ d/2
3 minimum 2 bars, $A_s \geq P_{min} Bd$
4 Maximum $A_s \leq P_{max} Bd$
5 Splice

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.

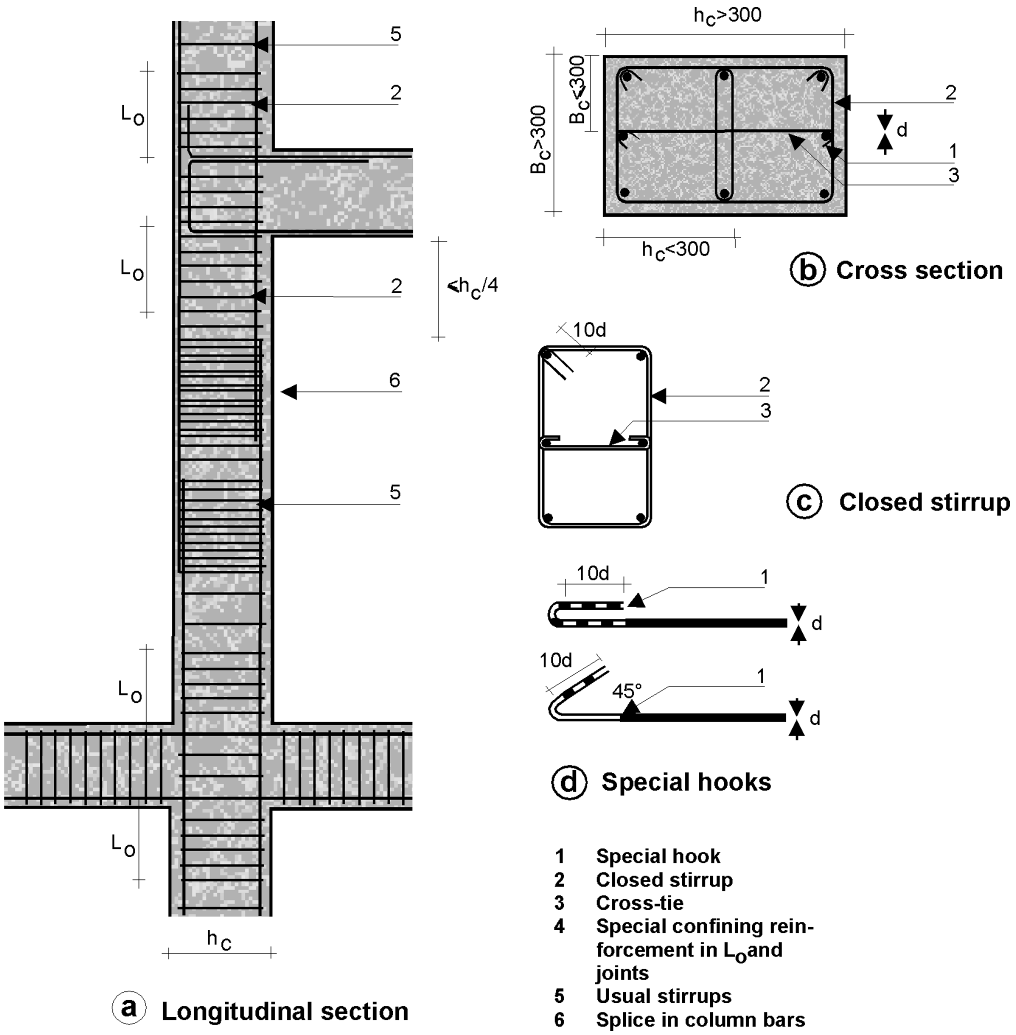


Fig. 19A Reinforcement detailing in RC column

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.

