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Manual on Safe Construction Practices and Disaster Resilient Shelter Construction through incorporating Global Best Practices and Social and Environmental Benefits

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Table of Contents

Executive Summary

This manual is a guideline for the creating disaster resilient building construction adopted by people for different typologies of building in Kerala. As in Kerala is vulnerable for different types of disaster like earthquake, landslides, cyclone, floods etc. In any case building experience additional dynamic loading which can cause damage or collapse in structure that leads loss in property and human life. In India, there are several types of construction practices are used based on locally available material, climate and other but in several study, it is found that most of the building are deficient to the different hazards that make our society more vulnerable. To prevent damage and reduce risk it is recommended that we have to avoid vulnerable structures construction by using different techniques. Before understanding disaster resilient construction techniques, it is important that to understand following topics like vulnerability profile of India, vulnerability profile of state, existing building typology, site selection criteria, construction material selection criteria, quality construction material selection criteria, Indian standard code provision,

There are several severe disaster events occurred in Kerala, one of the most eye-opening flood event happened in 2018 i.e. because of Kerala received heavy monsoon rainfall which it was about 75% more than usual rainfall in Kerala, Because of the heavy rainfall the water level rapidly rise in the dams to avoid any damage in dams immediate water discharge was processed, it was the first time in the state's history 35 out of its 54 dams has been opened. Due to this, flood is induced in the state. There are several districts In Kerala was severely affected by flood over 3274 relief camps have been opened at various locations to accommodate the flood victims. it is estimated that 1,247,496 People have found shelter in such camps. The three most affected districts were Pathanamthitta, Wayanad and Idukki.

The different type of building structures presents in Kerala which can broadly divide building types in two ways first on the basis of architectural configuration and second on the basis of Building construction material. When these structures are exposed to the different hazards response behavior of the buildings will change accordingly. There is one the deciding factor for building response is material quality of built structure, that is why the quality material is needed to be selected for the construction. There are some general criteria are discussed further in the manual.

Site selection plays important role to reduce the risk that may cause due to any disaster. There are several factors which need to be considered while we are going to construct a building in flood or landslide prone area. Some of the most important factors are like Site drainage, Flooding, Soil erosion, Proximity of natural hazards and distance from nearest water body.

In India there are different type of construction practices are going on. It is very important to adopt most suitable and resilient techniques for the construction of building. It contributes to decrease vulnerability of country.

Asymmetrically designed buildings are subject to substantial torsional forces The more symmetrical the structure is about both axes, the better. during earthquakes, making them considerably dangerous. In addition, simple designs with rectangular shapes tend to hold up better than more complicated designs with protruding sections. There are some major construction techniques which make structure disister resilient are like base isolation, less damageability, proper foundation etc. By using theses techniques while building new structures we can create disaster resilient society.

In Kerala, most of the area comes under seismic zone three that means there are moderate risk for the earthquake, which may lead damage of intensity VII, that can cause structural damage in RCC structures and masonry structures may be collapse. There are different effective techniques are available for building earthquake resistant buildings which needed to be followed for the construction are like proper reinforcement pattern, strengthening of wall, corners, opening etc.

For the flood and landslide vulnerable area, it is important to create hazard analysis before finalizing site for the construction and there are some of the basic principles that needed to be followed for the resilient construction like, in flood prone are building plinth must be above highest level of flood, if it is placed on platform than bracing in needed to be installed for the protection of buildings, similarly for the landslides prone area a well-designed and good quality retaining wall is mandatory to install which can protect landslides. Further all the details are discussed in detail.

In case of flood hazard there are some common failures are observed after Kerala flood i.e. cracks in walls, settlement in foundation, partial damage in structure, uneven column settlements etc. Some structures are survived but needed special attention for the future. To minimized impact of flood water there are several construction principles which need to be followed like plinth protection, plinth raise, proper site selection, durable construction material etc. In landslide hazard there are very few techniques are available that may be prevent building due to the scale of hazard. Landslide generally effect a huge land mass due to which mitigation and retrofitting is needed at larger scale to stabilize slope, but in case of individual buildings there are some common principles we need to follow before construction that may reduce the impact and mitigate future loss.

Key idea to build disaster resilient structure is to make it durable and achieve factor of safety at the time of any disaster, for that there are some important recommendations like analysis the structure in different perspectives like site of building, material used for construction, damage appear, building configuration, maintained quality on the basis of above mention disaster resilient technique should be adopted which include several factors like expert executor available, quality of intervention needed to be quantified, supervision of site engineer is must etc. To build safer society it is very important to build disaster resilient structures so that impact of any disaster would be minimized, and chance of economic and human loss can be reduced. In Kerala it is need of this hour to carry a detail survey of all flood effected area and create a common structure damage pattern inventory for the vulnerable structure which shows damage the people which are the best practices are available in the area that they can adopt to build there house or building so that damage probability will be than a training program needed to be conducted with the practical session to selected masons. There is a need to create some demo units using all the local material available which includes disaster resilient feature for the future reference of native people.

Chapter 1

Disaster Profile of India

Chapter 1

Disasters Profile in India

1.1.1 Disaster Profile

The Indian subcontinent is among the world's most disaster-prone areas. Almost 85% of India's area is vulnerable to one or multiple hazard. Of the 28 states and 7 union territories, 22 are disaster-prone. It is vulnerable to wind storms spawned in the Bay of Bengal and the Arabian Sea, earthquakes caused by active crustal movement in the Himalayan mountains, floods brought by monsoons, and droughts in the country's arid and semi-arid areas. Almost 57% of the land is vulnerable to earthquake (high seismic zones III–V), 68% to drought, 8% to cyclones and 12% to floods. India has also become much more vulnerable to tsunamis since the 2004 Indian Ocean tsunami.

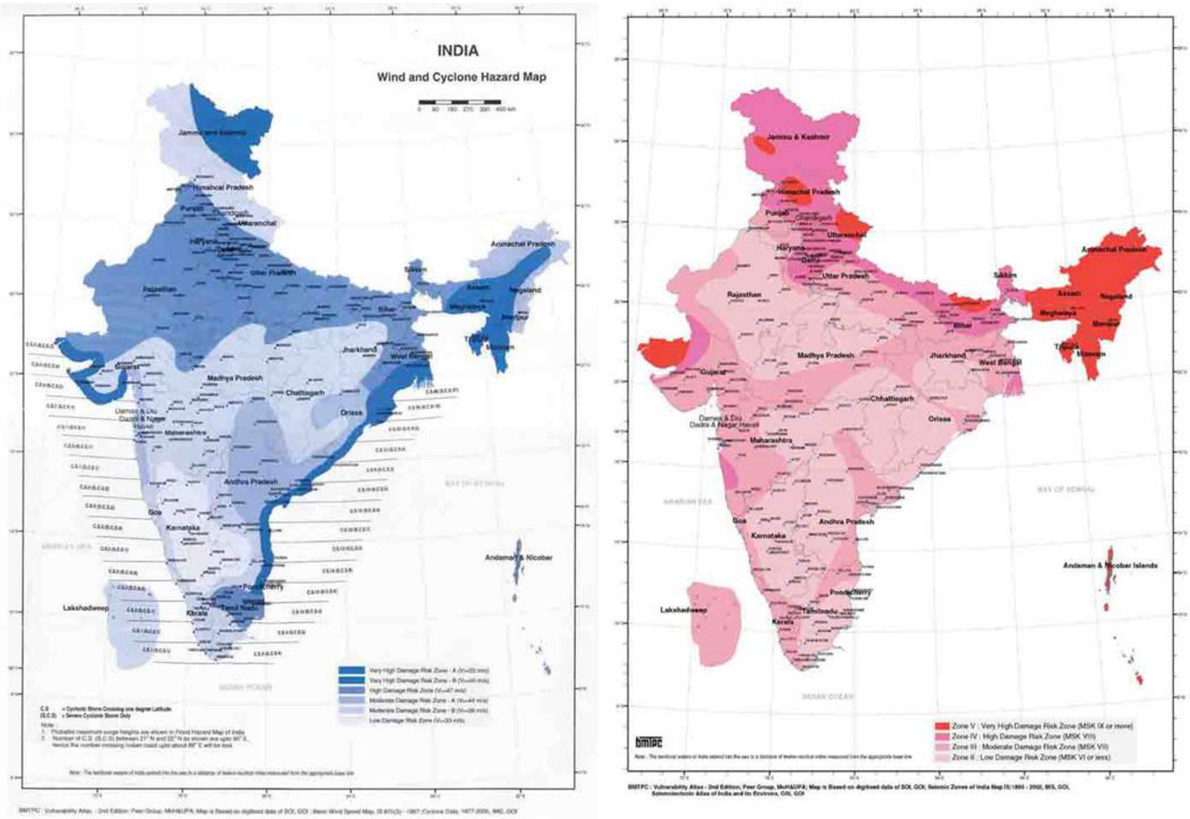

Figure 1: Map shows different disaster vulnerability profile in India (source: GSI)

1.1.2 Earthquakes:

Of the earthquake-prone areas, 12% is prone to very severe earthquakes,18% to severe earthquakes and 25% to damageable earthquakes. The biggest quakes occur in the Andaman and Nicobar Islands, Kutch, Himachal and the North-East. The Himalayan regions are particularly prone to earthquakes. The last two major earthquakes shook Gujarat in January 2001 and Jammu and Kashmir in October 2005. Many smaller-scale quakes occurred in other parts of India in 2006. All 7 North East states of India – Assam, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura and Meghalaya; Andaman & Nicobar

Islands; and parts of 6 other states in the North/North-West (Jammu and Kashmir, Uttaranchal, Bihar) and West (Gujarat), are in Seismic Zone V.

1.1.3 Floods:

About 30 million people are affected annually. Floods in the Indo–Gangetic–Brahmaputra plains are an annual feature. On an average, a few hundred lives are lost, millions are rendered homeless and several hectares of crops are damaged every year. Nearly 75% of the total rainfall occurs over a short monsoon season (June – September). 40 million hectares, or 12% of Indian land, is considered prone to floods. Floods are a perennial phenomenon in at least 5 states – Assam, Bihar, Orissa, Uttar Pradesh and West Bengal. On account of climate change, floods have also occurred in recent years in areas that are normally not flood prone. In 2006, drought prone parts of Rajasthan experienced floods.

1.1.4 Droughts:

About 50 million people are affected annually by drought. Of approximately 90 million hectares of rain-fed areas, about 40 million hectares are prone to scanty or no rain. Rainfall is poor in nine meteorological subdivisions out of 36 subdivision (each meteorological sub division covers a geographic area of more than ten revenue districts in India). In India annually 33% area receive rainfall less than 750 mm (low rainfall area) and 35 % area receive between 750 to 1125 mm rainfall Medium rainfall) and only 32percent falls in the high rainfall (>1126 mm)zone.

1.1.5 Cyclones:

About 8% of the land is vulnerable to cyclones of which coastal areas experience two or three tropical cyclones of varying intensity each year. Cyclonic activities on the east coast are more severe than on the west coast. The Indian continent is considered to be the worst cyclone-affected part of the world, as a result of low-depth ocean bed topography and coastal configuration. The principal threat from a cyclone are in the form of gales and strong winds; torrential rain and high tidal waves/storm surges. Most casualties are caused due to coastal inundation by tidal waves and storm surges. Cyclones typically strike the East Coast of India, along the Bay of Bengal, ie. the states of West Bengal, Orissa, Andhra Pradesh and Tamil Nadu, but also parts of Maharashtra and Gujarat at the Arabian Sea West Coast.

1.1.6 Landslides:

Landslides occur in the hilly regions such as the Himalayas, North-East India, the Nilgiris, and Eastern and Western Ghats. Landslides in India are another recurrent phenomenon. Landslide-prone areas largely correspond to earthquake-prone areas, i.e. North-west and North-East, where the incidence of landslides is the highest.

1.1.7 Droughts:

Drought is another recurrent phenomenon which results in widespread adverse impact on vulnerable people’s livelihoods and young children’s nutrition status. It typically strikes arid areas of Rajasthan (chronically) and Gujarat states. Drought is not uncommon in certain districts of Uttar Pradesh, Madhya Pradesh, Orissa, Andhra Pradesh, etc. Although a slow onset emergency, and to an extent predictable emergency, drought has caused severe suffering in the affected areas in recent years, including effects on poverty, hunger, and unemployment.

1.1.8 Cold waves:

Cold waves are recurrent phenomenon in North India. Hundreds if not thousands of people die of cold and related diseases every year, most of them from poor urban areas in northern parts of the country. According to India's Tenth Five Year Plan, natural disasters have affected nearly 6% of the population and 24% of deaths in Asia caused by disasters have occurred in India. Between 1996 and 2001, 2% of national GDP was lost because of natural disasters, and nearly 12% of Government revenue was spent on relief, rehabilitation and reconstruction during the same period.

Chapter 2

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Disaster Profile of Kerala

Chapter 2

Introduction of various Disasters Profile in Kerala

2.1 Introduction:

A disaster is a serious disruption, occurring over a relatively short time, of the functioning of a community or a society involving widespread human, material, economic or environmental loss and impacts, which exceeds the ability of the affected community or society to cope using its own resources. Disaster are seen as the consequences of inappropriately managed risk. these risks are the product of combination of both hazards and vulnerability. hazards that strikes in the areas with low vulnerability will never become disasters, as in the case of uninhabited reasons. developing countries suffer the greatest cost when disaster hits- more than 95% of old debts caused by the hazards occur in developing countries and losses due to natural hazards are 50 times greater (as a percentage of GDP) in developing countries then industrialized countries.

