National Disaster Management Authority

TEMPLATES AND METHODOLOGIES FOR DISASTER RESILIENT INFRASTRUCTURE 2024

Infrastructure Advisory & Project Development Wing

www.ndma.gov.pk

Foreword

Pakistan is considered 7th most vulnerable country exposed to climate change risks. We are amongst 23 nations facing acute water stress by the end of the year 2024. Current weather anomalies are threatening all global zones with exacerbated frequency & impacts recurrences. Pakistan's spectrum of disasters management is exacerbated by huge population, urban mismanagement, water stress, drought and seasonal rains.

National systems have been enacted for collating global best practices to design Pakistan specific templates for referral guidance in all pre & post disasters stages. Robust mechanism of anticipatory actions (AAs) is functional to communicate, train and upgrade doable actions for every component, in all projected vulnerable zones, in all calendar months, in all disasters / emergencies.

Due to varying geographical zones in Pakistan, it is critical to have area specific solutions. Infrastructure, being key enabler of survival and security in disasters, ought to have templates which are embedded with local cultural preferences and community choices. Infrastructure needs to conform to the religious, ethnic and area needs. Thus, NDMA's proactive disasters management strategies included specific guidebook on disasters resilient infrastructure development and maintenance in Pakistan.

This book covers various construction methodologies best suited to specific disaster vulnerable zones, aligned with NDMA's vision of saving lives & economy and promoting sustainability by encouraging use of locally available low-cost materials.

All provinces, public, social and private sectors (including all humanitarian enablers and partners organizations) are expected to follow standardized templates and add value through valuable post use feedback for constant evaluation and optimization.

Lieutenant General Inam Haider Malik HI (M)
Chairman
National Disaster Management Authority (NDMA)

Acknowledgement

The Infrastructure Advisory and Project Development (IA&PD) Wing of NDMA, is pleased to launch the Resilient Construction Options for Pakistan based on various disasters. The book provides guidance for the resilient construction against disaster based on Pakistan socio-economic conditions. For this purpose, a thorough study was conducted on the current construction practices in different districts.

We would like to acknowledge the efforts of Chairman NDMA for his guidance and constant support in formulating and compiling this book.

The IA&PD would like to acknowledge the PBS Housing database based on which the current building types were deduced. In the light of this, NDMA database of the type of disaster helped the IA&PD Wing to recommend the best practices that can be adopted against the specific disaster for regions.

We would like to acknowledge the guidance of Consultant (IA&PD) and his team in the compilation of this book. His valuable input enabled the IA&PD Wing to formulate specific methodologies against specific disasters.

In the end, we would like to extend our gratitude to all our relevant stakeholders who contributed towards the compilation of the book.

Preface

The region of Pakistan is blessed with natural features ranging from the mountains of Himalayas to the deserts of Thar and Thal, to natural vegetation areas of Punjab and the coastal region of Sindh and Balochistan. Along these, Pakistan faces several natural hazards which may vary from district to district based on the natural attributes of the area. For example, the earthquakes and landslides in the mountains area, flood near the rivers and coastal area and Glacial Lake Outburst Flow (GLOF) in the northern regions of Pakistan. The ever-changing dynamics of the disaster with time due to population growth and development incorporated with the Climate change impacts such as heatwaves have resulted in increased causalities. Furthermore, the flaw in our construction practices resulting in the weaker structures increase the Risk of Disasters. Our Infrastructure Advisory & Project Development (IA&PD) Wing of NDMA, precisely focuses on how to improve the construction practices and building strength to reduce the disaster impact. This book gives an introduction and addresses the questions of what type of disaster we face in each region, the flaws in our construction practices and how we may be able to improve these against specific disaster. The suggestions provided in this book have been gathered from around the world based on the disaster type and keeping in view Pakistan’s socio-economic status. The most important aspect to keep in mind is that these proposals provide a brief on how to change our approach during construction which will help us to build disaster resilient structures.

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CHAPTER 1

Introduction

1. Background

Pakistan is one of the worst affected countries by Climate change. According to the climate risk index 2021 Pakistan is ranked as the 5th most affected country which exposes it to a multitude of natural disasters. In the first quarter of FY2023, floods engulfed large parts of agricultural land and disrupted the domestic supply. Flood damages, GDP loss, and rehabilitation expenditures have been estimated to be about US$ 14.9 Billion, US$ 15.2 Billion and US $ 16.3 Billion respectively. Thus, disasters not only cause the loss of life and property but also create a situation of food insecurity and weaken the economy of the country in the longer run. Therefore, there is a need to develop resilient structures to mitigate the effects of these disasters.

This guideline is aimed at imparting information about the various disaster zones of Pakistan, the prevalent techniques of Construction being employed in these zones and strategies to effectively minimize the loss of life and property by enhancing Infrastructure Resilience of Pakistan.

Pakistan is divided into 4 zones based on topography and geographical factors. This guideline aims to discuss the types of topography in 3 different zones, specific types of hazards in these zones, prevalent construction methodologies and recommendations for rebuilt construction methodologies.

The Map depicting the various disaster zones of Pakistan is shown below:

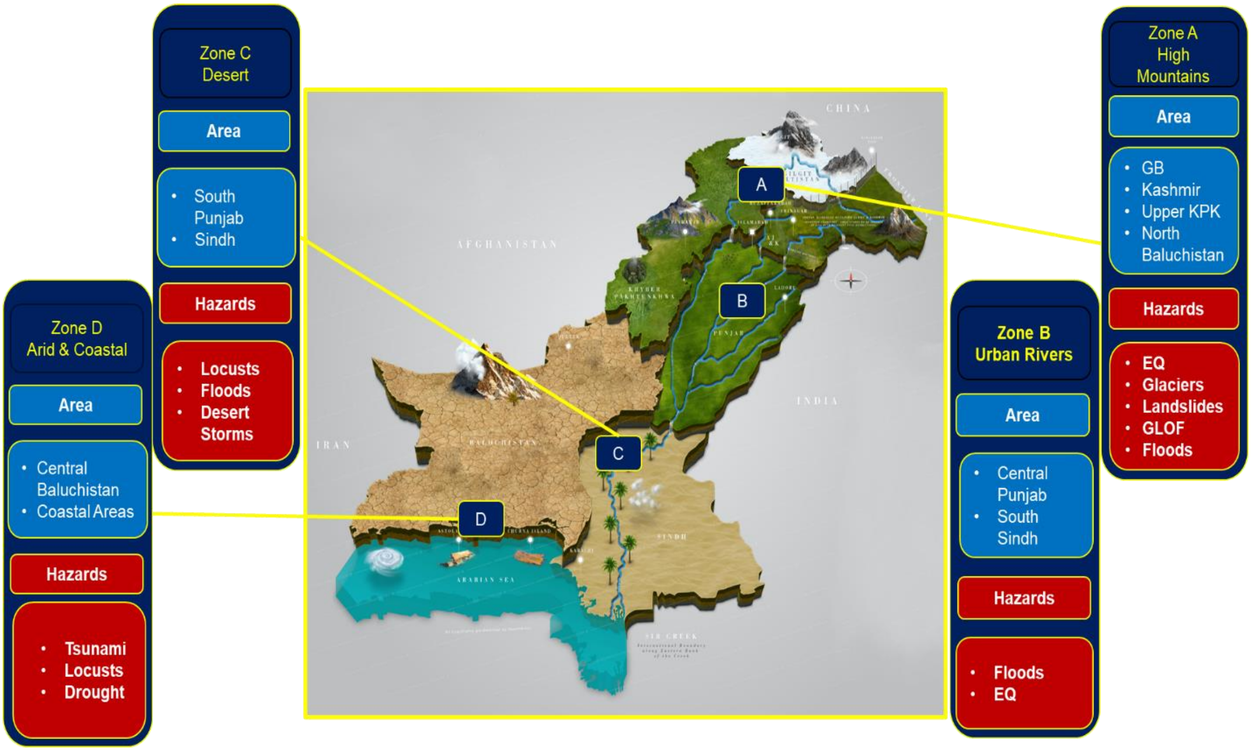


Figure 1 Division of Pakistan based on Characteristics (Source NDMA)

2. Peculiarities of Infrastructure in Various Disaster Zones

Based on the Figure.1, each zone has specific characteristics that separates it from the rest of Pakistan. Following this, here they have been further categorized based on the most vulnerable areas with respect to Hazards and the historical data on the disasters and their damages:

a. Prioritized Most Vulnerable Areas

A brief description of several types of hazards and the most vulnerable districts of Pakistan against those hazards extracted from National Disaster Management Plan – III (2024) are as follows:

i. Flood

Table 1 List of Vulnerable Districts to Flood Hazard

Province	Districts
Balochistan	Bolan, Chaghai, Gwadar, Jaffarabad, Jhal Magsi, Kech, Kharan, Khuzdar, Lasbela, Nasirabad, Nushki & Sibbi
Punjab	Bhakkar, D.G.Khan, Gujranwala, Gujrat, Jhang, Khushab, Layyah, Mianwali, Muzaffargarh, Narowal, R.Y.Khan, Ranjanpur, Rawalpindi, Sialkot & Sheikhupura
KP	Buner, Charsadda, Nowshera, Swat, Chitral, D.I.Khan, Dir Upper, Dir Lower, Kohistan, Kurram, Lakki Marwat, Malakand ,Mansehra, Mardan, North Waziristan, Nowshera, Orakzai, Peshawar, Shangla, South Waziristan, Swabi, Swat & Tank
Sindh	Badin, Dadu, Ghotki, Jacobabad, Mirpur khas, Jamshoro, Qamber Shahdadaot, Karachi, Kashmore, Khairpur, Larkana, Sanghar, Shikarpur, Sukkhur, Tando M Khan & Thatta
Gilgit Baltistan	Astore, Chillas, Diamer, Ghanche, Gilgit, Ghizar, Hunza, Nagar & Skardu
AJ&K	Bagh, Bhimber, Muzaffarabad, Neelum & Poonch

ii. Earthquake

Table2 Vulnerable Districts to Earthquake Hazards

Province	Districts
Balochistan	Awaran, Barkhan, Dera Bugti, Gwadar, Jhal Magsi, Kachhi, Kallat, Kech, Kharan, Khuzdar, Killa Abdullah, Lasbela ,Loralai, Mastung, Musakhel, Nasirabad, Nushki, Panjgur, Pishin, Quetta, Sherani, Sibbi, Sohbatpur & Washuk
Punjab	Attock, Bhakkar, Chakwal, Dera Ghazi Khan, Gujranwala, Gujrat, Jhelum, Khushab, Mandi Bahauddin, Mianwali Narowal, Rajanpur & Rawalpindi
KP	Bannu, Charsadda, Hangu, Karak, Kohat, Lakki Marwat, Mardan, Peshawar, Swabi, Khyber, Kurram & Mohmand
Sindh	Badin, Central Karachi, East Karachi, Korangi, Malir, South Karachi & West Karachi
Islamabad	Islamabad

iii. Locusts

Table3 List of Vulnerable Districts to Locusts Hazard

Province	Districts
Balochistan	Chaghai, Kharan, Panjgur, Khuzadar, Awaran, Pishin, Barkhan, Harnai, Kohlu, Washuk, Gwadar, Kech & Lasbela
Sindh	Badin, Sukkur, Khairpur, Shaheed Benazirabad, Sanghar, Tharparkar & Ghotki
Punjab	Ramin Yar Khan, Bahawlpur, Bahwalnagar, Bhakkar, Khushab, Rajanpur & Muzafargarh
KP	Dera Ismail Khan, Bannu, Lakki, Orakzai, Kurram & Tank

b. Archived Disasters

Description of various type of disaster events that have occurred over the period of last 70 years are as follows:

i. Flood

Table4 Major Flood Disasters in Pakistan

Year	Death	People Affected	Year	Deaths	People Affected
2022	1730	33 Mn	**2007**	586	6,498
2021	198	Not Reported	**2006**	541	2,477
2020	423	1,193,353	**2005**	59	1,931
2019	235	Not Reported	**2004**	85	47
2018	135	Not Reported	**2003**	484	4,376
2017	271	Not Reported	**2001**	219	50
2016	153	45	**1995**	591	6,582
2015	238	4,111	**1992**	1008	13,208
2014	367	3,798	**1988**	508	1,000
2013	243	8,297	**1978**	393	9.199
2012	571	14,159	**1976**	425	18,390
2011	520	38,700	**1973**	474	9,719
2010	1985	17,553	**1957**	83	4,498
2009	99	89	**1956**	160	11,609
2008	157	800	**1950**	2190	10,000

ii. Tsunami

Table 5 Major Tsunami Disasters in Pakistan

Date	Time	Magnitude	Run up (In meter)	Location
28 Nov 1945	21:56:40	8.3	15.24	Karachi, Gawadar, Omara and Pasni
27 Aug 1883	02:59	Volcano	0.50	Karachi

iii. Earthquake

Table 6 Major Earthquake Disasters in Pakistan

Year	Location	Magnitude	Deaths	Losses
Jun 2022	North Waziristan	6.2	10	25 Injured, 600 affected
Oct 2021	Harnai, Balochistan	5.9	42	300 injured, 10,000 houses
Sep 2019	Mirpur, AJK	5.4	40	850 injured & 135 houses severe
Oct 2015	KP, Punjab, AJK, GB	8.1	280	98,069 houses
Sep 2013	Awaran	7.1	376	6,842 houses
Oct 2008	Ziarat	6.4	160	5,943 houses
Oct 2005	KP & AJK	7.6	73,338	4,400 houses
Dec 1974	Northern Area	7.4	5,300	-
Nov 1945	Makran Coast	8.3	4,000	-
May 1835	Quetta	7.7	60,000	-

iv. Cyclones

Table 7 Major Cyclones Disasters in Pakistan

Year	Death	Number Affected	Districts Affected
2010	15	0.2 Mn	Balochistan 30, Sindh 3
2007	Balochistan 380, Sindh 250	1.5 Mn	Balochistan 10, Sindh 4
1999	202	0.6 Mn	Badin and Thatta

c. Enumeration of Zonal Areas

i. Zone A (High Mountains)