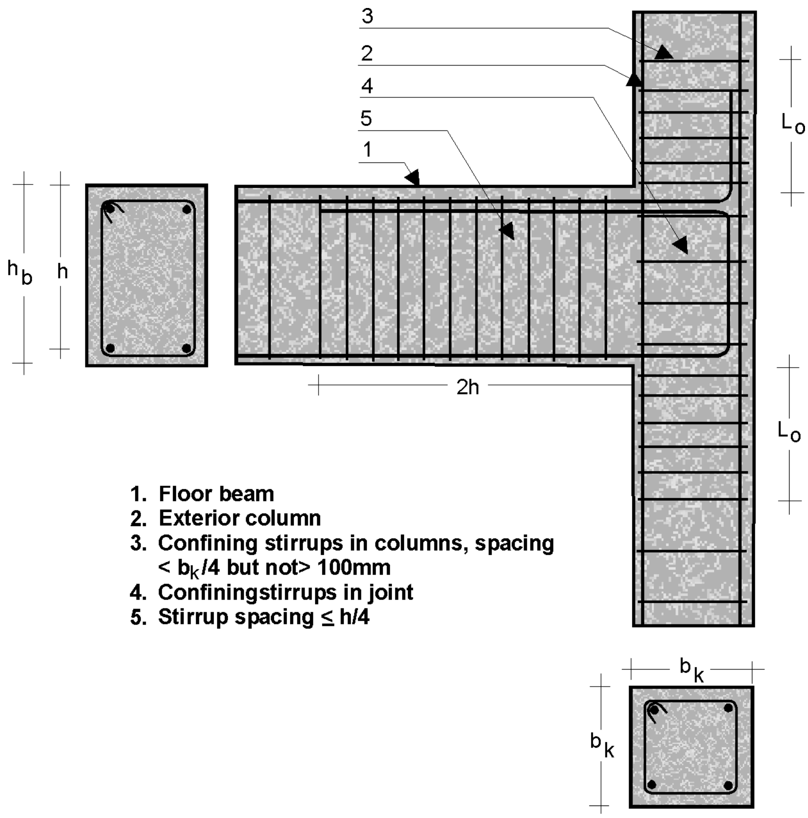


Fig. 20A Detailing of column beam joint

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.

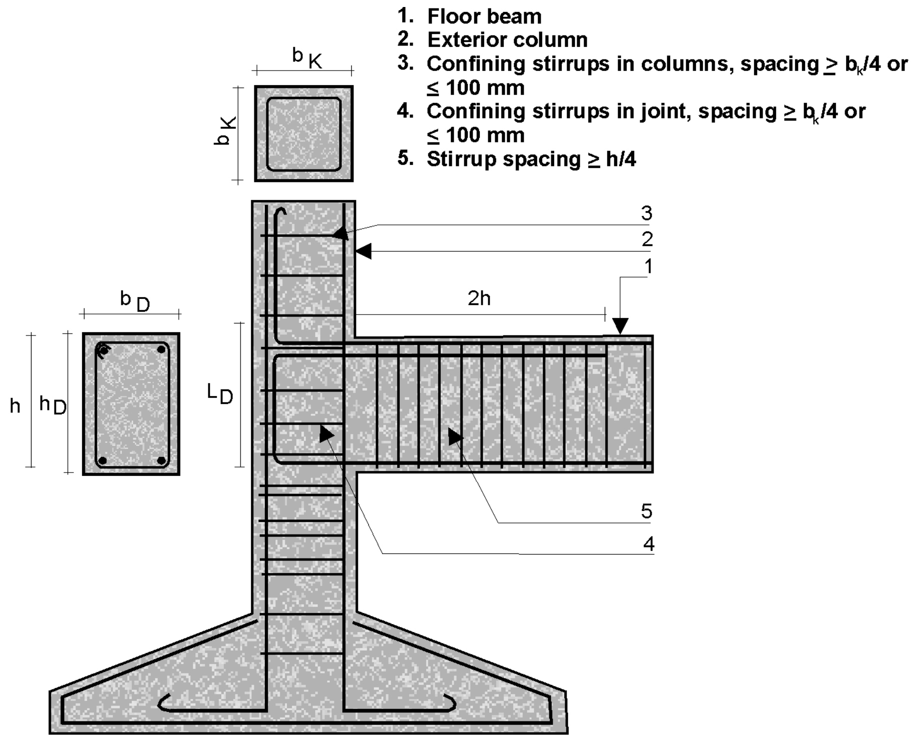


Fig. 21A Detailing of joint of column with plinth beam and footing

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Annexure

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.