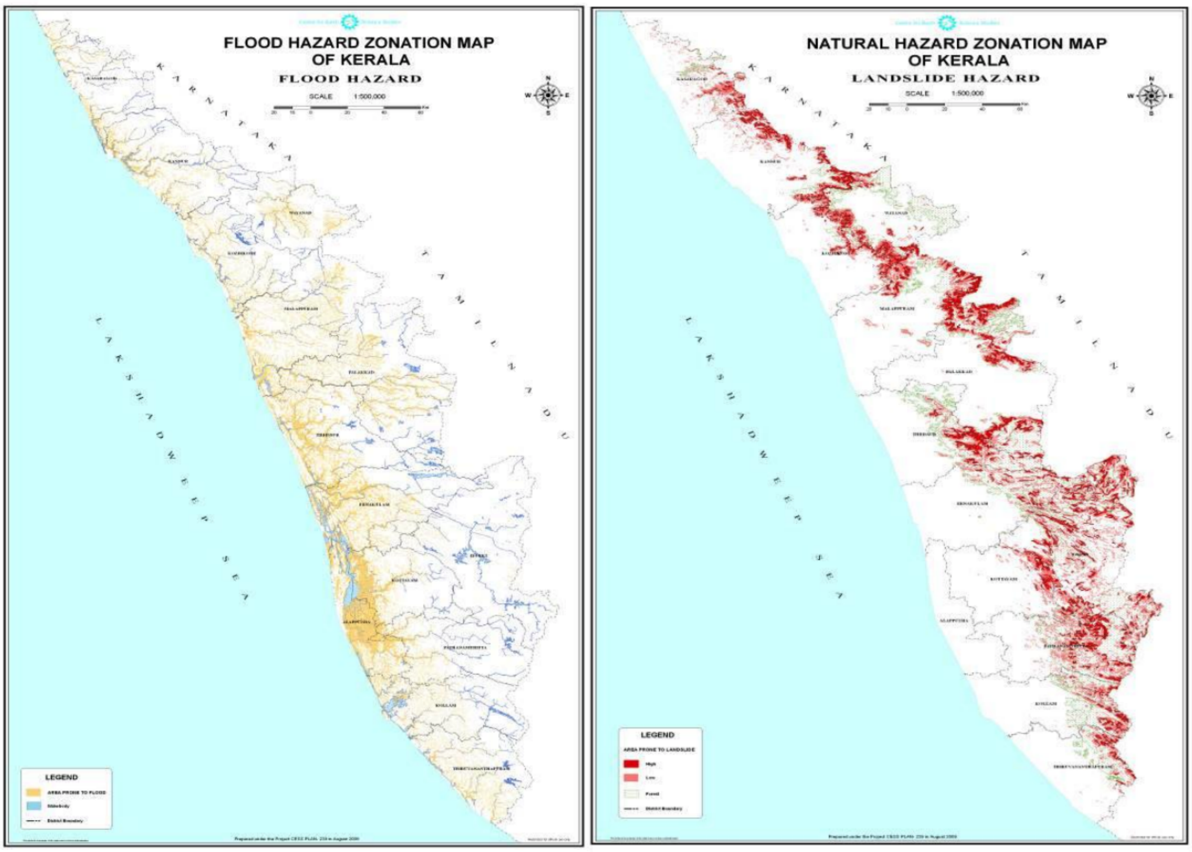


Figure 2: Maps of Flood hazard zonation *(left)* and Landslide hazard zonation *(right)*
(credit: Kerala State Disaster Management Plan Profile)

Kerala is prone for various types of disasters, some of the common disasters are cyclones, floods, earthquake, landslides and forest fires. some of the specific vulnerability of the state as follows:

- Kerala has a long coastline of 590 kms out of which, 322 km is prone to severe sea erosion the density of population is 819 persons per sq.km which is the second highest density in the country.
- About 96.9% of the total area in the state lies in the 140.4km/h wind zone which is classified as Moderate Damage Risk Zone by the BMTPC Atlas while the remaining area lies in 118.8km/h wind zone.
- The mean maximum storm surge height in the state is 3.5m and minimum is 2.3m. If the storm surge is during high tide, the maximum surge height in the state will be 4.2m and minimum storm height will reach up to 3m, as observed by the Meteorological Department, Thiruvananthapuram.
- The coastal belt of Kerala is one of the most densely populated regions in the country, which adds to its vulnerability.
- The Western flank of the Western Ghats covering the eastern part of Kerala is identified as one of the major landslide prone areas of the country.

In past years, There are several severe disaster events occurred in Kerala, one of the most eye-opening flood event happened in 2018 i.e. because of Kerala received heavy monsoon rainfall which it was about 75% more than usual rainfall in Kerala, Because of the heavy rainfall the water level rapidly rise in the dams to avoid any damage in dams immediate water discharge was processed, it was the first time in the state's history 35 out of its 54 dams has been opened. Due to this, flood is induced in the state. There are several districts In Kerala was severely affected by flood over 3274 relief camps have been opened at various locations to accommodate the flood victims. it is estimated that 1,247,496 People have found shelter in such camps. The three most affected districts were Pathanamthitta, Wayanad and Idukki. Due to flooding there are several multi-disaster scenarios generated in different districts. There are different landslides events induced by flood is also recorded in the different districts of Kerala.

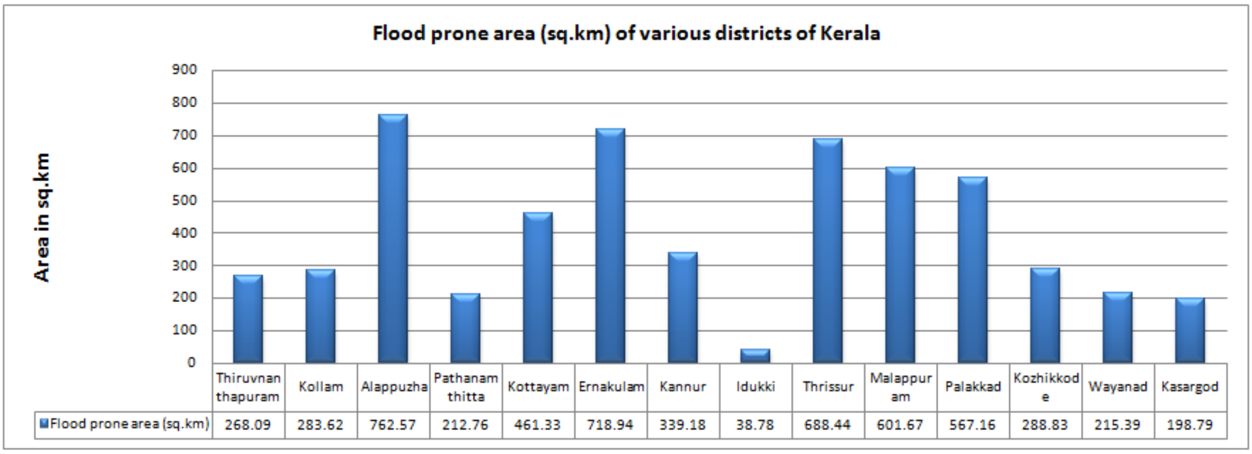
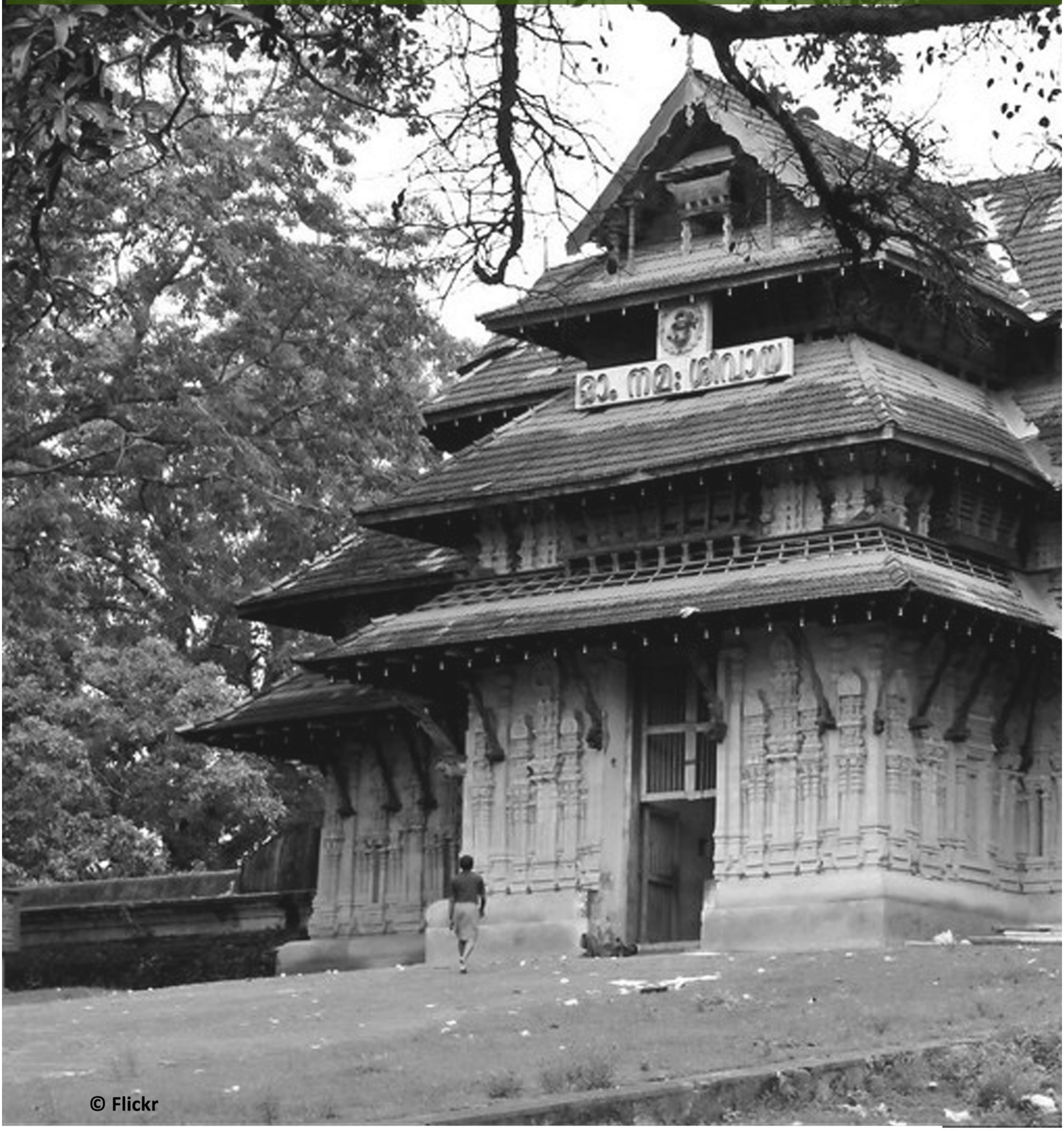


Figure 3: Chart showing Flood scenario in Kerala
(source: Consult CESS, 2010. Plan project 249 for taluk wise area)

Chapter 3



Construction Practices

Chapter 3

Traditional and Modern Construction Practices

3.1 Modern Construction practices globally:

The term modern methods of construction embrace a number of approaches involving off-site manufacture or assembly. The definitions of have varied over the years but for the purposes of this research for the purposes of this research, the following types of were used:

1. Volumetric construction
2. Pods
3. Panelized systems
4. Sub-assemblies and component
5. Site-based modern methods construction.

Some more common advance construction technologies:

1. Super-structure
    a. Modular Construction
    b. Pod Construction
    c. Open panel – Timber frame and Steel frame
    d. Structural Insulated Panels
    e. Solid Cross Laminated Timber Panels
2. On-site technologies.
    a. Insulated Concrete Formwork (ICF)
    b. External Finishing Systems
    c. Timber Cladding
    d. External Insulated Finishing Systems (EIFS)
    e. Brick Slip System • Green Wall and Roofs

Figure 4: Pre-feb building structure (left) Gypsum Board pre-feb house (right) *(credit: www.satec.co.in)*

3.2 Various existing buildings typology in Kerala:

In this chapter, we are going to discuss about the different type of building structures present in Kerala. we can broadly divide building types in two ways:

1. on the basis of architectural configuration.
2. on the basis of Building construction material.

3.2.1 Architectural configuration:

Kerala architecture can be broadly divided into 2 distinctive areas based on their functionality, each guided by different set of principles.

1. Religious Architecture
2. Domestic Architecture

Religious architecture primarily patronized by temples of Kerala as well as several old churches, mosque etc. Domestic architecture recognizes in most of the residential houses that have common architectural style and features.

Figure 5: Image showing typical house type in Kerala *(credit: pinterest.com)*

3.2.2 Building construction material:

There are different typology of the building present in Kerala, some of the common building typologies are RCC structures, masonry structures (brick masonry structures and stone masonry structures), confined masonry structures, Adobe construction, mud houses, temporary structures, Steel or prefab structures etc. In most of the urban areas general topology of the structures are found of RCC and brick masonry while in rural areas, stone masonry buildings, confined masonry buildings, temporary structures and mud houses are present.

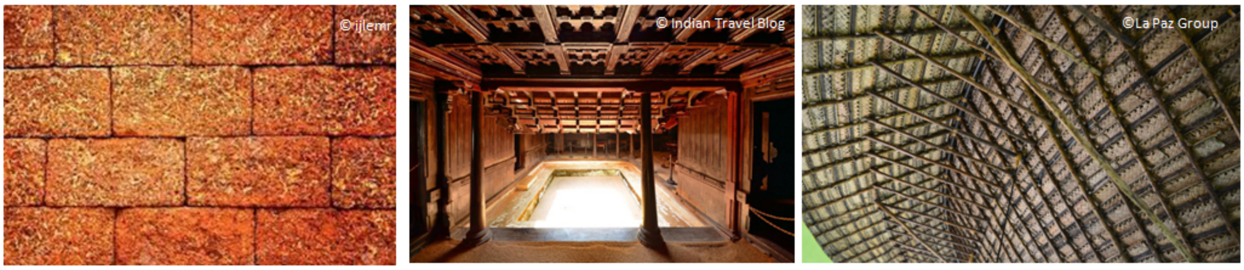
Figure 6: Image showing common residential building *(credit: pinterest.com)*

Figure 7: Image showing urban residential Building using laterite stone *(left)*, typical rural residential building *(right)*. *(credit: pinterest.com)*

3.2.3 Common building materials used in Kerala:

The natural building materials available for construction in Kerala are stones, timber, clay and palm leaves. Granite is a strong and durable building stone; however, its availability is restricted mostly to the highlands and only marginally to other zones. Owing to this, the skill in quarrying, dressing and sculpturing of stone is scarce in Kerala. Laterite on the other hand is the most abundant stone found as outcrops in most zones. Soft laterite available at shallow depth can be easily cut, dressed and used as building blocks. It is a rare local stone which gets stronger and durable with exposure at atmospheric air. Laterite blocks may be bonded in mortars of shell lime, which have been the classic binding material used in traditional buildings. Lime mortar can be improved in strength and performance by admixtures of vegetable juices.

Such enriched mortars were used for plastering or for serving as the base for mural painting and low relief work. Timber is the prime structural material abundantly available in many varieties in Kerala – from bamboo to teak. Perhaps the skillful choice of timber, accurate joinery, artful assembly and delicate carving of wood work for columns, walls and roofs frames are the unique characteristics of Kerala architecture. Clay was used in many forms – for walling, in filling the timber floors and making bricks and tiles after pugging and tempering with admixtures. Palm leaves were used effectively for thatching the roofs and for making partition walls. From the limitations of the materials, a mixed mode of construction was evolved in Kerala architecture. The stone work was restricted to the plinth even in important buildings such as temples. Laterite was used for walls. The roof structure in timber was covered with palm leaf thatching for most buildings and rarely with tiles for palaces or temples. The exterior of the laterite walls was either left as such or plastered with lime mortar to serve as the base for mural painting. The sculpturing of the stone was mainly molding in horizontal bands in the plinth portion (adhistans) whereas the carving of timber covered all elements pillars, beams, ceiling, rafters and the supporting brackets. The Kerala murals are paintings with vegetable dyes on wet walls in subdued shades of brown. The indigenous adoption of the available raw materials and their transformation as enduring media for architectural expression thus became the dominant feature of the Kerala style.



Laterite blocks Timber Thatch Weaving

Figure 8: The images showing Construction Materials commonly used in Kerala

Chapter 4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Site & Construction Material Selection Criteria

Chapter 4

Site & Construction Material Selection Criteria

This chapter is all about site and construction material selection criteria which is important to take in consideration before building construction.