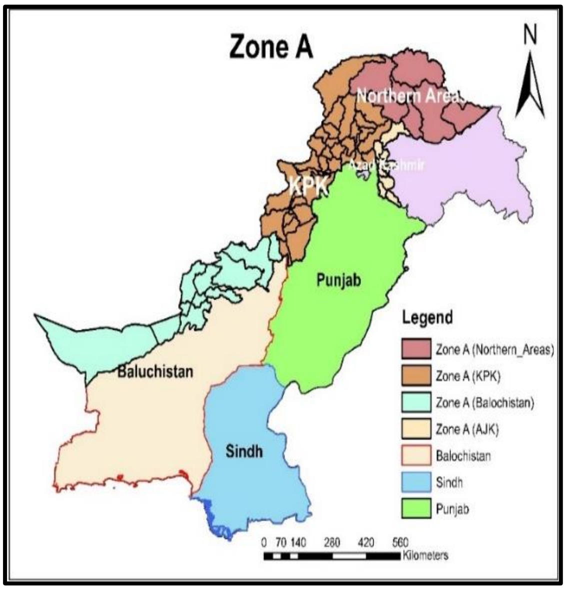


Figure 2 District Identifications for Zone A

Geographical Setting: Zone A comprises of High Mountains. These includes the areas adjacent to the three major mountain ranges of Pakistan i.e., the Karakorum, Himalaya and Hindu Kush This Zone consists of parts of Kashmir, Gilgit Baltistan, Upper KPK and North Balochistan.

Hazards: The different types of hazards prevalent in this zone are Earthquakes, Glaciers, Landslides and floods. However, the hazards that have a significant impact on infrastructure of this region are Earthquakes floods and landslides.

ii. Zone B (Plains)

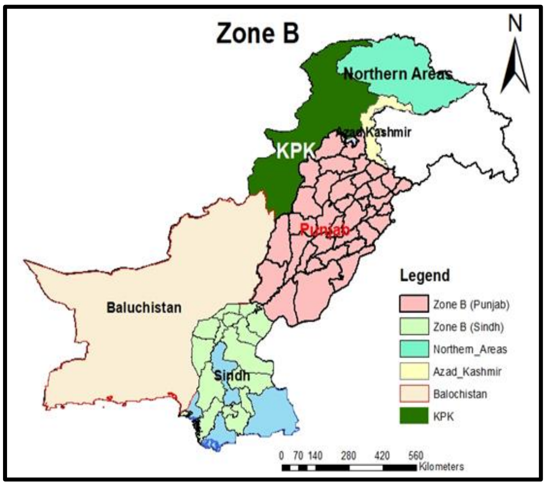


Figure 3 District Identification for Zone B

Geographical Setting: Zone B comprises of Urban Rivers. This zone includes the plains of Punjab and Parts of Southern Sindh including the districts Badin, Dadu, Ghotki, Jacobabad, Mirpur Khas, Jamshoro, Qamber Shahdadkot, Karachi, Kashmore, Khairpur, Larkana, Sanghar, Shikarpur, Sukkur, T.M.Khan and Thatta.

Hazards: The different types of hazards prevalent in this zone are Floods and Earthquakes.

iii. Zone C (Deserts)

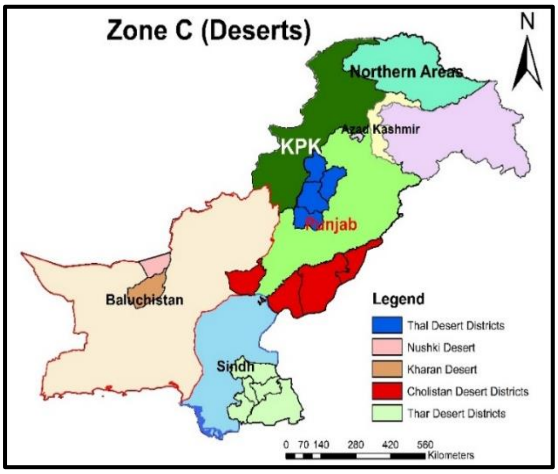


Figure 4 District Identification for Zone C

Geographical Setting: Zone C comprises of the desert areas of Pakistan. These areas are not geographically contigous but rather occur seperately. The major deserts of Pakistan are as follows:

- Thar & Thal Deserts
- Cholistan Desert
- Nushki Kharan Deserts

Hazard: The different types of hazards prevalent in this zone are Heatwave and Drought

iv. Zone D (Arid and Coastal)

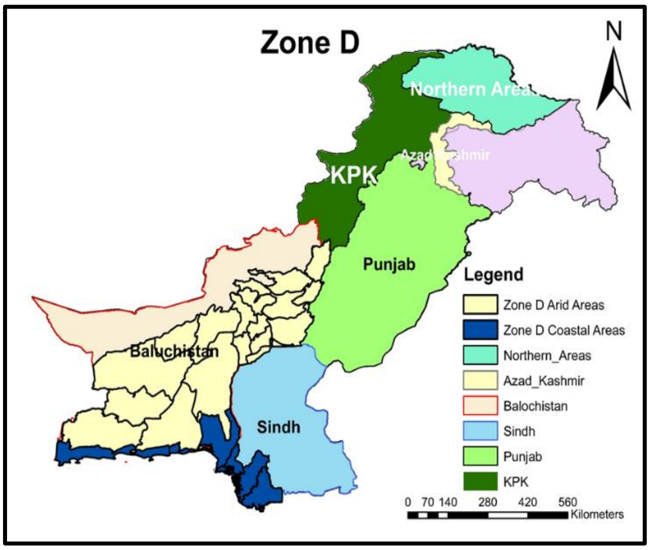


Figure 5 District Identification for Zone D of Pakistan

Geographical Setting:

The Zone D is Arid and Coastal Region of Pakistan. For the Arid Region it comprises of the Central Balochistan containing the districts Dera Bugti, Kalat, Kharan, Loralai, Awaran, Harnai, Sibi, Barkhan, Jaffarabad, Jhal Magso, Kech, Kholu, Hub and Chaman. These regions are apart from those included in the Zone A i.e., mountains. These districts face hot and dry climate with little vegetation.

The Coastal region of Pakistan includes the districts of Balochistan i.e. Gawadar and Lasbela and for Sindh coastal districts of Karachi, Sujhewal and Thatta. These regions form the boundary of Pakistan between Land and Arabian Sea. Due to being on Coastal side, the weather in Summer tends to be hot with occasional winds from sea side and in winters, these regions are relatively on the warmer side compared to whole Pakistan. Furthermore, near the coastal region of Balochistan this region shares its borders with the Makran Subduction Zone in the Arabian Sea.

Hazard: Due to large spatial distribution of the districts, the region faces a number of Natural Hazards. For the regions on the Coastal side, they are faced with the following natural hazards:

- Tsunami and Coastal Flooding
- Cyclones and Strong Winds
- Heatwave
- Earthquake (Due to Makran Subduction Zone)

The Arid region which is the Central Balochistan, faces the following natural hazards:

- Drought
- Locusts
- Heatwave
- Earthquake
- Flood

3. Existing Construction Practices

a. Zone A (High Mountains)

There are 4 major types of Conventional Methodologies that are currently being followed in Zone-A. The details of these Construction Methodologies along with their merits and demerits are as follows:

Reinforced Concrete (RCC)

MERITS	DEMERITS
Earthquake Resilient	High Cost
Thermal Insulation	Skilled Labor req
Design Flexibility	Slow Const Speed
Durable	
Minimum Maintenance	

Wooden Structures

MERITS	DEMERITS
Earthquake Resilient	Fire Hazard
Thermal Insulation	Termite Infestation
Renewable Resource	Deforestation
	Maintenance Cost
	Limited Durability

Confined Masonry

MERITS	DEMERITS
Earthquake Resilient	High Cost
Thermal Insulation	Skilled Labor req
Minimum Maintenance	Slow Const Speed
Durable	

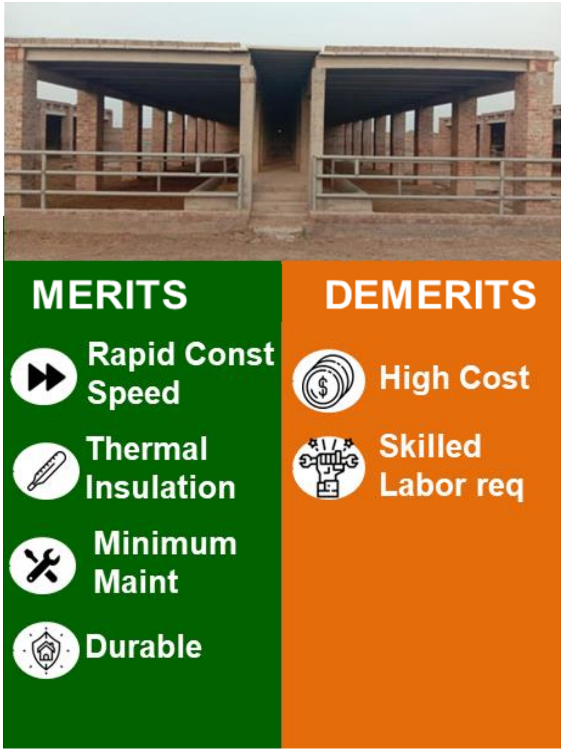
Stone Masonry

MERITS	DEMERITS
Earthquake Resilient	Slow Const Speed
Renewable Resource	Skilled Labor Req
Thermal Insulation	Maintenance Cost

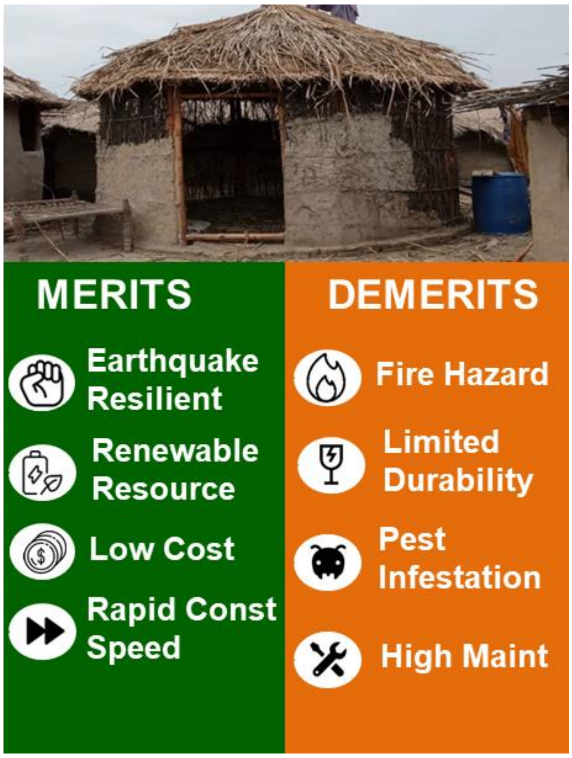
b. Zone B (Plains)

There are 4 major types of Conventional Methodologies that are currently being followed in Zone-B. The details of these Construction Methodologies along with their merits and demerits are as follows:

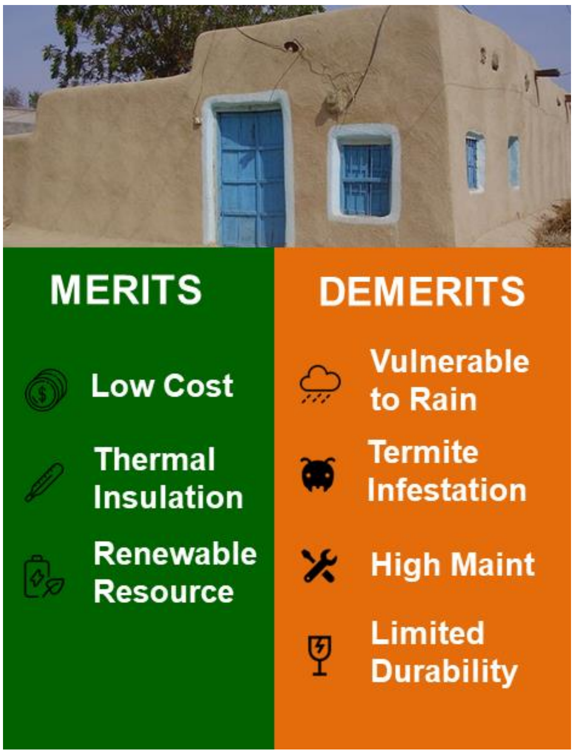
Pre-Cast Construction



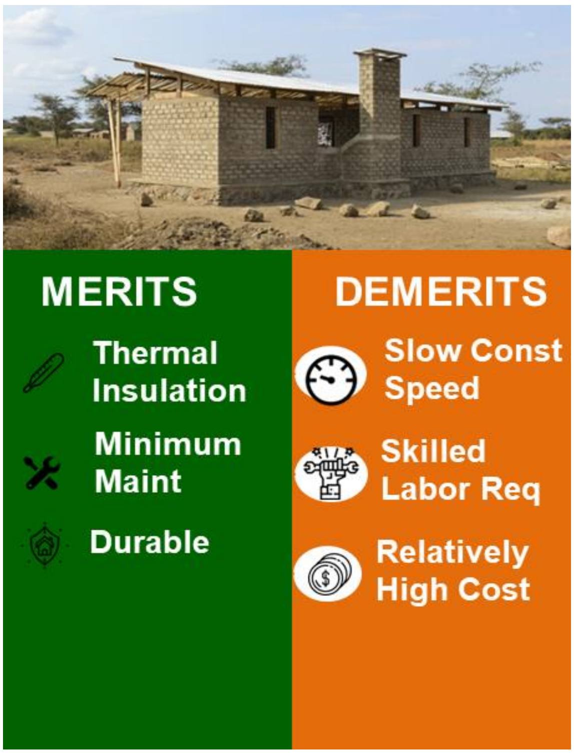
Bamboo Construction



Mud/Brick Construction



Fire-Brick Construction



c. Zone D (Arid and Coastal)

The Arid and Coastal regions have their own predominant construction practices. These practices are influenced by the socio-economic status of the region, the development status, presence of industries and the presence of Urban region in the vicinity.