4.1.1 Site Selection Criteria:

- The selection of suitable site is a crucial step in the design of a building or planning a settlement in an earthquake prone area.
- There are a number of earthquake related hazards which should always be considered when choosing a site, together with the influence of the ground conditions at the site on the ground motion which the building may experience in a future earthquake.
- An assessment of extent of earthquake hazard should always form a part of overall site assessment and of specification for the design of any structures to be built there.
- No site can be expected to be ideal in all respects, so the choice of site will often involve a judgment about relative risks and the costs of designing to protect from them
- But there can be some sites which could be so hazardous that they should be avoided if at all possible, since the cost of building is likely to be prohibitive.
- A few important considerations for selecting an appropriate site are given below:

4.1.2 Macro level

- Before taking considerations for site at micro level we have to look at the parameters which influence at macro level.
- Statistical analysis for considerations at macro level can be done in following steps:
    - By knowing the position of site on the tectonic plate
    - By classifying the site in respective seismic zones which the country is divided into, and even evaluating other risk factors which the site is subjected to, or example the presence of hills and rocky areas near the site increases the risk of landslides during earthquake.

4.1.3 Micro level

Site selection plays important role to reduce the risk that may cause due to any disaster. There are several factors which need to be considered while we are going to construct a building in flood or landslide prone area. some of the most important factors as follows:

4.1.4 Site near flood prone areas:

a. Site drainage.
b. Flooding.
c. Soil erosion.
d. Proximity of natural hazards.
e. Distance from nearest water body.

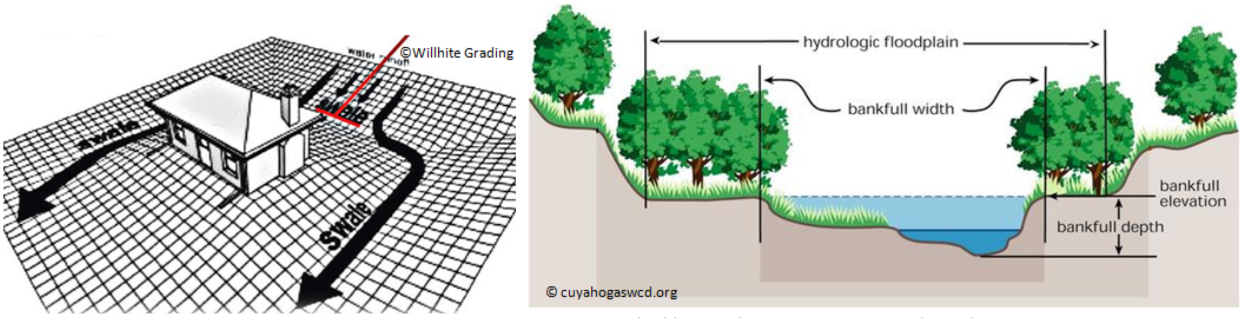


Figure 9: Image showing site drainage (left) and flood prone area (right)

4.1.4.1 Site drainage:

Natural drainage of the site is very important to avoid any flooding condition. If any building is exposed to the flood and water is penetrate in the foundation, it will directly impact on the structural strength, In such cases there is a probability of sinking in foundation will be increased. Before finalizing the site for the construction, one should properly map drainage plan of site w.r.t. surrounding area.

4.1.4.2 Flooding:

Before finalizing any site for the construction, it is very important to gather information of past flooding. If it is found that there was any flood happened in the past than all the precautionary measures should be taken while adopting construction typology.

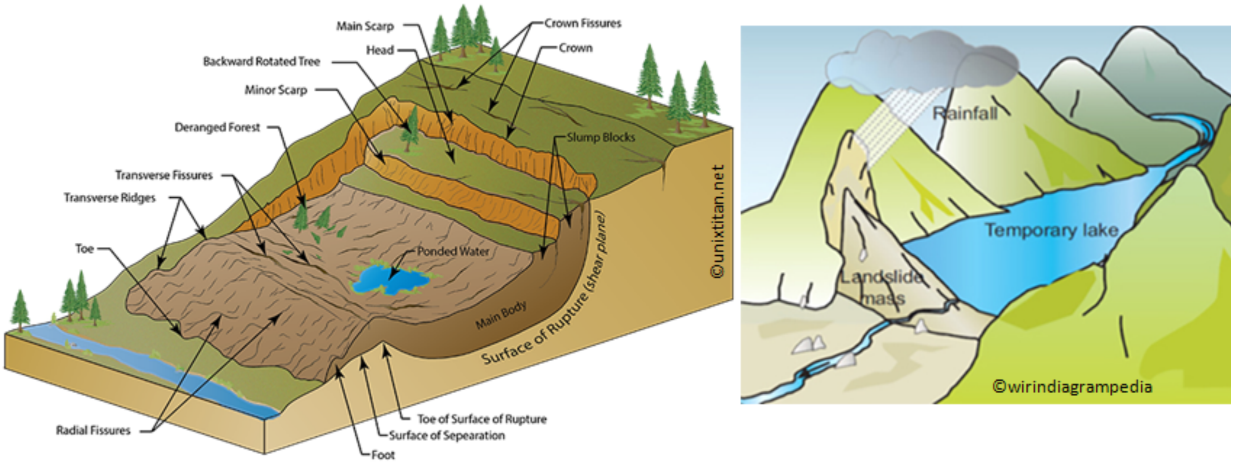


Figure 10: Image showing erosion (left) and Multi-hazard scenario (right)

4.1.4.3 Soil erosion:

Soil erosion causes various structural damages like cracks, collapse of walls, foundation displacement etc. If there is any probability of soil erosion is observed than before construction proper site protection techniques should be adopted.

4.1.4.4 Proximity of natural hazards:

Risk on the site is associated with proximity of natural hazards, before finalizing the construction site detailed multi hazard risk assessment must be carried out on the basis of assessment results. You should adopt different mitigation techniques for the safe construction.

4.1.4.5 Distance from nearest water body:

Detailed mapping process of different types of water body must be carried out before the site selection. if any major river stream or lake is present near the site then proper mitigation technique should be adopted before construction.

4.1.5 Site near Landslide prone areas:

f. Site Slope.
g. Distance from the foothill.
h. Type of Soil.
i. Drainage.

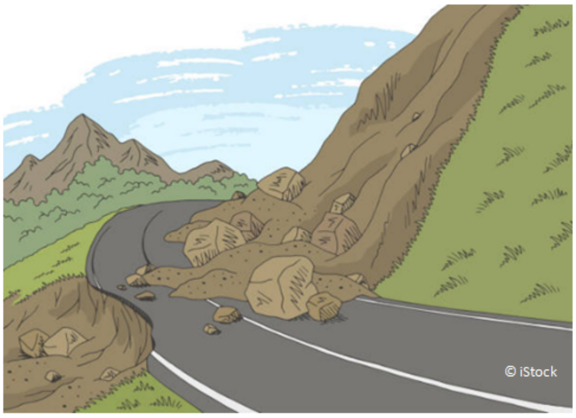


Figure 11: Image showing symbolic landslide prone area (left) and Site slope representation (right)

4.1.5.1 Site Slope:

Natural slope of the site plays a key role to decide structural stability. If the slope is steep then the building is more prone for the damage, in moderate slope the structure will be relatively safe and best site for the construction is flat ground.

4.1.5.2 Distance from the foothill:

Distance from the foothill is very important factor for the site selection. If the site is nearby foothill then proper measure should be adopted. It is recommended to avoid any construction activity near potential landslide hazard zone.

4.1.5.3 Type of soil:

Soil profile is deciding factor which may induced landslides. for example, loose soil is easily drained with rainwater and cause landslide. Before finalizing the site for the construction detailed analysis need to be carried out.

4.1.5.4 Drainage:

Natural drainage of the site is very important to avoid landslide. There are maximum landslides are induced due to heavy rain. If the water drainage of the site is proper, then it will not penetrate in the soil and decrease the probability of landslide.

4.1.6 Construction material Selection Criteria:

4.1.6.1 Factors to Be Considered Before Selecting Material:

1. **Natural, plentiful or renewable -** Are the products made from material that is rapidly renewable such as cork or bamboo. Wood products are also a renewable resource.

Many engineered wood products are made from fast growing trees such as aspen and require less wood to make them than conventional timber.

2. **Durability** - Choose products that will stand the test of time and require little maintenance. This will save time, money and energy on repairs at a later date.
3. **Locally available**: Building materials, components, and systems found locally or regionally, saving energy and resources in transportation to the project site.
4. **Moisture resistant**: Products and systems that resist moisture or inhibit the growth of biological contaminants in buildings.
5. **Healthy environment maintained:** Materials, components, and systems that require only simple, non - toxic, or low VOC methods of cleaning.
6. **Consistent quality:** all the construction material should be consistent in shape, size and property.

4.1.6.2 On the basis of Energy efficiency:

Energy Efficiency can be maximized by utilizing materials, components and systems that help reduce energy consumption in buildings and facilities. Water Conservation can be obtained by utilizing products, materials and systems that help reduce water consumption in buildings and landscaped areas, and increase water recycling and reuse. Indoor Air Quality can be enhanced by utilizing materials that meet one or more of the following criteria:

1. **Low or non-toxic:** Materials that emit few or no carcinogens, reproductive toxicants, or irritants as demonstrated by the manufacturer through appropriate testing.
2. **Minimal chemical emissions:** Products that have minimal emissions of Volatile Organic Compounds (VOCs). Products that also maximize resource and energy efficiency while reducing chemical emissions.
3. **Low-**VOC assembly: Materials installed with minimal VOC-producing compounds, or no-VOC mechanical attachment methods and minimal hazards.
4. **Moisture resistant**: Products and systems that resist moisture or inhibit the growth of biological contaminants in buildings.
5. **Healthy environment maintained:** Materials, components, and systems that require only simple, non - toxic, or low VOC methods of cleaning.

Affordability can be considered when building product life-cycle costs are lower or comparable to those of “conventional” products, or are within a project-defined percentage of the overall budget

Chapter 5

Common Disaster Resilient Features in Building

Chapter 5

Common Disaster Resilient Features in Building

5.1 General Design Aspects

Asymmetrically designed buildings are subject to substantial torsional forces The more symmetrical the structure is about both axes, the better. during earthquakes, making them considerably dangerous. In addition, simple designs with rectangular shapes tend to hold up better than more complicated designs with protruding sections. In some cases, a large building performs better in an earthquake if it is separated into several appropriately spaced blocks, in order to maintain this symmetry and regularity in each block. The spacing between these blocks is carefully calculated to prevent contact or hammering in a severe seismic event.

5.1.1 Proper Foundation

An appropriate foundation is also critical in the design of any disaster resilient building. The type of soil on which the structure is built is classified as either firm, soft or weak, according to its bearing capacity. Soft soil is avoided whenever possible, although methods do exist to provide special strengthening, if necessary. Weak soils are too dangerous to build on top and must either be compacted to bring their quality up to firm or soft, or avoided entirely. The foundation itself must be well tied together, as well as tied securely to the walls.

Ductility

Ductility refers to the ability of a material or structure to deform and yield, dampen vibration and absorb energy. Materials such as steel and wrought iron are considered ductile, thus making them more suitable for use in the construction of a disaster resilient building. Materials that are brittle (non-ductile), such as concrete, adobe or cast iron may break suddenly when subjected to stress. In order for ductile materials to have the proper effect within the body of a structure, there must be a sufficient quantity of them placed in areas of high tensile stress. In addition, any materials used must be of high quality and care must be taken that they are protected from the elements, insects and any other action that could potentially weaken them, so that their strength will last.

5.1.2 Damageability

The ability to withstand substantial damage without collapsing is referred to as a structure's damageability. The structural framing system must be designed to furnish sufficient lateral resistance, such as with diagonal bracing or very rigid jointed beams. Redundancy, by providing additional means of support for critical structural members, greatly improves the level of damageability. In the event that certain components fail, the additional support would serve to hold the surrounding components together, preventing a total collapse of the structure. Care must be taken to avoid reliance on centrally located support columns and walls to hold up large portions of the structure.

5.1.3 Base Isolation

A recent approach to disaster resilient building called Base Isolation involves reducing the vibrations in a structure by isolating it from the motions in the ground. This can be accomplished by reducing friction between the structure itself and its foundation or by using some type of flexible connection in that area. One method by which this is done is through the use of special bearings. When this method is utilized, the sideways movement occurs mostly in the bearings themselves, reducing the effect on the building. Another method is to use two layers of high-quality plastic beneath the structure, that will slide over each other, reducing friction.

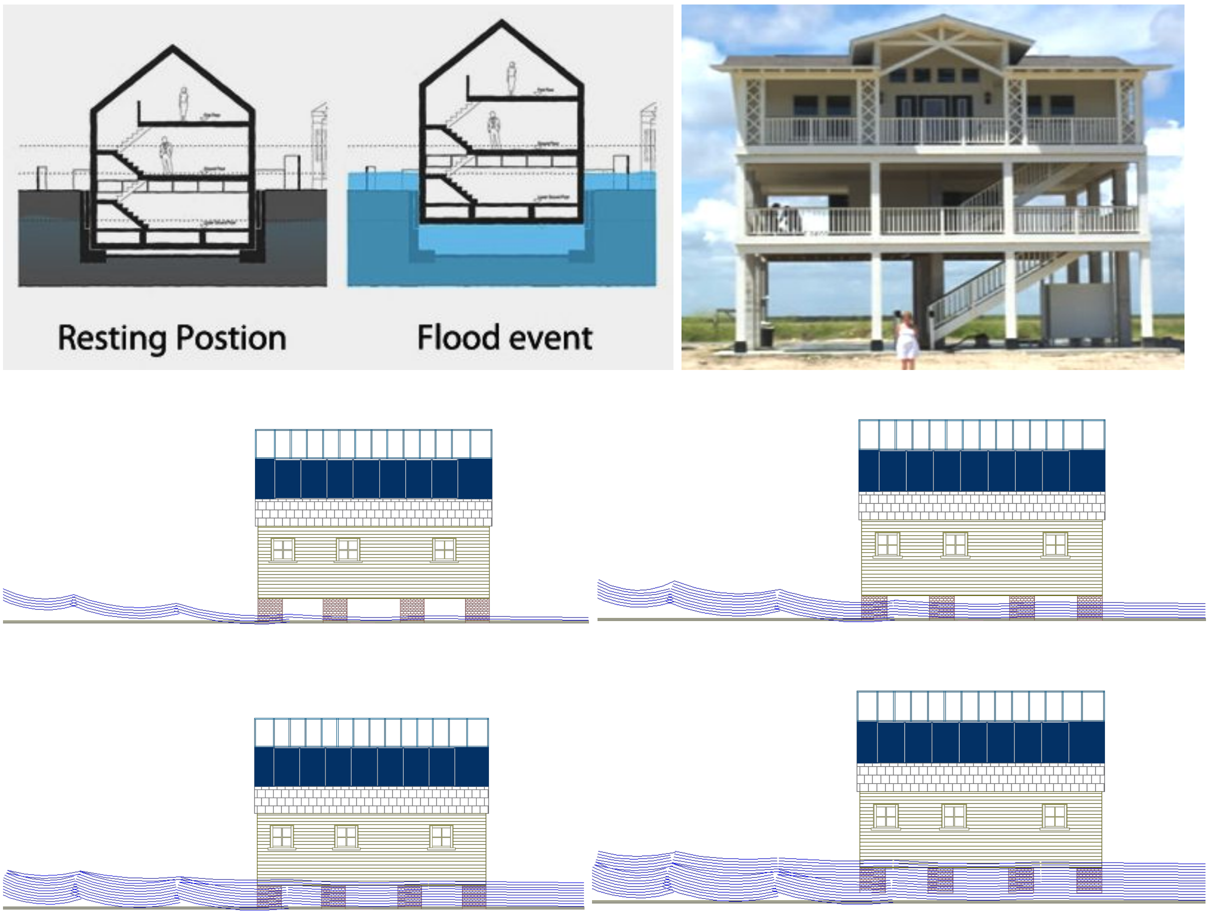


Figure 12: images showing flood resilient construction techniques *(credit: recoveryplatform.org)*

5.1.4 High floodwater:

The house lifts off the ground and floats until the floodwater subsides. A special tethering system absorbs shock and returns the building to its original location. The building is waterproof. so, will be undamaged after the flood. with all contents kept dry and safe. if you are planning living in an area subject to seasonal storms. why even consider any other type of home.