In general, the following 4 types of construction practices are observed to be dominant in this region. However, it is not necessary for each of these practices to resist the impact of natural hazards in the area. Following are these common practices merits and demerits:

Adobe/Mud Structures

MERITS	DEMERITS
Renewable Resource	Maintenance Cost
Thermal Insulation	Build Codes Non-Comply
Cost Effective	Earthquake Prone
Fire Resist	Flood Prone

Stone Masonry

MERITS	DEMERITS
Earthquake Resilient	Slow Const Speed
Renewable Resource	Skilled Labor Req
Thermal Insulation	Maintenance Cost

Concrete Block Masonry

MERITS	DEMERITS
Earthquake Resilient	High Cost
Thermal Insulation	Skilled Labor req
Design Flexibility	Slow Const Speed
Durable	
Minimum Maintenance	

Confined Masonry

MERITS	DEMERITS
Earthquake Resilient	High Cost
Thermal Insulation	Skilled Labor req
Minimum Maintenance	Slow Const Speed
Durable	

Despite the structures having benefits that may act as resilient against the specific hazard in these regions, the structures most dominant are those that have been prevalent for a long time such as kacha ghar/ mud structure or Adobe or those structure that have been influenced by the development such as in Gwadar and Karachi resulting in dominant construction type of Brick Masonry and Concrete Block Masonry.

Through survey, it has been observed that the mud/adobe houses are dominant in the region of Balochistan specifically in Central Balochistan. The availability of material has a massive impact on the prevalent construction practices. As stated above, it is not necessary for the structure to withstand the hazard impact. For example, adobe structures cannot withstand the impact of earthquakes and flood and will be destroyed. Despite previous disasters in the region showing that the adobe structure will be destroyed by the hazard impact, it is still the predominant structure in the region, especially in Balochistan. This shows the predictability that during an event, these structures will be destroyed. There is a need to shift the construction approach towards disaster resilient practices to enhance the structural capacity against specific disasters.

4. Reasons behind default choices

Causes for adoption of less resilient infrastructure in disaster prone areas by local communities are as follows:

- Developing robust infrastructure frequently necessitates a large initial outlay of funds. When resources are scarce, decision-makers choose less expensive but more durable options over more costly but less resilient ones.
- Projects with immediate advantages may be given priority by politicians and policymakers over long-term resilience measures. This narrow concentration may result in infrastructure that is ill-equipped to withstand future calamities.
- There may occasionally be a lack of knowledge or comprehension of the particular risks that come with natural disasters. As a result, infrastructure plans may be made without considering the possible effects of these occurrences.
- The need for expansion and development, coupled with economic pressures, might force the construction of infrastructure in high-risk places, such as floodplains or coastal regions vulnerable to storms. The vulnerability of infrastructure to natural disasters is increased by this development.
- Political influence can occasionally result in infrastructure projects being situated in disaster-prone locations. Resilience considerations might not be given priority in these decisions.
- It is challenging to coordinate the implementation of complete resilience measures in areas where governance is fragmented, or duties are split among several bodies.
- Some communities lack the resources available for them to invest in resilient infrastructure, specifically those in low-income areas or developing countries. They could therefore be more prone to the effects of natural calamities.

CHAPTER 2

Recommendations from Around the World

1. Global practices against Disasters

a. Zone A (High Mountains)

i. Nepal

Nepal is a landlocked country situated in South Asia. Country's topography consists of multiple towering peaks and is geographically divided into three regions: Himalayan region in the north, hilly region in the center and Terai region in south. This magnificent topography also makes Nepal prone to various natural hazards such as earthquakes, floods, landslides and GLOFs. Nepal faces ongoing challenges in disaster management and following measures are being taken to make infrastructure more resilient:

- **Improved Masonry:** Various new methods are being developed and used to enhance structural performance of buildings such as incorporation of band beams in walls at every 3 feet and using timber trusses fitted with CGI sheets for lightweight roofs.

Figure 6 Improved Masonry Construction in district Gorkha, Nepal

- **Timber Laced Masonry Construction (Taq System):** This method consists of load-bearing masonry walls with horizontal timber frames, embedded in them. These timbers are tied together like horizontal ladders and are laid into the walls at each floor level and at the lintel levels of the windows, respectively.
  This combination of wood and masonry together with a weak mortar increases the susceptibility of buildings to deform slightly during earthquakes without significant damage. The mud mortar facilitates relative motion between the walls and the wooden members. A key factor in the structural integrity of Taq is that the full weight of the masonry is allowed to rest on the timbers, holding them in place while the timbers in turn keep the masonry from spreading.

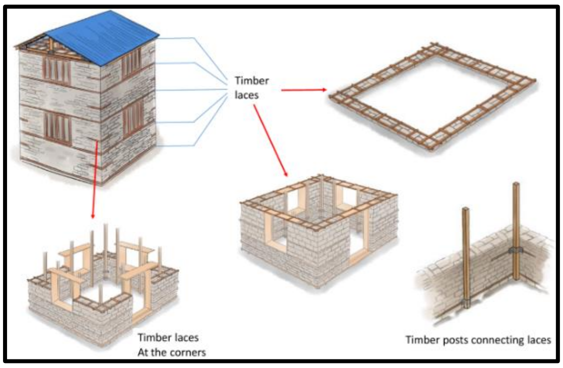


Figure 7 Example of Timber Laced Masonry

Figure 8 Wooden House Nuwakot, Nepal

- **Wooden Construction:** There has been a resurgence of interest in wooden construction as a sustainable and disaster resilient building solution. Timber structures in Nepal have demonstrated a remarkable resilience towards seismic forces and are rapidly reconstructed after an event of disaster.

- **Vernacular Construction:** Creating a platform up to a certain height (usually from 1m to 3m) which is unconstructed, and arrangement of the living environment is made from the first story onwards above the unconstructed platform. Due to water logging problems, locally available and dampness resistant heartwood of Shorea Robusta is found to be used as wooden pillar running up to the roof level. Construction in such buildings is limited to the first story only, however the gable part of houses is isolated by creating a wooden or bamboo slab. Such low height and weight houses constructed with timber elements have sound performance during earthquakes due to high ductility and low weight of overall construction.

Figure 9 Example of Vernacular Construction, Nepal

ii. Iran

The Elbroz and Zagros Mountain chains separate the central areas of Iran from Caspian Sea in the North and Mesopotamia in the west. The weather ranges from severe chill in winters and temperate weather in summers with extreme difference in day and night temperatures. The city texture in mountainous region has been developed in manner to cope up with extreme cold while presenting an amicable picture of harmonious relationship with the surrounding. It can be characterized by; compact and intensive texture; small and enclosed areas; focusing on sun and earth directions; and narrowing of the passages along the ground level. The factors being considered in the mountainous regions of Iran for resilient construction are as following:

- **Controlling Shape and Size of buildings:** The buildings in the mountainous region have a compact plan and texture. The houses built are usually cubes or cubic rectangular reducing the outer surface of the building as compared to its inner volume. Buildings in these regions have smaller verandas and the floor of the building yards in these regions is 1 to 5 meters below the sidewalk to direct the water. The buildings of this region are made of locally available material since they have good thermal capacity and the resistance to keep the building warm in its inner area. The body of these buildings is made from stone or wood, cob mortar, adobe and bricks and the roof are made of timber and cob.

  The principles that have been thought for adaptation to climatic conditions of these regions are very important; and they are as follows:

- Using common walls as much as possible, creating a heaped and compacted texture in complexes.
- Preparing compressed and compact plans; Forming the building to create shade in summer and receive proper heat in winter.
- Placing heat generating spaces like kitchen in the center of building plan.
- Considering non-important spaces like stores as heat insulator in sides or cold parts of building.


Figure 10 Example for Controlling Shape and Size of Building in Iran

iii. Japan

Country’s terrain is dominated by rugged mountain ranges, fertile plains, and coastal regions. Japan lies along the Pacific Ring of Fire, a horse-shoe shaped zone which faces intense tectonic movement due to which it bears a massive amount of seismic activity. The country has some of the most advanced and effective earthquake resilient construction practices. It has implemented various earthquake resilient practices to mitigate the impact of seismic events and ensure the safety of its population which are as following:

- **Base Isolation:** Base isolation is a seismic retrofitting technique used in building construction to enhance the earthquake resilience of structures, particularly in regions prone to seismic activity. Base isolation is the process of separating a building's superstructure and foundation from ground motion during an earthquake by putting in flexible bearings or isolators between them. By serving as shock absorbers, these isolators enable the building to move apart from the trembling ground. The aim of reducing the amount of seismic forces that reach the structure is to minimize damage and enhance occupant safety.

Figure 11 Example of base isolation system installed in Japan

- **Dampers:** To improve seismic resilience, dampers are crucial elements that are employed in infrastructure and building designs, especially in earthquake-prone areas like Japan. During seismic occurrences, these devices are essential for energy dissipation, structural vibration reduction and damage minimization.

Figure 12 Example for Dampers installation in Buildings, Japan

- **Wooden Construction:** In Japan, wooden structures provide notable earthquake resilience when paired with contemporary engineering concepts, especially when using traditional timber frame techniques. Japan has a long history of employing wood as their major building material, despite its reputation as a seismically active nation. Improvements in construction techniques have made wooden structures more earthquake resistant.


Figure 13 Example of wooden construction in Japan

- **Prefabricated/Modular Houses:** Prefabricated and modular houses are increasingly popular in Japan due to their efficiency, speed of construction and potential for seismic resistance. Prefabricated and modular houses have engineered designs, lightweight materials and seismic retrofitting options.

Figure 15 Example of modular construction, MUJI Hut, Japan

Figure 14 Example of Modular Construction

iv. China

China's topography is incredibly diverse, encompassing mountains, plateaus, plains, deserts and coastlines. China's unique topography and climatic circumstances make it susceptible to a wide range of natural risks and calamities. China is seismically active, with frequent earthquakes occurring in various regions, particularly in the western and southwestern parts of the country. China experiences flooding, typhoons, droughts and landslides. The factors opted for resilient construction are as following:

- **Dougong:** The "dougong" system is made from several precisely measured interlocking beams that, when crushed by the weight of the massive timber roofs of the buildings, allow the structures to be both flexible and robust enough to resist earthquakes. There is no glue or nails used in fitting the parts together. The craftsmanship and accuracy required to create each wooden component is astounding. Because there are many sections in the design, the weight is distributed, preventing individual components from breaking or splitting. Buildings that make use of this technology have their pillars rest lightly on the ground rather than being buried deeply below the surface on a foundation.

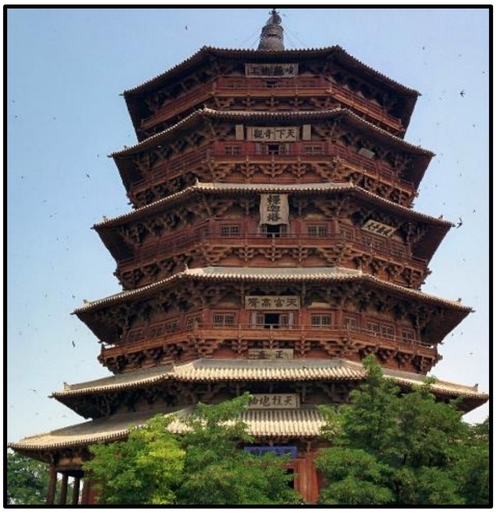


Figure 16 Yingxian County Wooden Pagoda in Suzhou, China

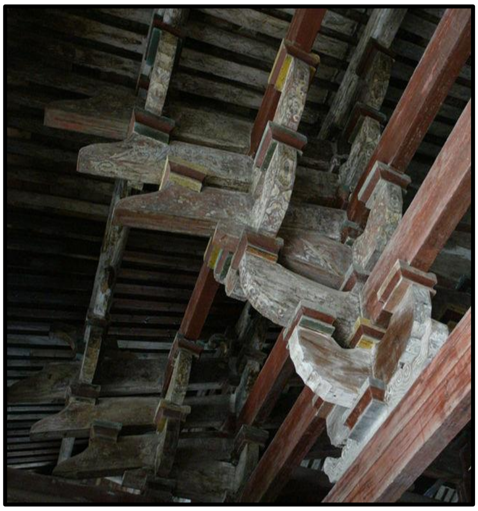


Figure 18 Example of Dougong Connection

- **Wooden Reinforced Stone Structures:** In the mountainous regions of China, particularly in areas such as Tibet, Yunnan and Sichuan. Wooden construction combined with stone is abundantly utilized in building infrastructure. This architectural approach is deeply rooted in traditional building practices and continues to be favored for its suitability to the local environment and its resilience against seismic activity, which is prevalent in earthquake-prone regions. Wood has natural insulating properties, helping to regulate indoor temperatures and improve energy efficiency. In combination with stone, which has high thermal mass, these buildings maintain comfortable interior climates year-round, reducing the need for artificial heating and cooling systems.