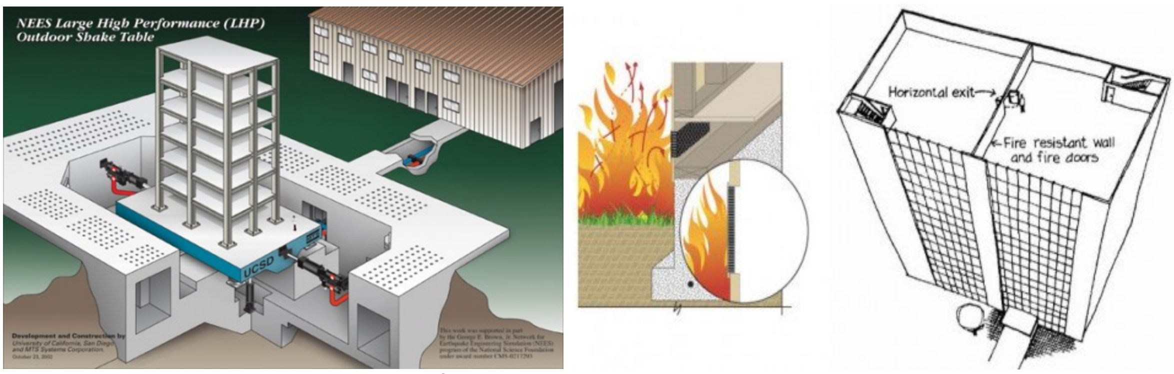


Figure 13:High flood water drainage *(credit: recoveryplatform.org)*

5.1.5 Various National standard code provision for safe & quality construction

Indian standard codes are list of codes used for civil engineers in India for the purpose of design and analysis of civil engineering structures. If the structure is built according to the codes, it will definitely sustain to any hazard. Some of the most common codes are:

Design of Concrete and steel structures:

- IS: 456 – code of practice for plain and reinforced concrete.
- IS: 383 – specifications for fine & coarse aggregate from natural sources for concrete.
- IS: 2386 – methods of tests for aggregate for concrete. (9 parts)
- IS: 2430 – methods of sampling.

Chapter 6

Earthquake Resilient Construction Practice

Chapter 6

Earthquake Resilient Construction Practice

6.1 Introduction

Earthquakes are known to have tremendous potential in causing a devastating impact on the built environment and human life. India has witnessed over 9 severe earthquakes in the last two decades between 1990 and 2010 and reports claim the death rate to be around 30000. Although certain parts of the country are more prone to earthquakes (seismic zone V of IS 1893(Part 1)- 2016) than the rest, no region can be considered as free from earthquakes. In the Indian scenario, multiple micro earthquakes are reported near the seduction zone (Himalayan belt) on a daily basis, whereas in the interpolate region (Deccan plateau) few major earthquakes have been witnessed over the years. The performance of the built environment during the past earthquakes has demonstrated its fragile nature and has created an urge among the engineers and architects to move towards seismically efficient buildings. The majority of the Indian landmass (about 60%), is susceptible to moderate to very severe earthquakes. A great earthquake in an uninhabited area may produce minimal damage when compared to a moderate earthquake in a densely populated area. All the field survey studies conducted after a major earthquake implied that the maximum casualties reported were caused by building collapse. The lack of earthquake knowledge and its incorporation in the building design and execution leads to failure of buildings. A large part of the rural and urban dwellings are low rise non engineered buildings and these suffer maximum damage.

During an earthquake, the seismic waves propagate in all directions. However, among the various components, the horizontal vibration is considered to be most predominant in causing structural failure. The seismic waves tend to move the foundation of a building inducing inertial forces in various structural elements. The seismic performance of a structure during an earthquake depends on its overall shape, size, geometry and the nature of load path. The seismic design philosophy aims to ensure safety to structural components and human life. It states that the load-bearing structural elements must suffer no damage in the event of a (frequent) minor shaking, sustain reparable damage in the event of (occasional) moderate shaking and sustain severe damage without collapse under (rare) strong shaking. The present paper outlines the building typologies encountered in the Indian subcontinent and their performance during earlier earthquakes. A glance through the current earthquake-safe construction practices has been attempted. Further, a brief description of the future trends in making buildings more resilient to earthquakes has been provided. Overall, in addition to effective and efficient seismic design philosophies, it is necessary to ensure strict code-compliant structural design and construction practices.

6.2 Necessity for The Earthquake Resistant Construction

According to the 2011 census of India, there are over 330 million housing units in the country, (GOI,2011) with two-thirds of these being rural houses. The Geological Survey of India has classified the country into four seismic zones with varying seismic potential.

Seismic zones IV and V constitute about 30% of the housing units. These rural building units are mainly constructed using locally available materials such as mud and unburnt bricks, stone walls or walls made of burnt bricks, all of which are quite vulnerable in the event of poor construction and maintenance (BMTPC,2006). In addition to the larger percentage of housing stock in the rural area, a rapid growth in the urban population has been witnessed over the last decade. The census of India indicates a 32% increase in growth of urban population from 286 million in 2001 to 377 million in 2011. The urban population by the end of 2030 is projected to be nearly 590 million. As per the statistics, 50% of the demand for construction activity in India comes from the infrastructure sector, the rest comes from industrial activities, residential and commercial development etc (Make India, 2015). Due to this rapid urbanization, there is an increased demand for infrastructure, essential basic amenities ,residential layouts and community development. The time of occurrence (day or night) of an earthquake plays a major role as they have a direct impact on the occupancy of buildings. For example, Latur earthquake (1993) occurred in the early hours around 3:53AM when the majority of the population in the affected area were asleep. On the contrary Bhuj earthquake (2001) occurred in the morning around 8.46 AM, with the majority of the people awake and minimum occupancy of the building. These two earthquakes exhibited the poor performance of non-engineered building units such as random rubble masonry in mud mortar with heavy roofs as well as modern multi-story RC framed buildings. The past earthquake experience has demonstrated the lack of seismic design in modern residential buildings. At the same time, the importance of incorporation of seismic principles in structural design for a building to perform as a single unit during an earthquake has become more clear. It is necessary to empower rural communities in ensuring seismic safety of the building stock by creating awareness about earthquakes and importance of earthquake-resistant buildings. The built environment in urban sectors has to be planned and designed carefully in the initial stages so that the building configuration is favorable for good seismic performance.

Figure 14: Apartment collapse in 2001 Bhuj earthquake with separation of the lift shaft (credit: IITK)

6.3 BUILDING TYPOLOGIES IN INDIA

The buildings are classified as engineered and non-engineered depending on the structural design and material that go in their construction.
the classification based on construction-type should be based on the knowledge of the structural system, load transfer mechanism, the predominant construction material used, and the performance during past earthquakes. Buildings are classified based on the material type as follows:

- Masonry and Mortar type
- Structural Concrete
- Steel

- Wooden Structure
- Masonry and Mortar type
- Structural Concrete
- Steel

In addition, various factors influence the Seismic performance of a building and are listed below:

The height of the building:
The seismic response of a building to a ground vibration is a function of its natural frequency - in other words, its inherent mass and stiffness. These factors vary with the height of the building and hence, its vulnerability. As a result, in severe seismic zones, the building height is restricted in accordance with the seismic hazard estimation, specific to a region.

Irregularities:
The obstruction to the load path in transferring the forces from roof to the foundation is caused by the horizontal and vertical irregularities present in the building. A more detailed description about the irregularities is given in IS 1893.

Quality of Construction
The Quality imparted by the local construction practices in terms of compliance with codal provisions and the Status of maintenance or visual appearance is a major factor.

Ground Slope
In several parts of the country such as in the Himalayas, along with the Eastern and Western Ghats and in North-Eastern states, the sloping terrain is often encountered, as a result of which, a large number of buildings are located on hill slopes. Depending on the sloping angle, the slopes are classified as the gentle slope (≤ 20°) and steep slope (> 20°). When houses are constructed on gentle slopes, the ground is typically leveled before construction. For a building constructed on a steep slope, the foundation will vary in terms of elevation along the plan of the building. This leads to vertical members with varying mass and stiffness resulting in vertical irregularity. The stability of the ground is also one of the major parameters that influence the seismic performance of a Building.

6.4 Earthquake Resistant Construction Practices

Masonry is the most commonly used structural material from times immemorial. Many of the greatest structures such as The Taj Mahal (Agra), Pyramids (Cairo, Egypt), Coliseum (Rome, Italy) and many other structures are live examples of masonry construction from the earlier civilization. In general, masonry buildings are brittle in nature and are most vulnerable to ground motions. Previous earthquake experiences have witnessed a catastrophic failure of masonry buildings in rural areas. These masonry buildings need to be engineered in order to make them sustain .earthquakes. Over the years several researchers have been working relentlessly in finding an effective solution for improving the seismic resistance of masonry structures. These investigations have led to the development of new seismic resistant technology and construction systems. A variety of masonry units are used in the country, e.g., clay bricks (burnt and unburnt), concrete blocks (solid and hollow), stone blocks. A masonry building has three major components roof, wall, and foundation) out of which the walls are most vulnerable to damage caused by horizontal forces due to the earthquake.

6.4.1 To ensure good seismic performance, the following conditions must be applied

1. Walls are the weaker components and when loaded in its weaker direction can lead to failure. In order to prevent this type of failure, it is necessary to ensure that a good bond exists between adjacent walls so that loaded in their weak direction can take advantage of the good lateral resistance offered by walls loaded in their strong direction. In addition, the tendency of a wall to topple when pushed in the weak direction can be reduced by limiting its length-to-thickness and height to-thickness ratios.
2. The window and door openings serve as a weak spot in masonry walls and hence, the size of the openings must be restricted to a minimum value. Steel bars must be provided in the wall all around the openings to restrict the initiation and propagation of cracks.
3. The vulnerability of the junction can be improved by ensuring good interlocking of the masonry courses.
4. Low porosity bricks must be used and they have to be pre-soaked before use to minimize the amount of water drawn from the mortar.
5. The strength of the mortar binding the bricks is also one of the crucial contributing factors. In this regard, Cement-sand mortar with lime is the most preferred mixture as this mortar mix provides excellent workability for laying bricks, stretches without crumbling at low earthquake shaking, and bonds well with bricks.
6. During Bhuj earthquake ,building configuration similar to that of a box type structure performed well with minimal damages. This box auction is possible only when the walls are tied to the roof and foundation to preserve their overall integrity.
7. To ensure box type action, horizontal seismic bands are provided and these bands tie all the walls together. There are four types of bands in a typical masonry building, namely gable band, roof band, lintel band and plinth band as shown in Figure 8. The Indian Standards IS:4326-2016 and IS:13828 (1993) provide sizes and details of the bands.
8. The vertical reinforcement bars are embedded in the edges of the wall piers and anchored to the foundation at the bottom and in the roof band at the top. This procedure forces the masonry structure to undergo bending instead of rocking. Figure below shows the placing of vertical reinforcement.
9. Most of the construction practices involve, erecting columns and beams (frames) followed by the stacking up of masonry infill. This method leads to diagonal tension in the infill walls and leads to spelling of the material. Hence, an alternate way to ensure earthquake resistance of RC frames with brick infill is Confined masonry. This construction technique is exactly opposite of the conventional method. The walls are built first and the concrete is poured into the tie columns and beams. This produces a structure of optimal capacity and it is also safe to build multi-story buildings in seismic prone areas. A typical example of confined masonry is the faculty quarters and student's hostel in IIT Gandhi Nagar. Figure below shows the construction sequence.

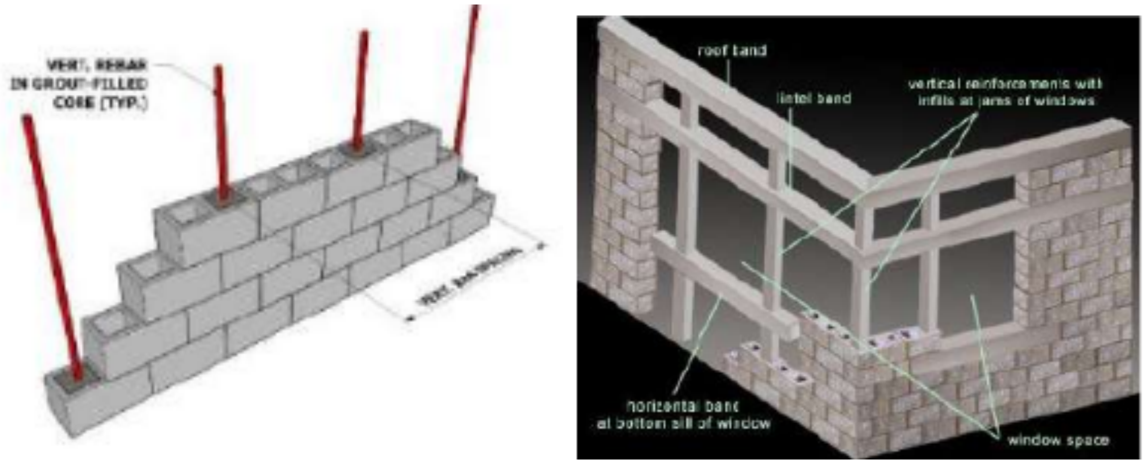
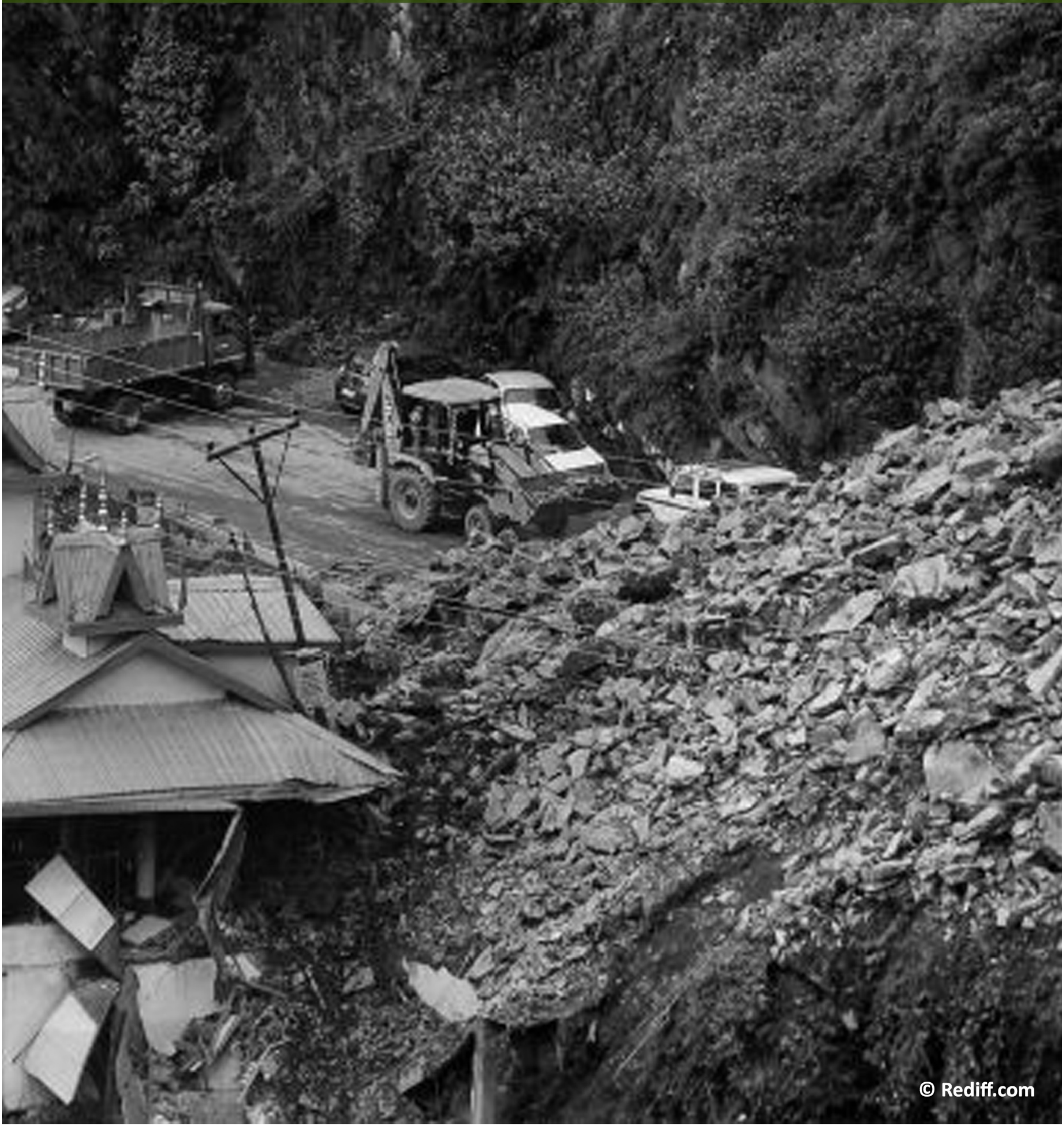


Figure 15: construction techniques for earthquake resilient structures *(credit: andhitapradipta)*

Chapter 7



Landslide Resilient Construction Practice

Chapter 7

Landslide Resilient Construction practice

7.1 Introduction

Landslides are significant ground movements on slopes such as rock, debris, and earth flows due to gravity. They could be the result of natural phenomenon such as intense rains, change in ground water levels, water level changes in coastlines, and earthquakes as well as manmade causes such as grading, terrain, cutting and fill in gland other developments (Landslides 2010).Several factors for classification of landslides are; rate of movement (ranges from a slow gradual movement to a rapid movement), types of material (composed of bedrock, unconsolidated sediment and/or organic debris), and nature of movement (slide ,slump, flow or fall) (Landslide Types 2010).Apart from the direct damage that can be caused to structures by debris or earth flow, landslides can also result in backwater flooding if water ways are blocked by the debris .Rock falls are a major component of landslide disasters, which consists of “free falling blocks of different sizes which are usually detached from a steep rock wall or a cliff” (Descoeudres etal.1999). The movement of the block may also be bouncing, rolling, and sliding as seen in Figure below.

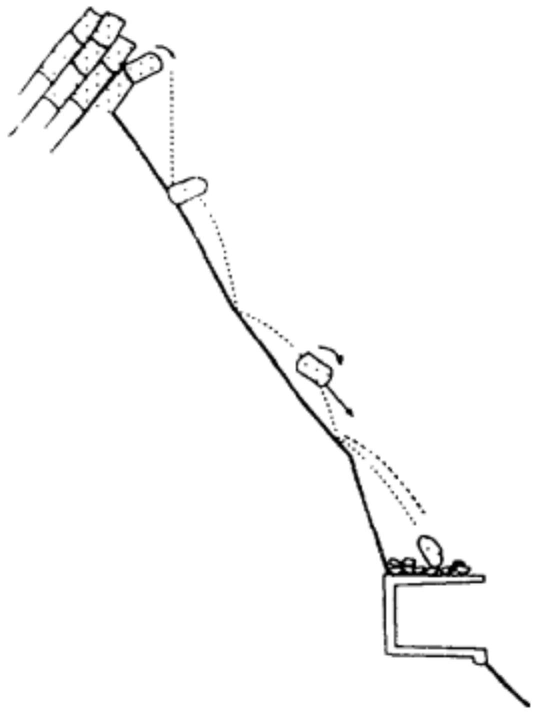


Figure 16: Movement of free falling blocks (Descoeudresetal.1999)

7.2 Landslide mitigation

Civil and Geotechnical Engineers of Sri Lanka are facing the most challenging task of mitigation and prevention of landslides. Catastrophic effects are avoided or minimized commonly by adopting appropriate landslide control techniques before the slope reaches the condition of incipient failure. There are many methods available for the control of landslides.

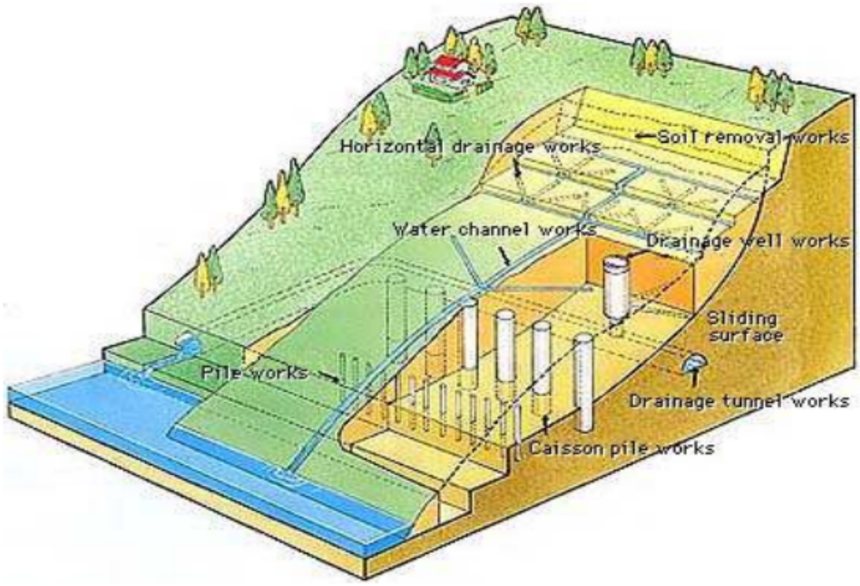


Figure 17: Landslide mitigation methods (*credit: http://www.stuff.co.nz)*

These control methods include prevention and determent work. The purpose of prevention work into stop or prevent landslide movement by changing natural conditions, such as topography, geology, and groundwater condition. On the other hand, the purpose of determent work is to deter part or all of landslide movement with structures. The application of the above methods for landslide mitigation is schematically shown in Figure 6.

7.3 Modification of Slope Geometry

It has been noted that the modification of slope geometry and drainage are the most commonly used and economical measures in minimizing the impact of landslides (Popescu and Sasahara2010).In order to improve the geometry of a slope, testability of the slope should be determined through the material the slope is made of, slope gradient, and the geological structure of the slope(Skinner &Hancock2010). Placing an appropriate cut or fill in the correct location of the slope will increase the slope stability. Geological and hydro geological conditions and soil parameters should be analyzed prior to cutting of the slope.
The recommended standard maximum slope gradient for cut slope with different ground conditions is shown in Figure below. However, the gradient indicated in Figure below is only indicative and detailed assessment and design of cut slopes should be carried out by considering the actual site condition.
Filling can be carried out at the toe of the slope to balance the driving force of loading from top, with proper gradation, compaction, and gradient. When selecting fill material, it is important to pay attention to their strength and deformation characteristics.

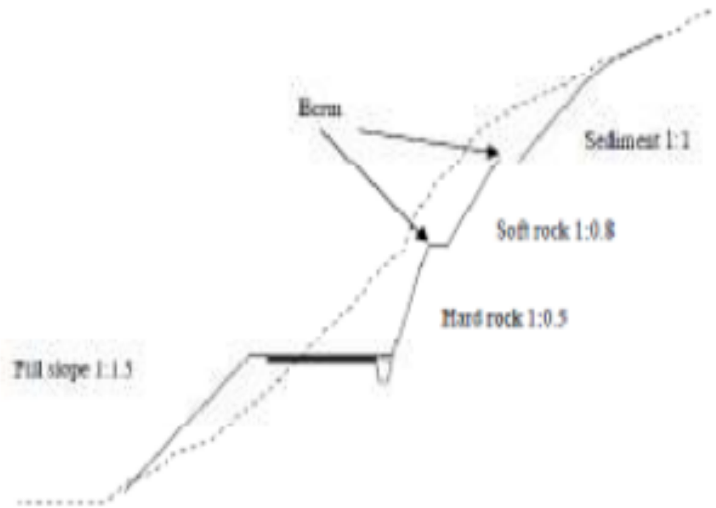


Figure 18:Ground condition and slope cut (*credit: http://www.stuff.co.nz)*

7.4 Improvement of Drainage

Majority of landslides mostly occur along with rainfall and consequently water is the main cause of landslides. The presence of water in a potential or existing sliding area can adversely affect the stability of the slope due to the increase in the water content of the soil resulting in a decrease in the shearing resistance of the soil, an increase in pore water pressures and seepage forces and the possible surface erosion. Thus, the control of surface and subsurface water by appropriate drainage techniques is of prime importance in controlling landslides as it results in improving the stability of the slope.

In general, proper drainage in slopes consist of surface and subsurface drainage systems that are capable of taking away the water to the natural drainage system safely and as quick as possible. Proper drainage technique to be adopted could be determined only with the knowledge on cause and mechanism of slope failure. Studies regarding the rainfall, topography, catchment area, ground surface condition, soil parameters, ground water conditions and existing natural and artificial drainage systems should be carried out and assessed to determine the required drainage discharge. Combination of both the surface and subsurface drains could be effectively used to manage the surface and groundwater conditions properly designed surface drainage network has to be constructed in order to prevent surface runoff water from springs and rainfall in filtrating the slopes and/or landslide area to avoid increase in pore water pressure. The surface water can be removed from the unstable slope by using a surface drainage system which comprises of cut off drain, berm drain, toe drain, drainage channels, and cascades (Figure below)

When lowering of ground water level is required in order to stabilize the slope, subsurface drains are constructed. In such cases, the ground water table is lowered by installation of horizontal drain, vertical drains, trench drains, drainage wells (Figure below), drainage tunnels, inclined drains by directional drilling etc.

Figure 19: surface drainage ditches (left) and wells for ground water drainages (right)
(credit: popescu & sasahara 2010)

7.5 Retaining Wall Construction

Stability of the slope can be improved by increasing the resisting forces by the construction of an appropriate type of retaining structure. Commonly used retaining structure types are masonry, reinforced concrete, Gabion wall and sheet pile walls. Crib walls are a more flexible type of retaining wall system. The retaining wall should be properly designed to resist the soil pressure. Other retaining structures include contiguous bored piles, steel sheet piles, reinforced soil walls, buttressed counter forts to increase shear resistance and georgic walls (Sin & Meng 2005). All of these structural measures are to increase the resisting forces along the slip plane. Soil nailing and anchoring have been widely used in the stabilization of cut slopes, especially in the construction of highways and roads, where limited building space is available. Also these methods create the minimum disturbance to the natural slope and can be used as internal soil reinforcement measures in reducing the susceptibility of certain land areas to landslides. Soil nailing is a stabilization method of reinforcing existing soil by installing threaded steel bars into the slope or cut as construction proceeds from the top down. Grouted bars are installed to create a stable mass of soil and build a solid wall as shown below.

Figure 20: Soil nailing (left) and soil anchoring for slope stabilization (right) (*credit: http://www.stuff.co.nz)*

Despite of the development of new stabilization techniques, the long term reliability of disaster resilient infrastructure tends to decrease with time, due to maintenance problems, whereas the safety requirement and induced risks increase, following the construction of more and more buildings and lifelines in exposed zones. Therefore any type of slope stability improvement works has to be completed by a comprehensive monitoring system allowing for early detection of a critical behavior, based on adequate warning signals. (Bonnard and Vulliet 1999)

Buildings in the areas which are prone to natural disasters like landslides need to be designed and constructed with suitable disaster mitigating features. In addition to that, the sustainability of such structures and their impacts on the environment also demand due consideration.

Listed below are the guidelines which need to be incorporated to ensure sturdy building structures.

- **Classification of Critical Infrastructure:**
  To develop the guidelines and special provisions for disaster flexibility of buildings which are part of the critical infrastructure, the initial step would be to define and classify them with prevailing categories in the building codes.
- **Hazard Identification:**
  Based on the building location and hazards map analysis, the main hazards which can disturb the critical infrastructure needs to be identified. Considering these hazards during the planning and location phase help in mitigating landslides and flood-related dangers.
- **Hazard Assessment:**
  Once the hazards are identified after referring to the available hazard maps (for both floods and landslides), they should be further deeply evaluated. Dependent on the type and scale of the maps, added information on the specific hazard sub type and its intensity should be determined for the building location.
- **Determining Building Characteristics For Landslide Resistance:**
  The dangers buildings face due to landslides is a combination of the total hazards posed by the location, the vulnerability of the specific site characteristics, and the vulnerability of the building structure characteristics. Some types of building structures are more exposed than the others. Below are the building characteristics to be considered exclusively for landslides.
- **Risk Assessment:**
  A complete risk assessment of the structure and critical infrastructures need to be evaluated based on:
    - Categorization
    - Hazard Levels
    - Site Specific Hazards,
    - Vulnerability Of The Building With Specific Vulnerability Of The Sites
    - Design And Construction Fundamentals Checklist

- **Foundation:**
  Should be designed and built to efficiently carry the building load according to the bearing capacity of the soil.
- **Plinth**:
  Must be above-known flood levels and should be free from structural cracks as these indicate weakness of the foundation. RCC Plinth beam should also be incorporated in the design to alleviate the powerful lateral forces of rains, floods, and sea surges.
- **Walls:**

Should be capable of withstanding strong lateral forces exerted by the flood waters. 8" – 9"thick bricks or blocks load bearing walls are preferred.