Figure 17 Example of Wooden Reinforced Stone Construction in China

- **Prefabricated Construction:** In the mountainous regions of China, prefabricated construction has emerged as a cornerstone of modern building practices, offering a host of advantages tailored to the unique geographical and seismic challenges. Prefabricated components are engineered with advanced seismic-resistant design principles.

Figure 19 Example of Prefabricated housing units in China

b. Zone B (Plains)

i. Japan

Japan, renowned for its technological advancements and densely populated urban centers, faces significant challenges in mitigating urban flooding due to its geographical characteristics and susceptibility to extreme weather events. The country's topography, characterized by steep terrain and narrow valleys, exacerbates the risk of flash floods and riverine inundation, particularly during the rainy season and typhoon seasons. Moreover, rapid urbanization and extensive infrastructure development in low-lying coastal areas have further heightened vulnerability to flooding.

- **Urban Floods**

Figure 20 Underground Discharge Channel (G-Cans)

Underground Reservoirs: Underground flood channels in Japan serve as vital infrastructure for mitigating flood risks in densely populated urban areas. These channels efficiently utilize limited space, minimizing disruption to surface infrastructure while enhancing safety by diverting excess water away from populated areas. By integrating these channels into urban planning and maintaining them regularly, Japan ensures sustainable flood management over the long term.

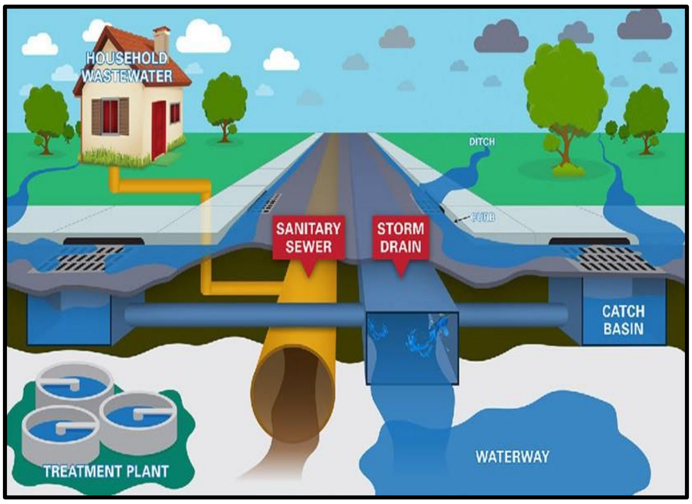


Figure 21 Efficient Stormwater Drainage System

Improved Drainage System: Improved drainage systems in Japan are critical for mitigating flood risks by efficiently removing excess water during heavy rainfall and typhoon events. These systems protect essential infrastructure, such as roads and railways, reducing disruptions to transportation networks and vital services. By minimizing water ingress into buildings, they also mitigate property damage and ensure public safety, reducing the potential for accidents and loss of life. Furthermore, effective drainage contributes to environmental protection by preventing soil erosion, sedimentation and runoff contamination. Integrated into long-term urban planning, these systems enhance resilience to future flood events, reflecting Japan's commitment to proactive flood risk management.

- **Flash Floods**

Early Warning System: Early warning systems for flash floods are of paramount importance in Japan due to the country's susceptibility to sudden and intense rainfall, especially during typhoon seasons. These systems provide timely alerts to at-risk communities, allowing for swift evacuation and proactive measures to minimize loss of life and property damage. By leveraging advanced meteorological technologies and real-time data monitoring, Japan's early warning systems enhance preparedness and resilience, enabling authorities to coordinate emergency responses effectively to safer areas before flash floods occur.

Gabion Walls: Gabion walls play a crucial role in mitigating flash floods in Japan by providing effective erosion control and sediment management along riverbanks and steep terrain. These wire mesh cages filled with rocks or other materials help stabilize slopes, reducing the risk of landslides and debris flow during heavy rainfall events.

By preventing soil erosion and channeling excess water away from vulnerable areas, gabion walls help protect infrastructure, communities and agricultural land from the destructive impacts of flash floods. Their versatility and cost-effectiveness make them an integral component of Japan's comprehensive approach to flood risk reduction and disaster resilience.

Figure 22 Riverbank Protection Works for Vennar River

Figure 23 Example of soil erosion due to flow of water

Figure 25 Kurobe Dam Japan

Figure 24 The side of a levee in Sacramento, California

- **Riverine Floods:** Irrigation channels in Japan serve a dual purpose in mitigating riverine floods by managing water flow and supporting agriculture. These channels, often integrated into Japan's intricate network of water management systems, help regulate river levels during periods of heavy rainfall or snowmelt, reducing the risk of overflow and subsequent flooding in downstream areas. Additionally, by diverting excess water to fields for irrigation, they contribute to soil moisture management and groundwater recharge, mitigating the impacts of drought while supporting sustainable agriculture practices. Thus, irrigation channels play a vital role in Japan's holistic approach to riverine flood mitigation, balancing flood control with agricultural water management for enhanced resilience and food security.

ii. United States of America (USA)

In the USA, urban flooding is a growing concern due to a mix of natural factors such as old infrastructure and urban growth. Different regions face different flood risks, from coastal cities dealing with rising sea levels to inland areas prone to flash floods from heavy rains. As cities expand, more paved surfaces lead to increased runoff and strain on drainage systems, making flooding worse.

- **Urban Floods**

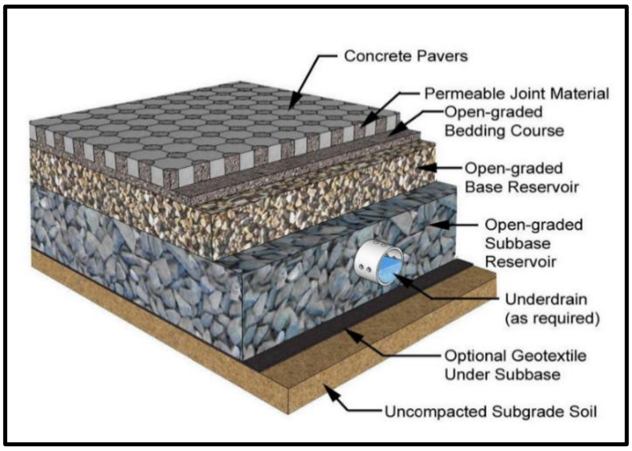


Figure 26 Profile of a typical permeable pavement

Permeable Pavements: Permeable pavement is significant in urban flood mitigation in the USA due to its ability to reduce surface runoff and alleviate pressure on stormwater drainage systems. By allowing rainwater to infiltrate through the pavement surface and into the underlying soil, permeable pavement helps to recharge groundwater, mitigate flooding and prevent pollutants from entering water bodies. In urban areas where impervious surfaces dominate, such as roads, parking lots and sidewalks, the widespread adoption of permeable pavement offers a sustainable solution to manage stormwater effectively, mitigate urban flooding and improve overall water quality, contributing to resilient and environmentally friendly urban infrastructure.

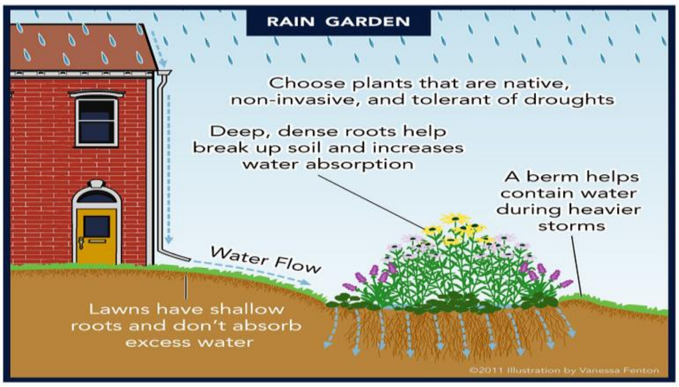


Figure 27 Components of Rain Garden

Rain Garden: Rain gardens are vital for urban flood mitigation in the USA, capturing, filtering, and absorbing stormwater runoff, thereby reducing localized flooding risks. These specially designed landscaping features are strategically placed in urban areas to collect rainwater from impervious surfaces like rooftops and driveways, allowing it to slowly infiltrate into the soil rather than flowing directly into storm drains. By promoting groundwater recharge, reducing peak flows and removing pollutants, rain gardens help alleviate strain on stormwater management systems, enhance flood resilience and improve water quality in urban environments, making them a valuable tool in sustainable urban flood mitigation strategies.

- **Flash Floods**

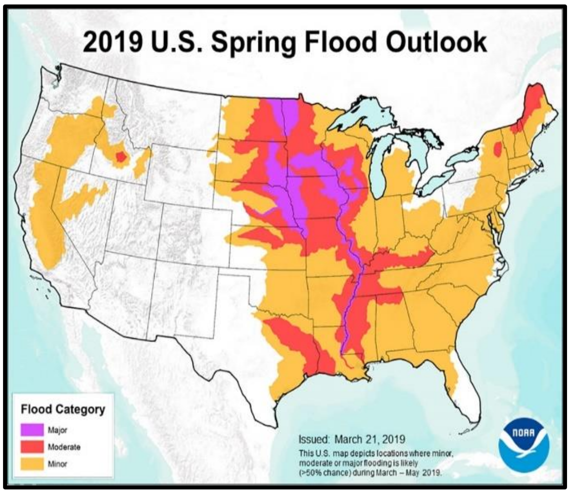


Figure 28 Flood Plain Map of USA

Floodplains Maps: Floodplain maps are instrumental in flash flood mitigation efforts in the USA by providing vital information on areas prone to inundation during intense rainfall events. These maps, developed through comprehensive hydrological analysis and historical flood data, identify flood-prone zones, delineate floodplains, and assess flood risk levels. By enabling policymakers, urban planners and residents to understand and anticipate flood hazards, floodplain maps support informed decision-making regarding land use, development and emergency preparedness measures. This proactive approach to flash flood mitigation helps minimize property damage, safeguard lives, and enhance community resilience to sudden and unpredictable flood events, making floodplain maps an essential tool in mitigating the impacts of flash floods across the USA.

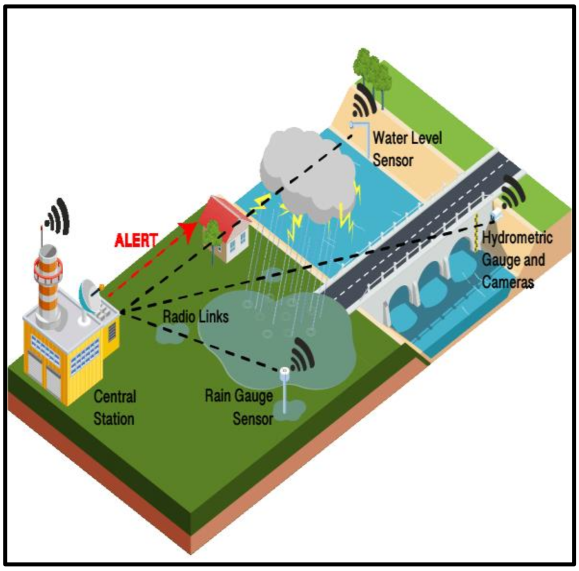


Figure 29 Example of Early Warning System

Early Warning Systems: Early warning systems are critical for flash flood mitigation in the USA as they provide timely alerts and actionable information to at-risk communities, emergency responders and authorities. By leveraging advanced meteorological technologies, real-time data monitoring and communication networks, these systems can detect and forecast flash flood events with high accuracy, allowing for rapid dissemination of warnings via various channels such as mobile alerts, sirens and media outlets. This proactive approach enables individuals to take preventive measures, such as evacuating to higher ground or securing property, minimizing the potential for loss of life and property damage. Early warning systems enhance preparedness, response and resilience to flash floods, making them a crucial component of disaster risk reduction efforts across the USA.

- **Riverine Floods**

Figure 30 A detention basin in Sterling, Virginia, United States

Detention Basin: Detention basins temporarily store excess stormwater runoff. It helps in recharging groundwater aquifer. It helps to Improve water quality and causes pollutants to settle out before they enter rivers & lakes.

Figure31 Flood wall

Flood Walls: A flood wall is a physical barrier to prevent floodwaters from reaching communities. It can be effective in supporting development & urbanization in flood-prone regions. These walls can protect infrastructure from inundation.

- **Coastal Floods**

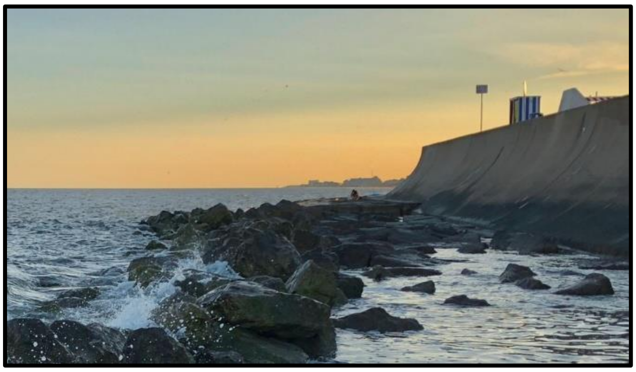


Figure 32 The Galveston Seawall, Texas, US

Galveston Seawall: It is a strong barrier to protect communities from storm surges and high tides. It prevents flooding and protects critical infrastructure i.e., ports and tourist attractions from inundation.

Figure 33 Dune Vegetation

Dune's Vegetation: Dune vegetation helps in preventing erosion and sand replenishment. It is quite effective for conservation of marsh areas. Furthermore, it provides habitat for wildlife & supports biodiversity.

iii. Australia

Australia faces urban flooding challenges due to its geography, climate and urban growth. From flash floods in cities to coastal storm surges, the country deals with diverse flood risks. Rapid urbanization and climate change make flooding worse, especially in low-lying areas with poor drainage.

- **Urban Floods**

Figure 34 Permeable Surfaces Australia

Permeable Pavements: The use of permeable pavements allows rainwater to soak into the ground and thus helps in recharging ground water supplies. They are also helpful in the mitigation of the urban heat island effect.

Green Roofs: Green roofs Reduce stormwater runoff by up to 65%. Such a structure delays stormwater runoff for up to three hours. They Add beauty and value to the building and helps in the mitigation of Urban Heat Island effect.

Figure 35 Green Roofing System, Australia

- **Flash Floods**

Figure 36 Flood Gauges in Australia

Flood Gauges: Flood gauges measure water levels in rivers and streams. They help in understanding flood risk in different areas and ensure effective flood management and infrastructure planning.

Land Use Planning: Land use planning helps to prevent construction in high-risk flood zones. It helps Reduce the economic & social costs of flood disasters and ensures that critical infrastructure lies in safer areas.

- **Riverine Floods**

Figure 37 Levee Built as an embankment along the river course

Levee: Levees are built along the river course. They help to contain flooding water from spreading in the built-up area and prevent critical infrastructure such as roads from being eroded during floods.

Detention Basin: Detention basins temporarily store excess stormwater runoff and help in recharging underground aquifers. They also Improve water quality and allow pollutants to settle out before they enter rivers & lakes. Detention basins can effectively help to restore levels of water table in areas with water scarcity.

Figure 38 A detention basin in Western Sydney, Australia

- **Coastal Floods**

Figure 39 Coastal vegetation

Coastal Vegetation: Coastal vegetation acts as Natural barrier against storm surges and high tides. They are also an environmentally friendly practice and improve biodiversity along the coast.

Dune's Stabilization: Sand dunes act as natural barriers against the erosive forces of wind and water, providing crucial protection to coastal communities, ecosystems, and infrastructure.

Figure 40 Coastal Sand Dunes near Streaky Bay, SA

iv. Cambodia

In Cambodia, urban flooding is a significant problem due to rapid urbanization, inadequate infrastructure, and heavy seasonal rains. Cities like Phnom Penh are especially vulnerable because of flat terrain, poor drainage and settlements in flood-prone areas. Climate change adds to the risk with more intense rainfall and rising sea levels, especially along the coast.

- **Elevated Construction using locally available material:**

Figure 41 Example of elevated houses

- ➤ Structures are elevated above flood levels to minimize flood damage.
- ➤ Utilization of locally sourced materials like bamboo, wood and palm leaves.
- ➤ Availability and affordability of local materials enhance sustainability and affordability.
- ➤ It empowers communities to build their own flood-resistant structures using local materials.

Figure 42 Water management through Barrage

- **Rehabilitation and Improvement of Irrigation / Water Management System:** Cambodia's barrage systems are crucial for flood mitigation by effectively managing water resources and reducing the impact of heavy rainfall. Upgraded barrage infrastructure regulates water levels in rivers and canals, decreasing the likelihood of flooding in surrounding areas.

v. Philippines

In the Philippines, urban flooding is a big problem due to natural factors, fast urban growth and poor infrastructure. With many coastal cities and a tropical climate, the country faces frequent typhoons, heavy rains, and flooding. Rapid population growth has led to more informal settlements in flood-prone areas, making the situation worse.

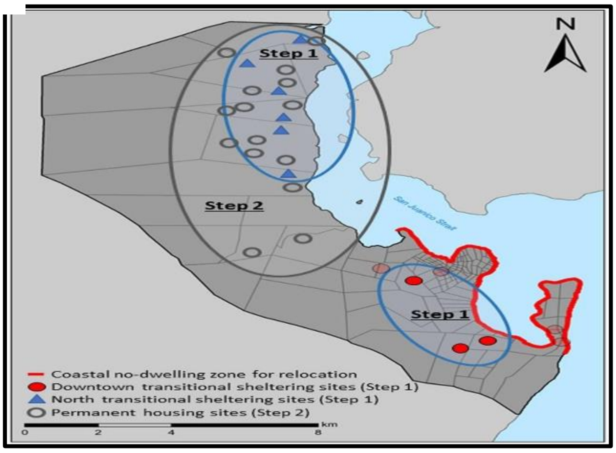


Figure 43 Resettlement post 2013 Typhoon, Philippines

- **Re settlement in less vulnerable areas:** This involves relocating communities from flood-prone areas to safer locations. By moving people away from high-risk zones, the impact of floods on human lives and property damage can be significantly reduced.
- **Construction of Revetments & Embankments:** Revetments are structures built along riverbanks or shorelines to prevent erosion and protect against flooding. Embankments are raised banks or barriers constructed along rivers or coastlines to contain floodwaters and prevent them from inundating surrounding areas. These structures help to control the flow of water and minimize flood damage to nearby settlements and infrastructure.

Figure 44 Example of sea dike and embankment

- **Construction of Raised Critical Roads:** Building critical roads at higher elevations or constructing raised roadways can help ensure essential transportation routes remain accessible during floods. Elevated roads are less prone to flooding, allowing for continued mobility and access to vital services such as emergency response, healthcare and supplies, even in times of severe flooding.
- **Extensive construction of Irrigation and Water Control Structures:** The extensive construction of irrigation and water control structures involves the implementation of a network of infrastructure aimed at managing water resources efficiently, especially during periods of heavy rainfall and flooding. This includes the development of irrigation systems to ensure agricultural fields receive adequate water for crop growth, as well as the construction of water control structures such as dams, reservoirs, channels, and canals to regulate water flow, store excess water, and release it gradually to mitigate the risk of downstream flooding. Additionally, flood control channels may be established to divert

Figure 45 Example of Dam Philippines

excess water away from populated areas and critical infrastructure, thus reducing the impact of floods on communities and preventing property damage.

vi. Bangladesh

Bangladesh deals with urban flooding due to natural factors, fast city growth, and poor infrastructure. The country's low-lying terrain and exposure to cyclones and heavy rains make cities like Dhaka and Chittagong prone to floods. More people moving to cities have led to informal settlements in flood-prone areas, making the problem worse. Drainage systems are often insufficient, and there's not enough done to manage floods. Climate change adds to the risk with rising sea levels and heavier rains.

- **Elevated Construction:** Building houses on raised platforms or stilts helps protect them from floodwaters, ensuring that homes remain habitable even during severe flooding. This approach minimizes damage to property and provides safer living conditions for residents.

Figure 46 Example of elevated house

- **Emergency Shelters:** Constructing emergency shelters on elevated platforms or sturdy structures ensures that they remain accessible and functional during floods, providing safe refuge for communities in times of crisis. Elevated shelters serve as crucial evacuation centers, offering temporary shelter and basic amenities to displaced individuals.

Figure 47 Elevated shelter at Rayenda union of Bagerhat district

- **Clustered Plinth:** This technique clusters buildings on raised platforms or plinths in flood-prone areas, keeping communities interconnected while minimizing flood damage to infrastructure and properties.

Figure 48 Example of Cluster Plinth in Bangladesh

- **Raising level of critical road network to make it more resilient:** Elevating critical road networks makes them more resilient to flooding, ensuring continuity of transportation routes and access to essential services during periods of inundation. Raised roads enable emergency response teams to reach affected areas swiftly and facilitate the movement of goods and people, contributing to disaster preparedness and recovery efforts.

Figure 49 Example of Raised Roads

c. Zone D (Arid and Coastal)

i. United States of America (USA)

USA faces several natural hazards which prove highly damaging to the structures. Despite these hazards, the region has developed practices which have reduced the vulnerabilities of structures over time thereby reducing the causality rate. For the USA, their coastal hazards include flood and tsunami, cyclones, hurricanes and strong winds, moisture and corrosion impact which reduced the structural integrity. Furthermore, their institutes are trained to work in coordination during a disaster event. One of the leading institutes includes FEMA (Federal Emergency Management Agency). FEMA acts as the disaster management authority where their mission is "Helping people before, during and after disaster".

Under FEMA, they tend to promote infrastructure development against the disaster whereby they have designed construction manual for regions such as the Coastal Construction Manual and Coastal Building Materials. These manuals act as a guideline for the construction on coastal areas of the USA.

The Coastal Construction Manual divides the coastal regions into specific category based on the hazard impacts on the coastal zone. Their prior focus is on the economical use of material and the specific loading of these hazards during the design of building so that they may resist the future disasters impact.

The Coastal Building Material by FEMA provides guidance on the selection of building materials used for coastal construction for home builders. Under this, they state different Flood Resistant Material as follows:

- **Lumber:** This is the most easily accessible material and cost economical material for construction in USA. They suggest using pressure-treated or decay resistant material such as redwood, cedar, oaks or bald cypress.

Figure 50 Elevated Lumber Houses in USA

Figure 51 High Rise Construction

- **Concrete**: One of the strong construction materials, if treated against sulphate and saltwater resistant chemical will help to resist the structure against the coastal moisture attack and will increase the building life.

Figure 52 Masonry Constructions in USA

- **Masonry**: Structure improved with reinforcement and grouting will resist the coastal flooding impact.

Furthermore, in this manual, they state that the wind resistant material should be used during construction of the houses against the strong winds and cyclones impact. It is suggested to take following measures to cater for the strong winds impact:

- Wind resistant glazing.
- Deformed-shank nails for sheathing attachments.
- Reinforced garage doors
- Tie down connectors used throughout structures.
- Wider framing members.

Figure 53 Prefabricated wood I-Joints

Lastly, the building materials should also stand resistant against corrosion and decay. This ranges from metal corrosion, moisture and termite related decay. The following guidelines are the recommendations:

- Galvanized or stainless-steel hardware and the reinforcing steel should be protected from corrosion by sound material such as masonry, mortar, gout and concrete. Epoxy coated reinforcing steel can also help in this situation where there is a potential for corrosion.

Figure 54 Galvanized Steel Structure

- Avoid combination of dissimilar metals. This may lead to reduced structural strength against the hazard impact.
- In case of use of lumber of wood, the use of preservation or steel treatments should not be used with the wood unless it is cleared or suitable for usage or else the reaction of the materials may decay the connections and result in weaker structure joints.
- For moisture resistance the decay material should be treated and in case of decay wood, should be controlled or separated from the structure.
- The concrete should be sound, dense and durable whereby the cracks should be controlled by using the welded wire fabric or reinforcement as suitable based on-site conditions.

Figure 55 Water proofing treatment

- The use of masonry, mortar and grout that conforms with the building codes will help to increase the overall structural strength.
- For termite resistance, the recommendation states the use of anti-termite proofing during the construction face or use of preservative or treated wood in the construction to avoid chances of termite attack in future.
- Use of anti-moisture material in the sub-structure will help to reduce the attack and movement of moisture through the structural foundation to super structure.

The practices being employed for specific coastal flooding is to raise/elevated sub-structure of the building. For this purpose, the following considerations should be taken while constructing structure:

- The selection for the construction should conform with the local planning and development laws for the allowed construction of structures.
- The structure must be elevated to a height above the base flood elevation (BFE) determined by relevant authority. The specific elevation requirements vary depending on the flood zone classification of the area.
- The foundation of the elevated structure is crucial for stability and resilience against flooding. Deep pile foundations or elevated piers are common methods used to elevate the structure above potential floodwaters.
- Flood vents are openings in the walls of the ground structure designed to allow floodwater to flow in and out freely, reducing hydrostatic pressure on the walls and foundation. These vents should be designed to prevent the movement of debris and pests in the substructure.

- Safe access and egress routes must be designed to ensure occupants can safely enter and exit the structure during a flood event. This may involve designing elevated walkways or stairs that remain above floodwaters.

For Wind resistant structure, the following steps are taken for construction:

- The design Engineer should analyze wind speeds and directions specific to the coastal location to determine the expected wind loads on the structure. This will impact the type of material required for the structure, the building design/shape and the reinforcement required to withstand the high winds pressure.