- **Roofs:**
  The roofs should be of the required slopes based on the type of roofing material used (Clay tiles or corrugated sheets) to survive heavy winds and rain.
- **Drainage System:**
  Safe drainage system can prevent landslides to a large extent. Water which drains from the roof and other areas like the portico should not be allowed to flow down the slopes but should be drained through proper drain pipes.
- **Sanitation systems:**
  Should be of approved type/s and of sturdy construction so that it doesn't allow the leeching of effluent (human waste) into the soil. Septic tanks where used should not be rendered by high water table levels or impermeable soil. Here, dry compost toilet system is a great option.

- Design professionals would agree that the most successful way to alleviate losses of life, property, and function is to construct buildings that are structurally strong and disaster-resistant. This approach should be incorporated into your project planning, design, and development at the earliest possible stage to ensure your design and material decisions are based on an integrated and all-inclusive approach.

Chapter 8

Flood Resilient Construction Practice

Chapter 8

Flood Resilient construction Practice

There is a wide range of accepted flood resilient construction practices for buildings to better withstand floods and reoccupy more quickly following a storm. These include:
• Elevating the lowest floor.
• Elevating mechanical equipment such as electrical, heating, and plumbing equipment.

8.1 Wet flood proofing:

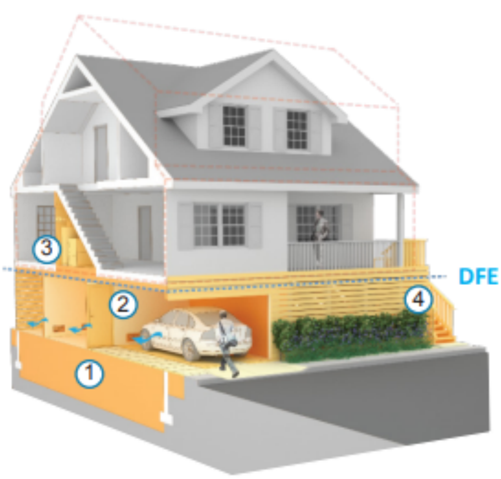
By utilizing water resistant building materials and limiting uses below the Design Flood Elevation (DFE) to parking, building access, and minor storage. This allows water to move in and out of uninhabited, lower portions of the building with minimal damage.

8.2 Dry flood proofing:

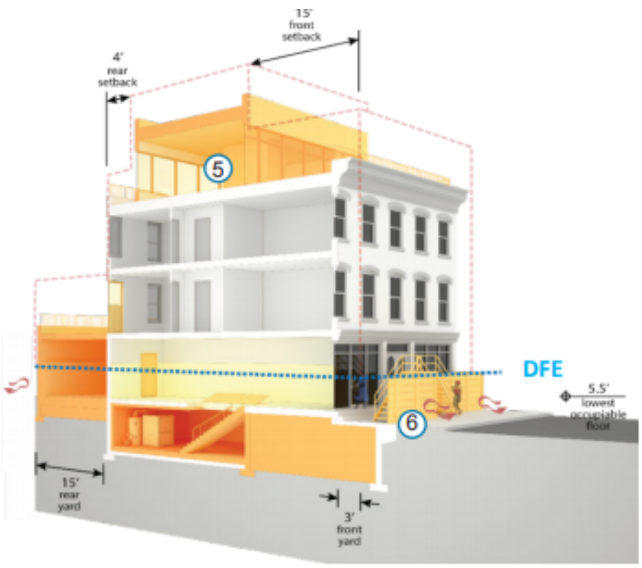
sealing the building's exterior to flood waters and using removable barriers at all entrances below the expected level of flooding in mixed-use and non-residential buildings.

8.2.1 Examples of Flood Resilient Construction:-

1. Site is filled to the lowest adjacent grade.
2. Space below the DFE is for parking, building access or minor storage.
3. Mechanical systems are above the DFE.
4. Plants and stair turns improve the look of the building from the street.
5. Rooftop addition replaces lost below grade space.
6. Commercial space is dry flood proofed with removable barriers.



Wet floodproofed residential building



Dry floodproofed mixed-use building

(credit: andhitapradipta.github.io)

8.2.2 "Successful" Building Designs:

- A "successful" building will resist flood loads and other loads over a period of decades, and will exhibit the following characteristics:
- any flood damage will be minor and easily repairable
- the foundation will remain intact and fully functional following a design flood
- any breakaway enclosures below the DFE will break free without causing damage to the elevated building, the foundation, building access structures, or utility systems
- the building envelope will remain sound
- utility connections will be intact or easily restorable after a design flood
- the building will be accessible and usable after a design flood

8.2.3 Lowest Floor Elevation:

Buildings within the Special Flood Hazard Area must have their lowest floor (including basement) elevated to or above the DFE (except for non-residential buildings which are dry-flood proofed). Top of the lowest floor must be set at or above the DFE (Designers should know that setting the top of the lowest floor at the DFE does not, by itself, eliminate potential flood damage during the design flood—construction materials below the DFE must be flood damage resistant. In some cases it may be easier and less expensive to elevate the bottom of the floor system above the DFE than to construct the entire lowest floor system with flood damage resistant materials).

8.2.4 Flood Proofing:

Flood proofing is the process of making a building resistant to flood damage, either by taking the building out of contact with floodwaters or by making the building resistant to any potential damage resulting from contact with floodwaters. (Note that this discussion states, where permitted and used, flood proofing must extend to the DFE. In fact, model building codes and some floodplain management regulations require flood proofing to extend to levels above the DFE in certain instances. Designers should determine any specific flood proofing elevations for their projects, based on applicable regulations and code requirements).

8.2.5 Active flood proofing:

Sometimes known as contingent (partial) or emergency (temporary) floodproofing, requires human intervention to implement actions that will protect a building and its contents from flooding. Successful use of this technique requires ample warning time to mobilize people and equipment and flood proofing materials.

8.2.6 Passive flood proofing:

Sometimes referred to as permanent flood proofing, requires no human intervention—the building (and/or its immediate surroundings) is designed and constructed to be flood proof without human intervention.

8.2.7 Sealants, Flood Shields and Valves:

A wide variety of materials and devices have been developed to make building walls, floors, openings, penetrations and utilities watertight during flooding.

Flood shields, panels, doors and gates are typically used to close medium to large openings in building walls. They can be temporary closures that are installed only when a flood threatens, or they can be permanent features that are closed manually or automatically. Key design parameters of these barriers are their height, their stiffness (and resistance to hydrostatic forces), their method of attachment or installation, and their seals and gaskets. As a general rule, flood shields, panels, doors and gates should not be attached to building windows, glazing or doors. Given the potential for large flood loads, they should be attached to exterior walls or the structural frame. Coordination with the design of exterior walls and fenestration is required.

Designers planning to incorporate flood shields, panels, doors or gates into a building design are advised to consult with engineers and vendors experienced with the design and installation of these components.

Figure 21: Temporary flood panels and permanent flood doors and gates *(credit: andhitapradipta.github.io)*

Backflow valves are often installed to prevent drains and sewers from backing up into a building and are an important component of flood proofing. They are relatively inexpensive to install and simple to operate.

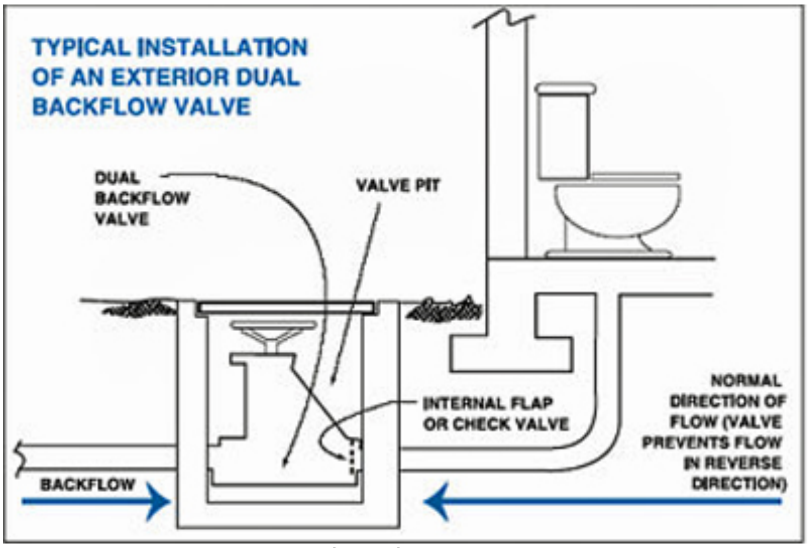


Figure 22: Typical installation of backflow valve *(credit: andhitapradipta.github.io)*

8.2.8 Wet-Flood Proofing:

Wet-flood proofing is employed commonly in parking garages, building access areas, crawlspaces and similar spaces. It is not employed in spaces where offices, commercial activity, residential uses and/or similar uses take place.
There are two principal methods used in to wet-flood proof areas below the DFE: in enclosed areas, installation of flood openings or vents in walls to allow the automatic equalization of flood levels on both sides of the walls (and to prevent wall failures due to unbalanced hydrostatic loads), and use of flood-resistant materials.

8.2.9 Flood Openings:

Unless dry-flood proofed, enclosed areas below the DFE must be equipped with flood openings capable of equalizing water levels and hydrostatic loads. The use of flood openings (also called flood vents, since vents are commonly installed in the openings) is discussed in FEMA Technical Bulletin 1, Openings in Foundation Walls and Walls of Enclosures. Since owners usually want to control temperature and moisture in these enclosed areas (and prevent rodents, birds and insects from entering), opening covers are often employed. These covers must not interfere with the equalization of water levels in the event of a flood and should be selected to minimize potential blockage by debris. There are a variety of commercially available covers, such as grates, louvers and grills (see illustration below) that allow for control of the enclosed space and the passage of floodwaters.

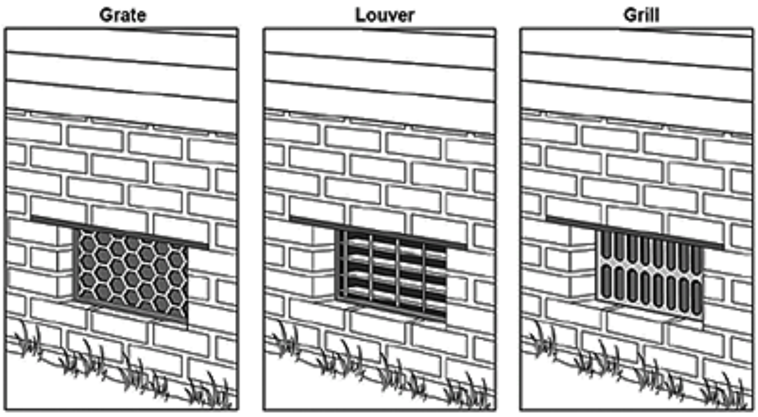


Figure 23: Typical opening covers *(credit: andhitapradipta.github.io)*

8.2.10 Levees and Flood Walls:

Levees and floodwalls are barriers constructed away from a building as a means of preventing floodwaters from reaching the building. Permanent barriers are typically constructed of earth, concrete or metal. Temporary barriers are typically installed using sand bags or water-filled tubes. Permanent barriers will typically require gates or doors at any locations where normal building access (vehicular and pedestrian) is maintained. Drainage systems will be required inside levees and floodwalls to remove rainfall that is trapped behind the barrier, and to remove floodwaters that enter through leaks in the barrier or seep through the ground. Designers are advised not to rely on temporary barriers for flood protection, and those contemplating use of a permanent levee or floodwall are advised to consult with engineers experienced in the design and construction of these structures.

Chapter 9

Recommendation for New Construction

Chapter 9

Environmental Protection Recommendation for New Construction

9.1 Environmental Practices in Construction Sites:

There are several methods are available which is very important for the environment protection. As construction activity is one of the major human intervention which is impacting our environment. It is our duty to adopt eco-friendly methods for the development. We have to take several action during construction and after that to reduce the impact of development on environment. The different environmental assessment methods for sustainable buildings present a series of good practice guidelines to be applied during the construction phase. In order to adopt best practices for a low environmental impact construction site, this study was divided into three stages:

1. identification of best practices;
2. selection and Implementation of best practices; and
3. monitoring, actions and learning.

9.2 Recommendations for the adoption of environmental practice on construction site

The construction site is a dynamic space in which several changes are made during the execution phase. Therefore, solutions and potential barriers should be forecasted before the construction phase or major activities start. The implementation of low environmental impact construction sites requires a set of guidelines, as discussed below.

9.2.1 Considering site sustainability in the design phase

During the project briefing stage, all designers should be given the necessary recommendations regarding the sustainability attributes to be adopted also considering the construction phase, such as the materials policy and construction methods with the aim of minimizing waste production and promoting rational resource use.

9.2.2 Planning the construction site

Before starting any construction work, it is necessary to characterize and analyze the construction site, the surrounding neighborhood and the legal requirements. Then, the environmental aspects and impacts relevant to each construction activity should be identified and prioritized. The selection of the practices should consider cost, efficiency and ease of employment criteria. The selected practices should put into a Construction Site Environmental Management Plan containing a detailed plan on how and when each solution should be implemented, what resources are required, who will be responsible and how it will be monitored. The Main Contractors' Quality Management system can be adjusted including the data control sheets, and relevant training material.

9.2.3 Implementing practices

The implementation of low impact construction sites should start with the training of workers and assigning a responsible for the work to guarantee effective implementation and monitoring of the low environmental impact construction site. This responsibility can be attributed to health and safety managers or an environmental manager. Provision of a visual communication program will assist implementation as well as training of workers in short daily meeting and specific lectures, with the aid of good practice photos and posters.

9.2.4 Hiring of subcontractors:

The responsibility of adhering to the construction site environmental management plan, policies and procedures must also be passed on to the subcontractors and inserted during negotiations and formalization of contracts. Existing management systems should be extrapolated and extended to subcontractor management systems, defining parameters for the formulation of contracts, stipulation of goals and rules regarding the reduction of losses, etc.

9.3 Sustainable Solid Waste Disposal Techniques for New Construction

9.3.1 Sustainable Waste Management Tips for Construction and Engineering Sector

Waste management is a key area of concern within the construction and engineering sector today, with landfills already overflowing everywhere. It's time to take salvage/reclamation opportunities, recycling or reusing materials, source reduction and waste disposal more seriously.

Like other solid waste, waste management systems can be broken down into these 6 functional elements:

- Generation
- Handling, separation, storage, and processing (at source)
- Collection
- Separation, processing and transformation
- Transfer and transport
- Disposal

Here are three ways to improve construction waste disposal and waste management:

9.3.2 Sustainable Design

If buildings are designed to be more adaptable, or disassembled and reused when required, there will be a lower demand for demolition and removal. This can have a tremendous impact on the amount of waste generated during each building's lifetime. Key strategies include:

- Planning adaptation or disassembly options that include relevant details such as materials and components, built drawings, structural properties, etc.