- Structures in coastal areas are required to be constructed using impact-resistant materials such as reinforced concrete, structural steel, and impact-resistant glass to minimize damage from wind-borne debris during hurricanes or cyclones.

- The roof is a critical component of wind-resistant construction. Hip roofs, which slope on all sides, are preferred over gable roofs, which are more susceptible to wind uplift. Roofing materials should be chosen for their ability to resist wind damage, such as metal roofing or asphalt shingles designed to withstand high winds.

- Proper anchorage and connection of building components are essential to prevent structural failure during high winds. This includes securely fastening roof trusses, walls, and other structural elements to the foundation and each other using hurricane straps, tie-downs, and other reinforcement methods.

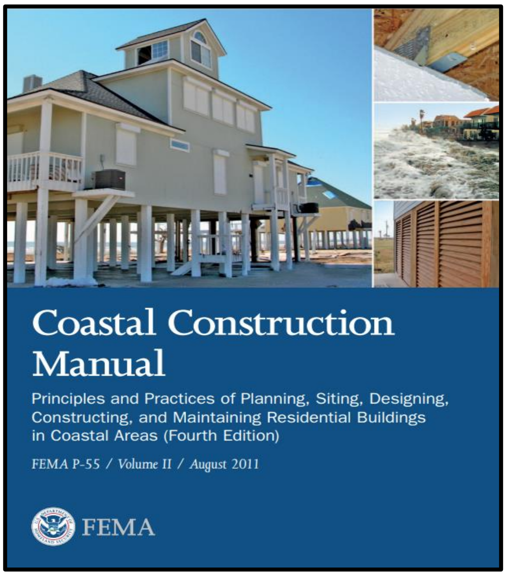


Figure 56 Coastal Construction Manual by FEMA, USA

The Coastal Construction Manual by FEMA aims to provide principles and practices of planning, siting, designing, constructing, and maintaining residential buildings in coastal areas. The book 1st Volume focuses on the historical introduction on coastal hazards of the USA Region, identification on the coastal hazards, costal construction guidelines, land use regulations and the fundamentals for risk analysis and risk reduction. The 2nd Volume focuses on how to improve the structural strength for coastal building such as the site-specific load calculation, building foundation, sub structure and super structure construction, and how to improve the strength of the existing buildings such as methods for retrofitting’s.

The manual is the site-specific manual whereby these manuals have been converted for home builders and assist them in the disaster resilient construction. This book can act as a guideline for Pakistan institution to have disaster resilient construction manuals that can be distributed among the relevant authorities.

ii. Japan

Like USA, Japan is a highly hazardous area against natural hazard where there is a long history of Earthquake and Tsunami. This has resulted in dynamic change in construction field in Japan. With the advancement of technology, the people in this region have shifted their approach from disaster mitigation to disaster preparedness and from vulnerability reduction to hazard impact reduction.

Japan has constructed massive disaster preventive structures such as seawalls and flood channels to reduce the impact of hazard and the enforcement of building codes with improve techniques against the disasters has resulted in disaster resilient structures. Furthermore, they have taken the compact city approach whereby they have constructed densely packed disaster resilient structures in the urban and low risk areas thereby diverting the population from the risk prone areas. The following approach is adopted to reduce disaster risk:

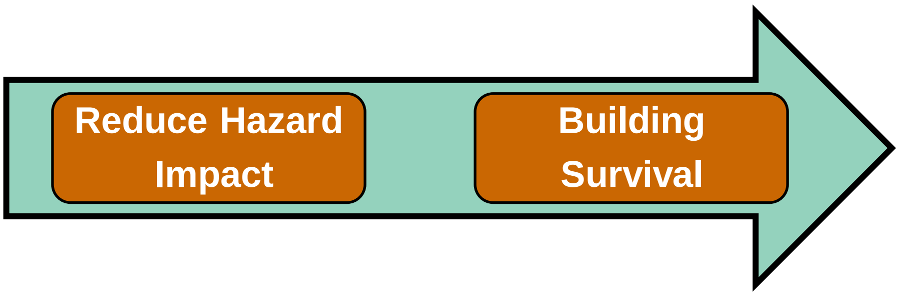


Figure 57 Flow path for reducing disaster risk

- **Breakwater:**
  Breakwaters serve as coastal defense structures designed to mitigate the impact of waves, storm surges, tsunamis, and flooding on coastal communities and infrastructure. They are typically constructed offshore or along the shoreline and serve several purposes in reducing the effects of natural hazards:

Figure 58 Tsukenjima Breakwater Lighthouse, Japan

➢ These breakwaters are constructed to dissipate the energy of incoming waves such as that of Tsunami. By breaking up the wave action, breakwaters reduce the height and force of waves before they reach the shoreline. These provide some level of protection for the shoreline.

- Breakwaters also help to reduce intensity of storm surges, which are elevated water levels generated by strong winds associated with tropical storms, hurricanes, and cyclones.
- Breakwaters play a role in controlling coastal erosion by reducing the impact of wave action on the shoreline. By breaking up waves and creating calmer water conditions behind the structure, breakwaters help prevent the erosion of beaches, cliffs, and dunes, thereby preserving valuable coastal habitats and recreational areas.
- In addition to their protective functions, breakwaters also serve as navigation aids for boats and ships entering and exiting harbors and ports.

- **Seawalls:** Seawalls are also coastal defense structures designed to protect coastal areas. Primarily, they serve as a physical barrier between the sea and coastal infrastructure, thereby reducing the impact of coastal hazards.

Figure 59 Shizuoka Prefecture-A massive Seawall to prevent flooding

- Seawalls are constructed parallel to the shoreline and are designed to absorb and dissipate the energy of incoming waves. When waves strike the seawall, their energy is partially reflected into the sea and partially dissipated as turbulence.
- Like breakwater, these structures also act as a barrier against the advance of storm surges, seawalls help prevent coastal inundation and flooding, thereby protecting coastal communities and infrastructure.
- Seawalls also help to reduce the height and speed of tsunami waves as they approach the shoreline.

- **Sea Dike:** Another technique being implemented in Japan for Tsunami counter measure is the construction of the Sea Dike. Sea dikes, also known as coastal dikes or embankments, are coastal defense structures like seawalls but typically broader and flatter:

- Sea dikes act as barriers to prevent seawater from flooding coastal areas during high tides, storm surges, and other flood events.
- Sea Dikes cannot protect from tsunami waves like Breakwater or sea wall structures, but they can provide some level of protection by absorbing and dispersing the energy of tsunami waves.
- By providing a broad and flat barrier, sea dikes help protect beaches, marshes, and other coastal habitats from erosion.

Figure 60 Sendau Airport Japan Sea Dike

- Sea dikes can be designed with drainage systems to manage excess water and prevent waterlogging behind the dike.

- **Evacuation Buildings:** Evacuation Building is another technique being used in Japan for tsunami risk zones:

- In the event of a tsunami, there is a short window of time for coastal residents to evacuate to higher ground. Evacuation buildings provide nearby, elevated refuge for those unable to evacuate quickly.
- Evacuation buildings are designed to withstand the impact of tsunamis and provide safe refuge on upper floors above potential flood levels.

Figure 61 SAGA AREA Tsunami Evacuation Tower

- In some coastal communities where horizontal evacuation routes may be limited, vertical evacuation structures such as multi-story buildings provide a viable alternative.
- Evacuation buildings are particularly important for protecting vulnerable populations, such as the elderly, disabled, and those with mobility limitations. These individuals may have difficulty evacuating quickly or traveling long distances to reach higher ground.

- **Flood Channels:** Japan also constructed flood channels in coastal areas primarily, to mitigate the risks associated with coastal flooding and storm surges.

➤ Flood channels in coastal areas help manage storm surges by providing a controlled pathway for floodwaters to flow away from populated areas and infrastructure, reducing the risk of inundation and damage.

➤ Flood channels are also constructed to help mitigate the impacts of tsunamis by providing a means of diverting tsunami waves away from populated areas and into designated flood-prone areas where the damage is minimized.

Figure 62 Underground Discharge Channel Tokyo, Japan

➤ Heavy rainfall, particularly during the typhoon season, which lead to surface runoff and flooding in coastal areas, the flood channels help by providing a controlled pathway for rainwater to drain into larger water bodies, such as rivers or the ocean, where it can be safely discharged without causing flooding in urban areas.

➤ They also help to protect coastal infrastructure by diverting floodwaters away from critical infrastructure corridors, minimizing disruptions to transportation networks and essential services during flooding events.

➤ Constructing flood channels in coastal areas enhances public safety and resilience by reducing the risk of coastal flooding and storm damage.

Figure 63 Underground connecting tunnel for flow channel, Tokyo Japan

iii. Bangladesh:

Bangladesh has a long-standing history of natural hazards including frequent tropical cyclones, tsunami and earthquakes. However, in the last two decades, the region of Bangladesh has diverted its massive resources in making the structures disaster resilient to withstand the harsh impacts of hazards. They have adopted methods to utilize locally available materials and making cost economical structures. For this purpose, the following techniques were adopted against coastal flooding:

- **Coastal Embankment Project:** The Coastal Embankment Improvement Project (CEIP) in Bangladesh is a large-scale initiative aimed at enhancing the resilience of coastal embankments to protect against tidal flooding, storm surges, and sea level rise in vulnerable coastal areas of the country. The project focuses on strengthening and improving the existing coastal embankments, which are earthen structures built along the coastline to protect inland areas from inundation by tidal waters and storm surges. These embankments also serve as a critical defense against coastal hazards, but they are often in need of maintenance and reinforcement due to erosion, breaches, and other factors.

Figure 64 Coastal Embankment Improvement (Phase-01) of Project

Key components of this project include the following:

- Repairing, raising, and reinforcing existing embankments to improve their structural integrity and resilience to coastal hazards. These include adding riprap or other erosion-resistant materials to the embankment slopes.
- Aims to improve the maintenance and management of coastal embankments to ensure their long-term effectiveness in protecting coastal communities and infrastructure.
- Community engagement and capacity building to enhance local resilience to coastal hazards through raising awareness about disaster preparedness and response, training community members in emergency evacuation procedures, and promoting community-based approaches to embankment management and maintenance.

- Lastly, the project integrates climate risk assessment into project designs to produce economical and disaster resilient structure.

- **Multi-Purpose Disaster Shelter Project:** The Multi-Purpose Disaster Shelter Project in Bangladesh is an initiative aimed at constructing and operating multi-purpose shelters in vulnerable coastal areas to provide safe refuge for communities during natural disasters, particularly cyclones and floods.
  Key features and objectives of the Multi-Purpose Disaster Shelter Project include:

- The construction of multi-purpose shelters, often elevated and reinforced concrete structures, capable of withstanding the impacts of cyclonic winds, storm surges, and flooding.

Figure 65 Bangladesh Multi-Purpose Cyclone Shelters

- While primarily designed to provide shelter during disasters, these facilities are also intended for multi-purpose use during non-emergency periods. They may serve as community centers, schools, healthcare clinics, or vocational training centers, providing benefits to local communities beyond disaster response.

- Furthermore, Multi-Purpose Disaster Shelters are integrated with early warning systems and disaster management networks to facilitate timely evacuation and response during emergencies. They serve as assembly points for evacuees, where they can receive information, assistance, and support from trained personnel.


Figure 66 Uttar Seral Government School as Shelter in Agulchara, Barishal

- The project involves collaboration and coordination with government agencies, non-governmental organizations (NGOs), and other stakeholders involved in disaster risk reduction and emergency response efforts.


Figure 67 Multipurpose Disaster Shelter in Shatkhira, Bangladesh

2. Need for Skill Development among Local Stakeholders

Skill development is necessary for effective disaster risk reduction. Furthermore, the case of infrastructure skill development of both communities and government entities is necessary.

For this purpose, skill development should always be initiated during the preparedness phase. Adopting such a proactive approach can effectively enhance the skill set of individuals and their response in case of a disaster event. During this phase trainings can be conducted in which knowledge about various infrastructure type, specific hazards, prevalent to the specific area, weakness and strengths of various structural types in case of disaster events and reconstruction techniques using indigenous material can be imparted.

After the occurrence of disaster, material awareness can be given to community, vulnerable groups such as women can be trained in a manner as to contribute to reconstruction efforts.

Government entities should be recommended to use indigenous materials, enhancement of local participation, enforcement of building standards and guidelines and ensuring that newly constructed infrastructure is sustainable. In this manner effective skill development can contribute positively to enhancing infrastructure resilience.

3. Infrastructure Disaster Management Audit

An infrastructure audit for disaster management involves assessing the resilience of critical infrastructure to various types of disasters. The framework for conducting such an audit is as follows:

a. **Identify Critical Infrastructure**: Determine which infrastructure assets are critical for disaster response and recovery. This may include transportation networks, utilities (water, electricity, gas), healthcare facilities, communication systems, and emergency shelters. These will help to identify critical infrastructure during an early warning system which can then be communicated to relevant authorities.

b. **Assess Vulnerabilities**: Identify potential hazards and vulnerabilities that could affect each infrastructure asset. This will require to consider the natural disasters such as earthquakes, hurricanes, floods, wildfires, and man-made hazards like cyberattacks or terrorism. Furthermore, the Infrastructure disaster management audit will cover the country primarily on district and tehsil level which can later be expanded to spatial distribution of structures.

   The database will be developed for different types of buildings based on material composition such as RCC Structures, Brick masonry structures, Stone masonry structures, Timber/Wood, and Adobe/Mud Structures. Identification of type of structure can help to model the type of structural damage behavior against specific hazard. This can help to identify structurally vulnerable areas and to divert the conventional trends towards disaster resilient structures.

c. **Evaluate Risk Exposure**: Determine the likelihood and potential impact of each hazard on the identified infrastructure assets. This involves analyzing historical data, modelling scenarios, and considering future climate change projections. Under this scope, the structural vulnerability data will be combined with the hazard information to identify the disaster risk zone and help in assessing how to reduce the disaster risk in the risk prone areas.

d. **Review Design Standards and Regulations**: Assess whether existing infrastructure meets relevant building codes, standards, and regulations for disaster resilience. Identify any gaps or deficiencies that need to be addressed. This will help to shift the construction trends for resilient structures to withstand the specific disaster in those areas.

e. **Conduct Structural Assessments**: Evaluate the structural integrity of buildings, bridges, dams, and other infrastructure assets. During the structural assessment the factors that are to be considered are age, material quality, and seismic retrofitting. These factors are helpful in identifying whether the structure may withstand the disaster impact or in case of any improvement required to improve structural resilience.

f. **Assess Redundancy and Interdependencies**: In this step the redundancy and interdependencies within the infrastructure network are identified. Identification of the critical nodes and connections that could disrupt the entire system if damaged are required. All these processes contribute towards disaster preparedness.

g. **Review Emergency Plans and Protocols**: This requires examining existing emergency response plans and protocols for each infrastructure asset. Assessing their effectiveness in mitigating disaster risks and coordinating response efforts can greatly enhance disaster preparedness.

h. **Identify Mitigation Measures**: Recommend specific mitigation measures to enhance the resilience of critical infrastructure. This may include structural upgrades, improved maintenance practices, land-use planning, and investment in backup systems.

i. **Prioritize Investments**: Prioritize infrastructure investments based on the severity of risks, cost-effectiveness of mitigation measures, and potential impact on public safety and economic stability.

j. **Promote Collaboration and Coordination**: Foster collaboration among stakeholders involved in infrastructure management, disaster response, and community resilience. It is highly important that information sharing, and coordination mechanisms are in place to facilitate effective response and recovery efforts.

k. **Monitor and Update**: Establish mechanisms for ongoing monitoring and evaluation of infrastructure resilience. Furthermore, the regular updating of the audit findings and recommendations based on new data, emerging risks, and lessons learned from past disasters will help to improve the district infrastructural resilience over time.

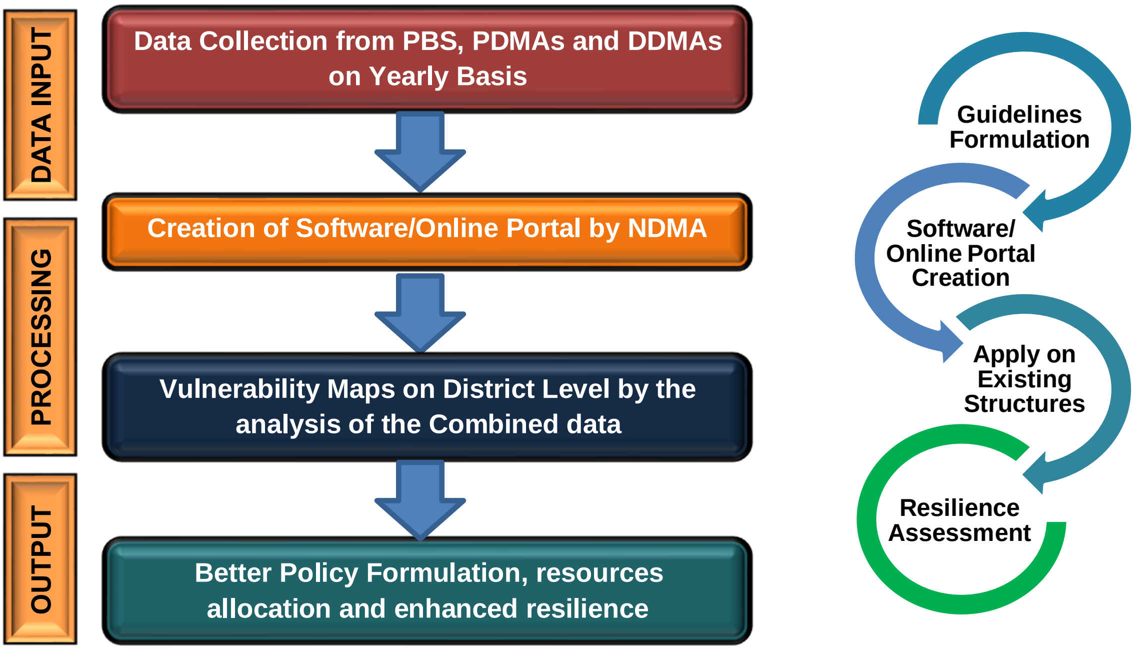


Figure 68 Framework for the establishment of Infrastructure Audit

Following the above stated measures, the IA&PD proceeds to develop the infrastructure audit system as per following pattern:

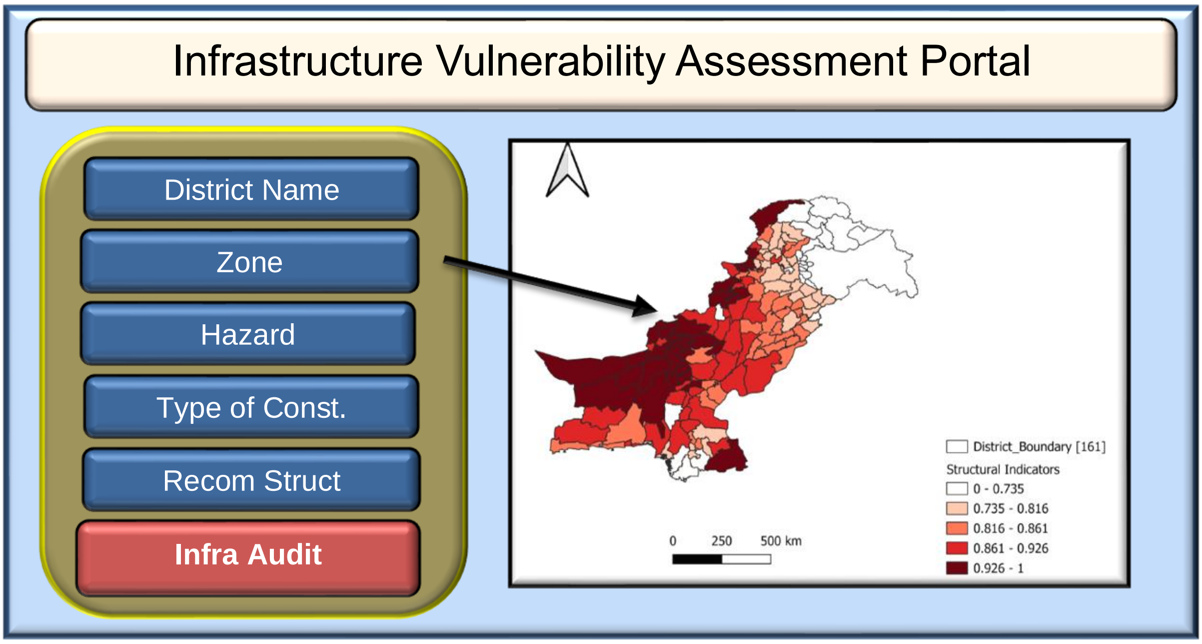


Figure 69 Infrastructure Vulnerability Assessment Portal for Infrastructure Audit

4. Advisory Target Audience

a. Provincial Disaster Management Authority (PDMAs)

The importance of Provincial Disaster Management Authorities (PDMAs) in disaster management in Pakistan cannot be overstated. They are responsible for coordinating disaster management efforts at the provincial level, allowing for a more localized and tailored response to specific hazards and vulnerabilities. They play a key role in disaster preparedness, early warning, and response activities and ensure a timely and effective response to disasters, minimizing loss of life and property damage.

PDMAs mobilize and allocate resources, including personnel, equipment, and funding, to support disaster management activities within their respective provinces. They coordinate with national disaster management authorities, international organizations, and donors to secure assistance and support for emergency response and recovery operations.

Overall, PDMAs play a critical role in enhancing the resilience of communities and reducing the impact of disasters in Pakistan. By strengthening disaster management capabilities at the provincial level, they contribute to the overall safety, security, and well-being of the population and support sustainable development efforts in the country.

Figure 70 PDMAs in Pakistan

b. Housing ministries

Housing ministries play a significant role in disaster management. They are responsible for urban planning, building regulations, and construction standards. By enforcing and updating building codes that incorporate disaster-resilient design principles, housing ministries can ensure that new infrastructure and housing developments are better able to withstand the impacts of disasters such as earthquakes, hurricanes, and floods. They oversee the development and maintenance of housing infrastructure, including public housing, residential buildings, and informal settlements.

Figure 71 Logo of Ministry of Housing and Works Pakistan

By integrating disaster risk reduction measures into housing projects, such as strengthening structures, improving drainage systems, and relocating vulnerable communities, housing ministries can reduce the risk of casualties and damage during disasters. During disasters, housing ministries play a critical role in providing emergency shelter to displaced populations. They may coordinate with other government agencies, humanitarian organizations, and community groups to set up temporary shelters in safe locations, distribute relief supplies, and ensure access to basic amenities such as water, sanitation, and healthcare.

Figure 72 Logo of Pakistan Public Works Departments, PWD

They have a leading role in efforts to facilitate the recovery and reconstruction of housing infrastructure in the aftermath of disasters. This may involve assessing damage, providing financial assistance or incentives for repairs and rebuilding, and implementing measures to prevent future vulnerabilities. Housing ministries can support community resilience building initiatives by engaging with residents, local authorities, and stakeholders to raise awareness about disaster risks, promote safer building practices, and encourage community-led initiatives for disaster preparedness and response.

Figure 73 Logo of National Rural Support Program, Pakistan

Overall, housing ministries play a crucial role in disaster management by ensuring the safety, stability, and resilience of housing infrastructure and communities. By integrating disaster risk reduction into housing policies, practices, and investments, they contribute to the overall resilience of societies and help mitigate the impacts of disasters on vulnerable populations.

c. Non-Governmental Organizations

Non-governmental organizations (NGOs) also play a vital role in disaster management before, during, and after emergencies. They often engage in community-based disaster risk reduction activities, such as raising awareness about hazards, conducting vulnerability assessments, and implementing mitigation measures. During disasters, NGOs provide immediate humanitarian assistance to affected populations. They deliver life-saving aid, including food, water, shelter, medical care, and psychosocial support, to those in need.

Figure 74 Logo of Shehri, Pakistan

NGOs often have the flexibility and agility to respond quickly to emergencies, complementing government efforts and filling gaps in service delivery. NGOs play a crucial role in coordinating disaster response efforts among various stakeholders, including government agencies, international organizations, and other NGOs. They participate in coordination mechanisms such as clusters or coordination forums to ensure a coherent and effective response. They also collaborate with local authorities and communities to identify needs, avoid duplication of efforts, and maximize the impact of humanitarian assistance.

NGOs are often involved in managing logistics and supply chains for humanitarian aid delivery. They procure, transport, and distribute relief supplies, shelter materials, and medical supplies to affected areas. They play a key role in providing emergency shelter and support for displaced populations. They may distribute shelter kits, tarpaulins, and other materials to help families construct temporary shelters or repair damaged homes. NGOs also support livelihood recovery efforts by providing cash assistance, vocational training, and income-generating activities to affected communities.

d. United Nation Organizations

United Nations (UN) organizations play a crucial role in disaster management at the global, regional, and national levels. UN organizations provide leadership and coordination in disaster response efforts. They facilitate collaboration among governments, humanitarian agencies, non-governmental organizations (NGOs), and other stakeholders to ensure a coherent and effective response to disasters. They conduct

Figure 75 Logo of OCHA, UN NGO

rapid assessments and analysis of humanitarian needs in disaster-affected areas. They gather data on the impact of disasters, assess the needs of affected populations, and identify priority areas for intervention. This information informs decision-making and resource allocation during the response phase.

UN NGOs deliver life-saving assistance to disaster-affected populations, including food, water, shelter, medical care, and other essential services. They deploy emergency response teams, establish temporary shelters and health facilities, and provide logistical support to ensure the timely delivery of aid to those in need. They prioritize the protection of human rights and the provision of assistance to vulnerable groups, including women, children, the elderly, and persons with disabilities, during disasters. Furthermore, they work to prevent and respond to gender-based violence, child exploitation, and other protection concerns in humanitarian settings.

Figure 76 United Nation Logo

UN NGOs take initiatives to support governments and local partners in building their capacity to prepare for, respond to, and recover from disasters. They provide technical assistance, training, and guidance on disaster risk reduction, emergency preparedness, and response planning to enhance national and local resilience organizations contribute to long-term recovery and rehabilitation efforts in disaster-affected areas. They support communities in rebuilding infrastructure, restoring livelihoods, and improving access to essential services such as education, healthcare, and water and sanitation. They also promote sustainable development practices that enhance resilience to future disasters.

Overall, UN organizations play a critical role in disaster management by providing leadership, coordination, technical expertise, and humanitarian assistance to address the needs of disaster-affected populations and support efforts to build resilience and sustainable development. Their collective efforts contribute to saving lives, alleviating suffering, and promoting recovery and resilience in the face of disasters.