- Developing buildings with modular and standard-sized assemblies/components, and structural systems that follow a simple, open-span design.
- Designing safe access points and easy movement for workers conducting repair, disassembly or adaptation tasks in the future.
- Reducing the use of different material types, and increasing the use of durable, reusable and recyclable materials in building construction.
- Providing visible connections that are easy to access, and using screws, nails, bolts and other mechanical fastenings instead of adhesives/sealants.

9.3.3 Demolition & Deconstruction

Building demolition results in heavy pollution and waste generation, so deconstruction needs to be the focus instead.
Deconstruction allows for extensive recovery of usable material at every level, right from systems and assemblies to entire structures and foundations. In addition to preserving resources and minimizing landfill waste, it also boosts the economy by creating new employment opportunities.
Here are some aspects to consider while designing/removing buildings:

- Complete deconstruction is not always possible, but most buildings can be partially deconstructed by combining demolition and deconstruction methods.
- Buildings that are wood-framed are highly deconstruct able, especially if they have been constructed with heavy timber or versatile, old growth wood.
- Hardwood flooring, architectural mouldings, electrical or plumbing components, unique windows/doors and other specialty materials have a high resale value.
- Paving or construction projects using high-quality brick covered with low-quality mortar are easier to deconstruct, clean and reuse in new buildings.
- Structurally sound buildings that are constructed with durable materials are the easiest to deconstruct, with the maximum salvage/recovery potential.

9.3.4 Eco-Friendly Construction

While the use of harmful materials is regulated by government or industry authorities, it's also important for construction and engineering businesses to consider the environmental impact of materials they use. Here's how to reduce it:

- Use low-impact materials that are sustainably sourced, reused from other construction projects or recycled from the construction waste stream.
- Focus on sustainable design, modular buildings or components that can be adapted or reused easily, and proper waste management systems.
- Maximize efficiency and reduce wastage by using equipment such as portable truck scales to accurately weigh materials required for construction projects.
- Include sustainable recycling/reuse practices at every stage of construction projects, focusing on deconstruction instead of demolition wherever possible.
- Set up waste reduction programs to train workers on sustainable construction, and tie up with local recycling companies at construction sites.
- Sustainable construction and design is all about reducing waste and increasing reuse or recycling potential during each project. Builders, contractors and others involved in construction/design need to make an active effort to reduce C&D waste going into landfills, and a little planning is all it takes.

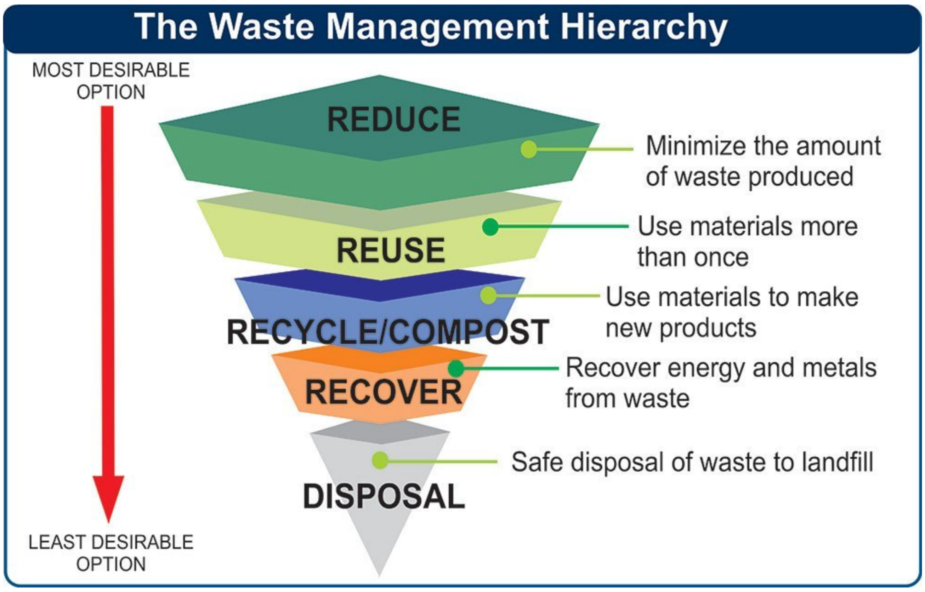


Figure 24:waste management hierarchy (*credit: http://www.stuff.co.nz)*

Figure 25: image showing different type of solid waste management. *(credit:http://www.stuff.co.nz)*

9.4 Three Key Execution Strategies:

9.4.1 Creating a Solid Waste Management Plan During Design

Develop during schematic design, incorporate in design development, include in the project specification and materials selection, congruent with the Construction Waste Management

Plan execution, adopted and implemented by occupancy and operations and facilities maintenance staff.

9.4.2 Implementing the Waste Management Plan During Construction

Logistical planning = Planning in Design phase, execution during construction, education and communication components, diversion calculation, measurement and reporting Construction Phase accountability.

9.4.3 Design for management of solid waste generated during occupancy

Develop comprehensive, realistic and efficient waste related operations and maintenance strategies in the Waste Management Plan.

Chapter 10

Site Supervision Guidelines

Chapter 10

Site Supervision Guidelines of Construction

The site engineer should possess basic knowledge about the practical construction procedures in site, along with the details of how they are planned. This idea of planning and coordination will help him to have proper execution of the activities in the site with desired performance.

10.1.1 Technical Activities

Site activities like establishment of the level and the survey control, which is required for the control of contracts must be performed by site engineer in required conditions. The works have to be set out as per the contract drawings. This requires checks at regular basis on the construction site.

The records maintained have to be accurate and they have to satisfy with the organizational and the legal requirements.

10.1.2 Preparation of Reports and Schedules

The site engineer is the one who have to ensure that the site have adequate resources to complete the tasks. This is conducted by having procurement schedules for the jobs carried out and liaise with the procurement department regarding the same.

A report on the future works to be carried out at site are prepared and produced by site engineers two weeks ahead. This is carried out in conjunction with the site agent. The site engineer is responsible for keeping site diaries and the respective sheets for allocation.

10.1.3 Site Engineer for Health and Safety

For highly dangerous work site, the site engineer will take up the role of safety engineer. He has to ensure that the work carried out by the workers and other related activities are as per the safety regulation of the respective state or area.
Every construction organization must possess a safe working culture and practice. Its implementation and practice of following is supervised by the site engineers. There may be other safety, health officers for the organization, but ensuring safety is a common need.

Other responsibilities are to undergo construction activities that will promote the environmental compliance. Each work has to be carried out safely within the deadline.

10.1.4 Quality Assurance by Site Engineer

As we know, quality is a parameter that have to be kept in practice from the initial stage of planning to the end of the project. The major issues with design and documentation can be corrected during the construction by the site engineer based on advice from the structural engineers.

Any undesirable activities in construction brings high loss of quality and money. The site engineer assures quality by the following means:

- Promoting the best construction practices
- Undergo activities and practices that comply with the procedures of the company and the specification.
- Assures the work is completed and delivered without any defect and delay
- One must highlight value engineering opportunities

Chapter 11

Do & Don't for Construction

Chapter 11

Do & Don't for the Construction

11.1.1 Settlement pattern and Design Considerations

PROVIDE:

- Clustered (zigzag) planning avoids tunneling effect and reduces susceptibility to disaster.
- Simple Square/Rectangular and Symmetrical plan is Suitable - Length of Building ≤ 2xWidth.
- Separation of wings into different rectangles in plan is preferable.
- Shorter wall facing wind direction.

AVOID

- Row house settlement with roads leading to Sea.
- Longer wall facing the direction of wind.

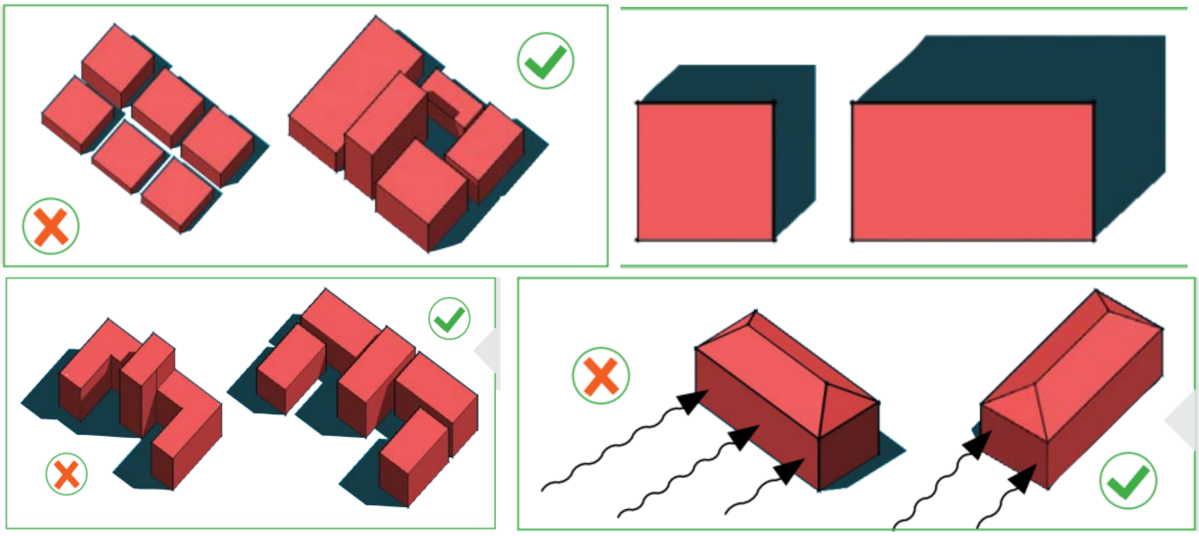


Figure 26: Disaster resilient building design pattern (*credit: TESRA ppt)*

11.2 Foundation:

PROVIDE

- Slightly Slanting cut - Sand Compaction thickness more than 150mm - PCC thickness more than 75mm.
- Foundation width should be 2½ times thickness of the wall or 0.8m, whichever is more.
- Use baked bricks and stones.
- Minimum depth should be 1000mm.
- Foundation on Hard Soil.

AVOID

- Straight Cut - Sand compaction less than 150mm - PCC less than 75mm.
- Foundation width should not be less than 2½ times thickness of the wall.
- Never make a wall without foundation B. Don't use unbaked bricks in the foundation.
- Foundation on Loose or Soft Soil.

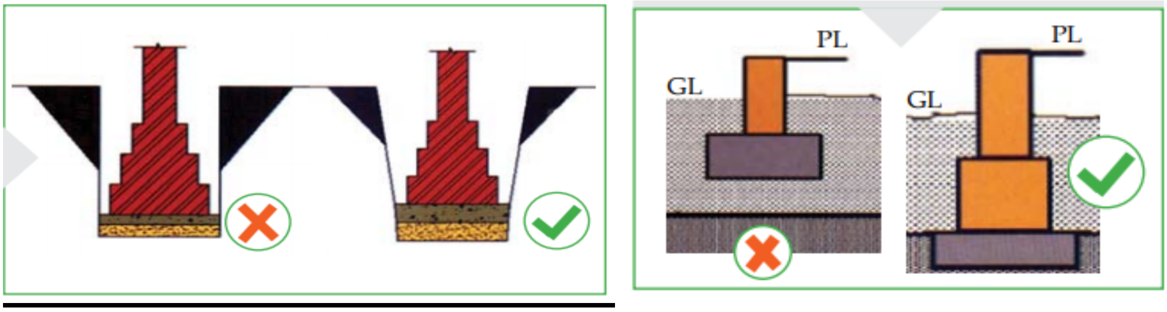


Figure 27: Foundation design and execution

11.2.1 Walls

PROVIDE

- Average wall height should be 2700 to 3000mm.
- The length of the wall should not exceed 8 times the thickness - Addition of a buttress wall reduces L/H Ratio.

AVOID

- Too High Walls.
- Walls that are too high or too long

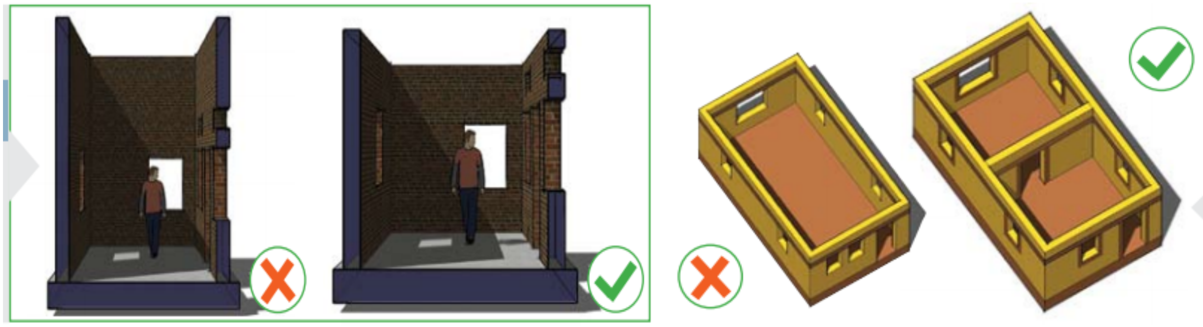


Figure 28: disaster resilient wall features (credit: TESRA ppt)

11.2.2 Stone Masonry

PROVIDE

- Through stone should be placed horizontally at a minimum spacing of 1200mm center-to-center.
- Through stone should be placed vertically at a minimum-spacing of 600mm.
- Vertical Rod should be placed at 125mm from the inner face of the wall.
- Vertical Rod should be placed at 245mm from the inner face of the Brickwork **Rat-trap Bond (L-Joint)**
- Vertical rod must be connected using extra "L" bar with main steel of Plinth band and Lintel band. The bar will be able to perform efficiently if it is anchored at Foundation and Slab and linked with plinth and lintel band.
- .Joints in brickwork should be staggered.
- For regular bond use only mortar of 1:6 or richer and for Rat - Trap bond 1:5 or richer.
- Vertical rods should be protected with a minimum cover of 40mm in M20 concrete
    1. Joints in brickwork should be staggered.
    2. For regular bond use only mortar of 1:6 or richer and for Rat - Trap bond 1:5 or richer.
- Vertical rods should be protected with a minimum cover of 40mm in M20 concrete

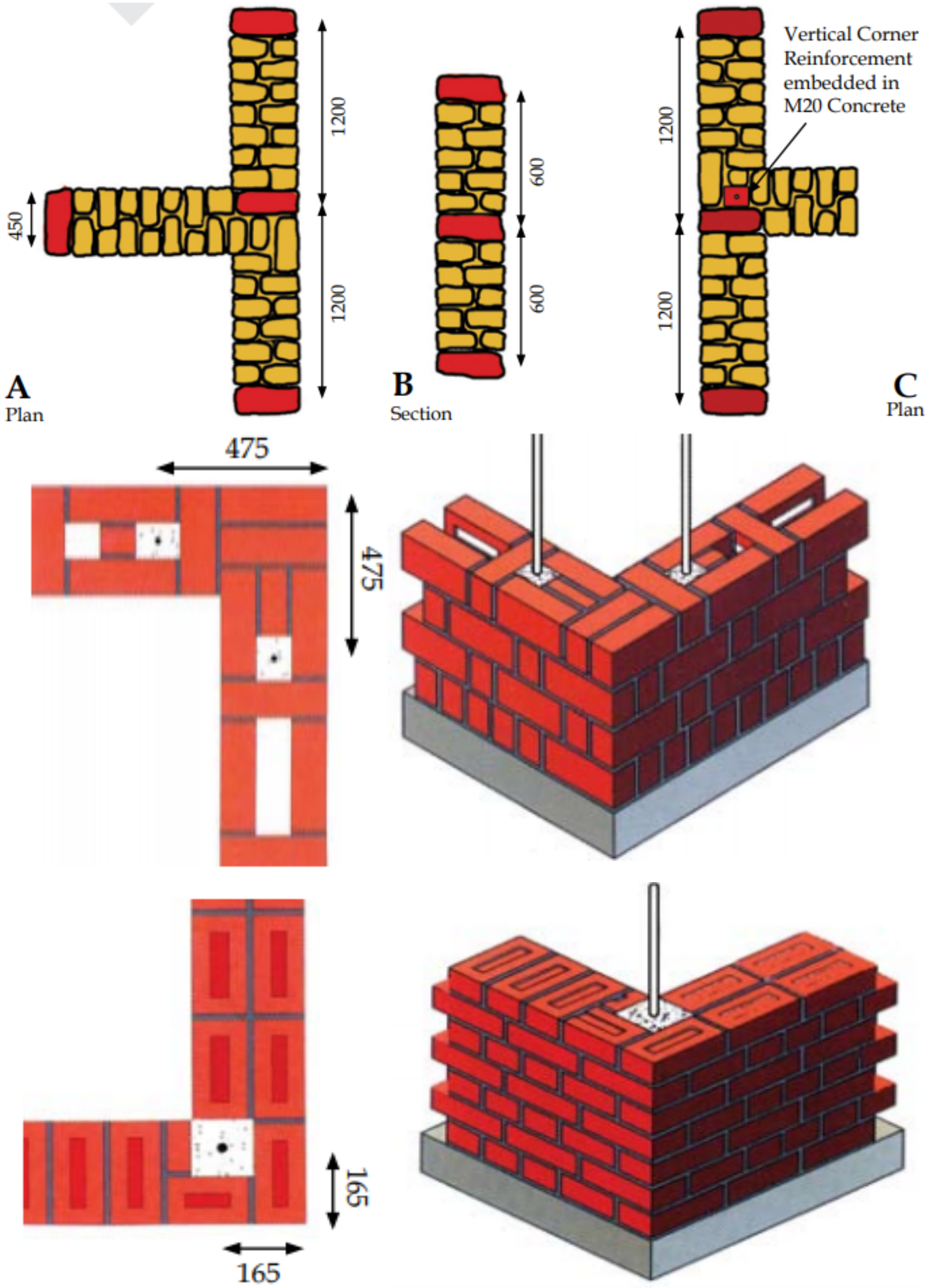
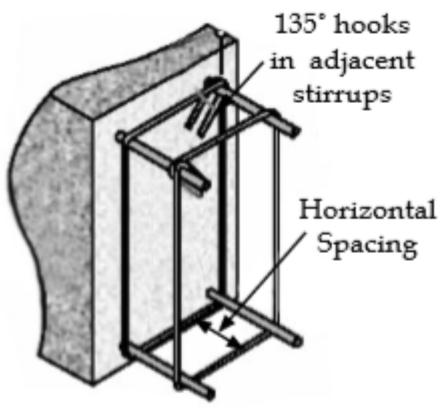
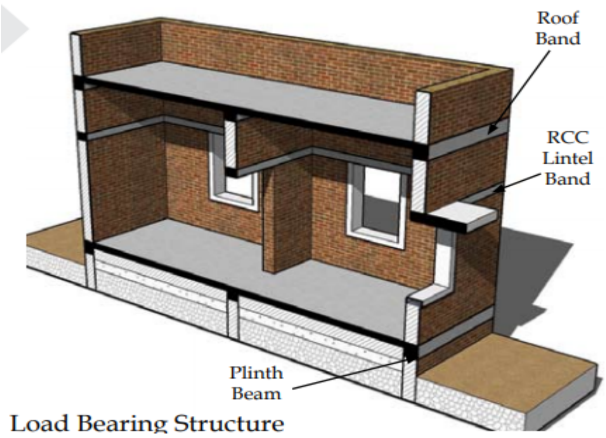


Figure 29: Different type of disaster resilient brick bonds *(credit: TESRA ppt)*





11.2.3 Openings

- Openings are the most Vulnerable part in a building. Large shear forces get accumulated around openings and therefore, edges of the openings should be specifically strengthened.
- Due to lateral thrust openings are subjected to movements attempting to make them a Rhombus - stretching opposite diagonals as shown. Because of this it is likely that after an Earthquake; diagonal / shear cracks occur around unsecured openings and brick piers.

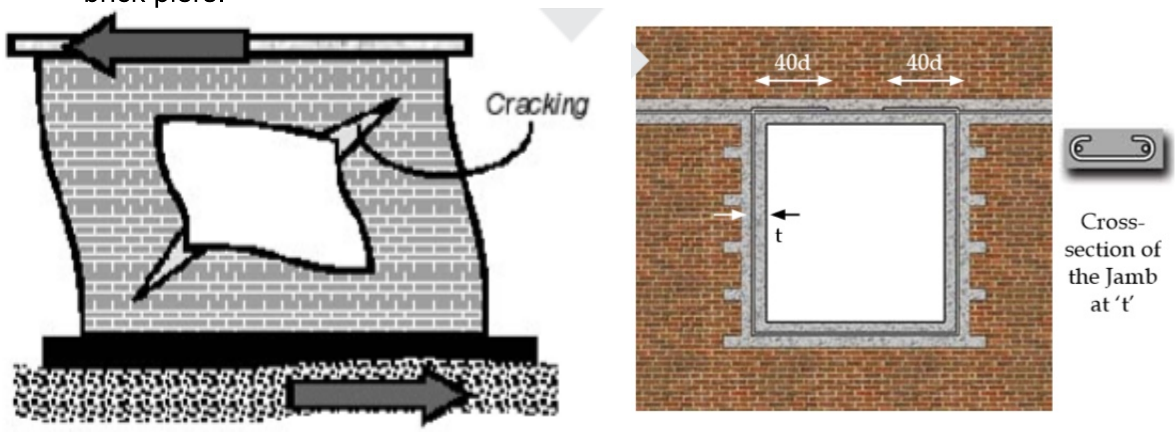
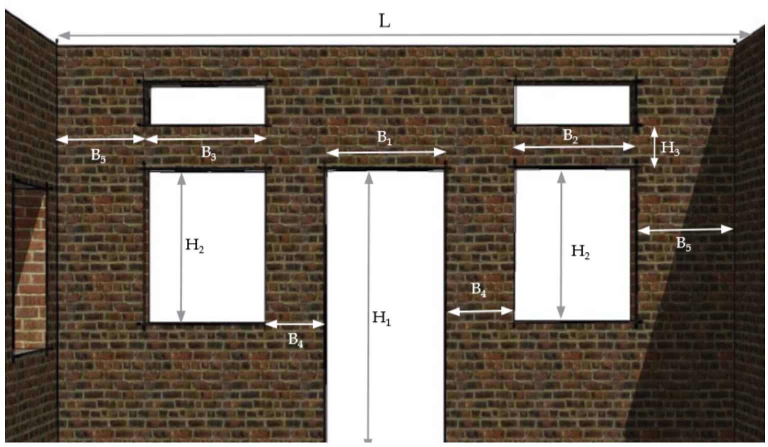


Figure 30: Protect Openings with Reinforced Band all around as shown. *(credit: TESRA ppt)*



Design Considerations -Avoid too many openings in the wall -The minimum distance between unreinforced openings should be 600mm

Brick Masonry

- B1+B2+B3 ≤ 0.5L (for One Storey) ≤ 0.42L (for Two Storey) ≤ 0.33L (for Three storey)
- **600mm ≤ B4 ≥ 0.5H2)]** Horizontal distance (pier width) between two openings should not be less than 50% the height of the shorter opening (and not less than 600mm)
- **600mm ≤ B5 ≥ 0.25H1]** Openings to be located away from the corners by clear distance equal to at least one fourth of the height of opening or 600mm whichever is more.
- **[H3 ≤ 600mm or 0.5(B2 or B3)]** Vertical distance from an opening to opening above should not be less than 600mm and half the width of smaller opening.

Stone Masonry

- B1 + B2 < 0.3L
- B4 ≥ = 0.50H2 ≮ 600mm
- B4 ≥ = 0.25H1 ≮ 600mm

11.2.4 Columns & Beams

Columns and Beams are main elements of the RCC frame construction. They should be designed for Earthquake resistance and detailed as per the ductile detailing norms. If the ductile detailing is not followed, the structure will be damaged in the event of a dynamic loading during disasters. Min. concrete Grade for RCC should be M20 i.e. 1: 1.5 :3 for volumetric proportioning. Where 3 is a mix of 10mm and 20mm down aggregates in 50/50 or 60/40 ratio.

PROVIDE

- Bend the Stirrup through 135°
- Adequate Lap Length with slope of 1:6
- Beam bars bent in joint region overstress the core concrete adjoining the bends
- Column should have minimum four 12 diameter bars. It is preferable to use TMT bars near the coast line
- Reinforcement Detail of Beam Column Joint at Roof Level.
- Reinforcement Detail of Beam Column Joint at Floor Level.

AVOID

- Inadequate Stirrup Details
- Splice with Offset Cranked bar in a Column

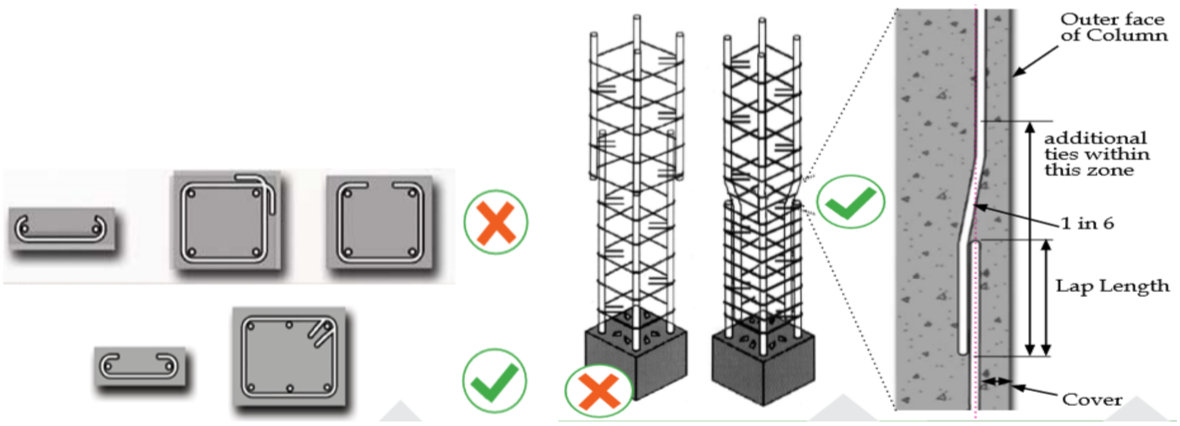


Figure 31: Reinforcement pattern in column and bar bending details *(credit: TESRA ppt)*

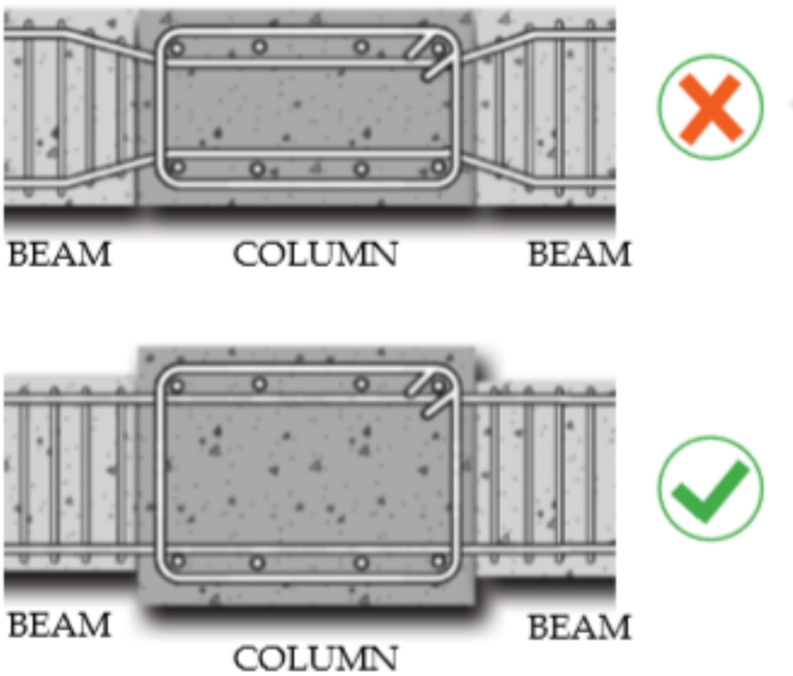


Figure 32: Reinforcement pattern on beam column joints *(credit: TESRA ppt)*

Chapter 12

Key recommendation & Conclusion

As per the overall studies, in Kerala all the structure which are built with stone & brick masonry without reinforcement are highly vulnerable for the damage, if it experiences any kind of disaster like earthquake, flood and landslides. In Kerala these types of structures are available in very high number and most of these types of structures are available in rural area which are prone for the flooding and landslides. As economy and development of our country in progressive stage so that all the new construction should be done in a way that it will resist any hazard and help to create disaster resilient society.

Key idea to build disaster resilient structure is to make it durable and achieve factor of safety at the time of any disaster, for that there are some important recommendations like analysis the structure in different perspectives like site of building, material used for construction, damage appear, building configuration, maintained quality on the basis of above mention disaster resilient technique should be adopted which include several factors like expert executor available, quality of intervention needed to be quantified, supervision of site engineer is must etc. To build safer society it is very important to build disaster resilient structures so that impact of any disaster would be minimized, and chance of economic and human loss can be reduced. In Kerala it is need of this hour to carry a detail survey of all flood effected area and create a common structure damage pattern inventory for the vulnerable structure which shows damage the people which are the best practices are available in the area that they can adopt to build their house or building so that damage probability will be than a training program needed to be conducted with the practical session to selected masons. There is a need to create some demo units using all the local material available which includes disaster resilient feature for the future reference of native people.

Some of the key recommendations are:

1. Identify available hazard which can affect proposed or existing construction site.
2. Documentation of past history of disaster event is needed to be document to analysis the frequency.
3. In Kerala it is need of this hour to carry a detail survey of all flood effected area and create a common structure damage pattern inventory for the vulnerable structure which shows damage the people which are the best practices are available in the area that they can adopt to build their house or building so that damage probability will be than a training program needed to be conducted with the practical session to selected masons.
4. There is a need to create some demo units using all the local material available which includes disaster resilient feature for the future reference of native people.
5. Quality control of construction material needed to be regulated by local engineers, government.
6. Awareness campaign on retrofitting and quality construction needed to be executed at different level.
7. Physical demo units needed to be constructed with all the detail demonstration of safe construction techniques in different districts.
8. Different level engineering training programs needed to be conducted at all the level in state.

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