Figure 77 Logo of United Nation High Commission for

CHAPTER 3

Zone Wise Construction Approach

1. Zone A (High Mountains)

a. Specification for Site Selection

The first recommendation for Site Selection is to avoid such areas that are prone to land sliding as these areas may experience soil liquefication in the event of a seismic activity resultantly leading to collapse of structures.

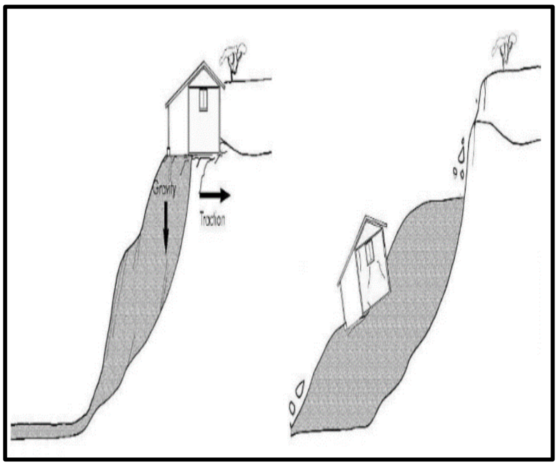


Figure 78 Site Selection to avoid Land Slide - 1

The second recommendation in this regard is avoiding such sites for construction that are located beneath slopes prone to land sliding. In the case of a land sliding or earthquake event structures in such areas are exposed to a high risk due to the falling debris and rocks.

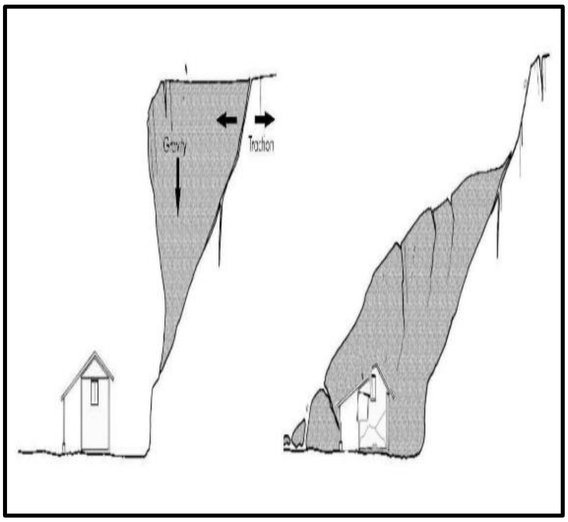


Figure 79 Site Selection to avoid Land Slide - 2

The final recommendation is to avoid low lying sites in flood prone areas. Structures in low lying areas are more exposed to inundation in the case of flood. In case the sites are not available, it is recommended to provide raised platforms for building houses to mitigate the risk of inundation during floods.

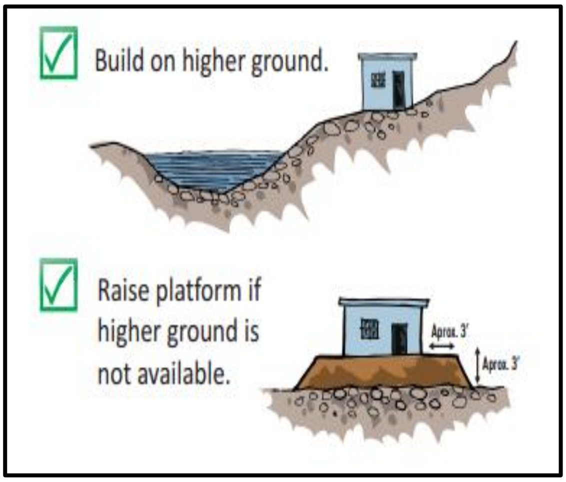


Figure 80 Elevated construction

b. Design Parameters

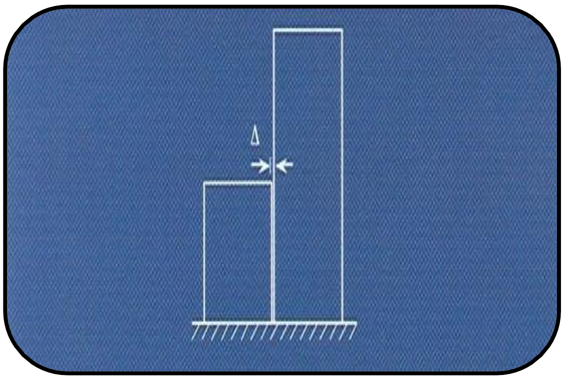


Figure 81 Non-Adjacent Building for Earthquake Prone Area

Adjacent buildings should be separated in order to minimize collateral damage in case of earthquakes. Most of the damage during earthquakes is caused due to the collapse of high-rise buildings on adjacent structures. Due consideration should be given to maintaining an adequate distance between buildings.

Usage of Slab ties help to join all elements and distribute forces in structures. Slab ties tend to enhance the structural unity of various components and increase the structural resilience of structures.

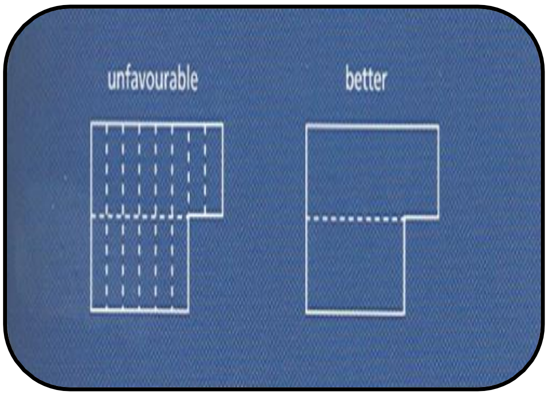


Figure 82 Slab Joints for Earthquake Prone Areas

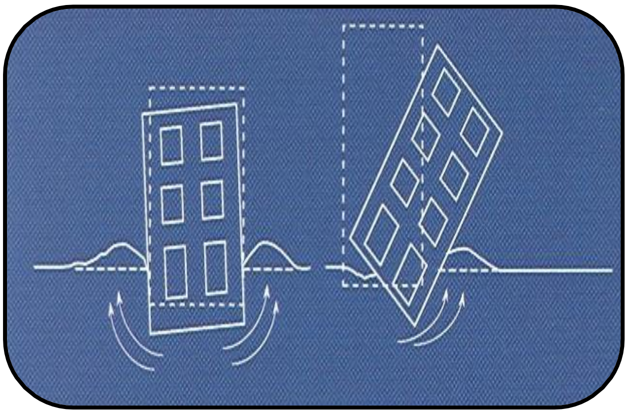


Figure 83 Soil Liquefication impact on the building stability

Soil Liquefication potential and soil bearing capacity should be assessed before construction of a structure. These geotechnical parameters have a major impact on the response of a structures during the occurrence of disasters such as Earthquake and Floods.

Avoid unsymmetrical buildings and promote symmetrical building designs as such designs ensure proper load transfer and reduce the chances of torsion and rotation in the event of earthquakes.

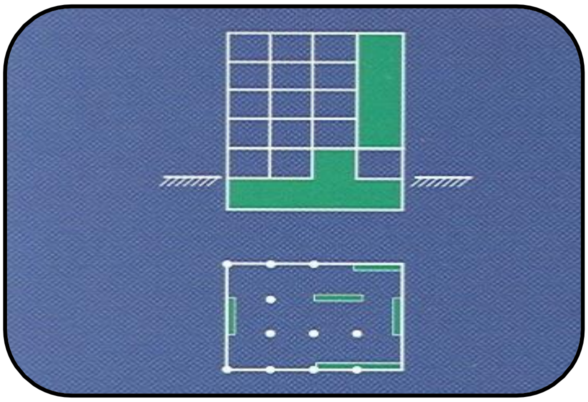


Figure 84 Symmetrical Building Design Blueprint

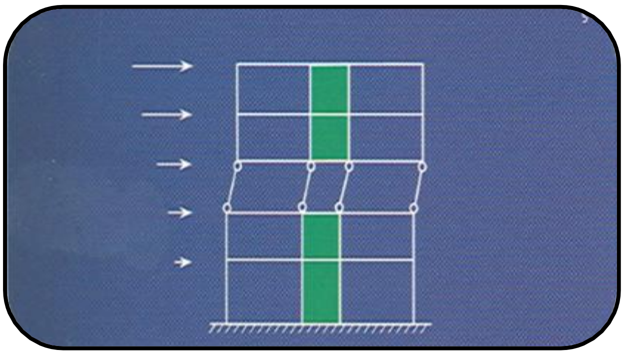


Figure 85 Impact of load on buildings with Soft Stories

Soft Stories should be avoided during design. The weight distribution of a building should be in such a manner that all the floors experience equal movement in case of seismic activity.

Seismic joints should be provided in RCC structures to separate structural components from masonry walls in order to avoid collapse during a seismic event.

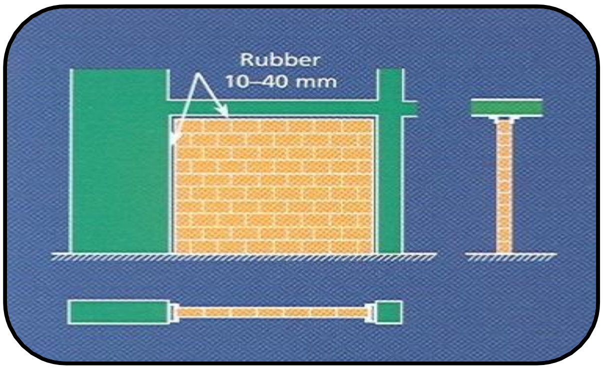


Figure 86 Provision of Seismic joints in RCC Structure

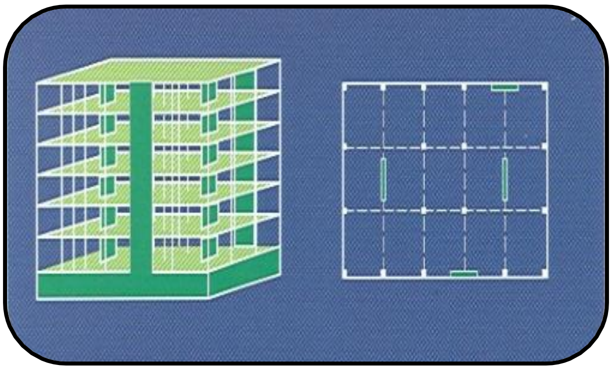


Figure 87 Shear Wall provision in Structures

Shear walls should be provided in buildings to cater Shear in principle Direction during the event of a disaster to increase structural resilience.

Horizontal steel bars should be provided at every 3 feet in masonry to make it discontinuous and to resist horizontal actions during seismic activity.

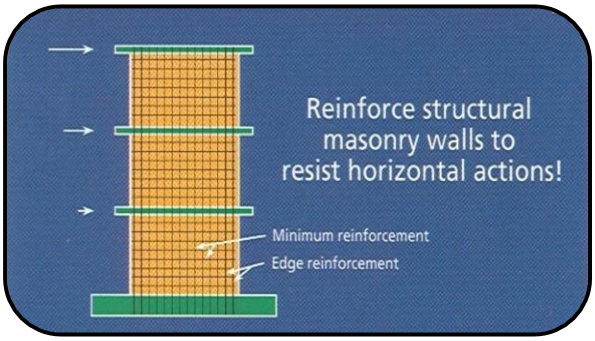


Figure 88 Reinforcement in Masonry Wall

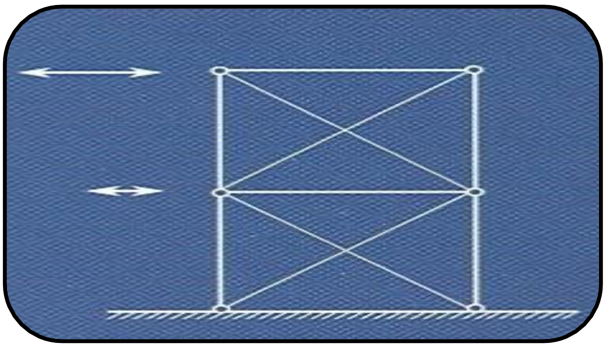


Figure 89 Importance of Diagonal Bracing in EQ Resistant structures

Diagonal Bracing should be provided to unify the various structural components and their response in case of sudden action horizontal forces.

Designs should be ductile allowing relatively free movement as compared to rigid RCC structures, however the joints should be fixed in order to secure the structure against lateral buckling.

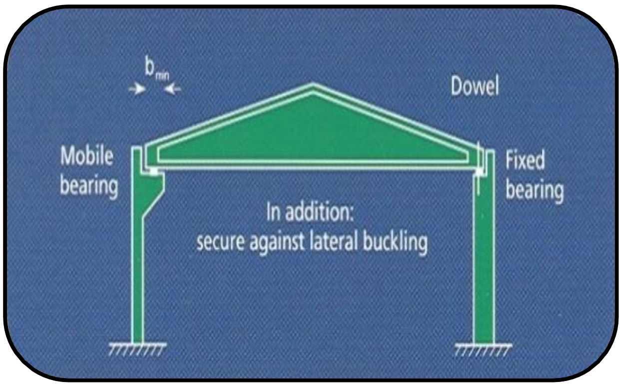


Figure 90 Method to improve structure ductility in EQ Zone

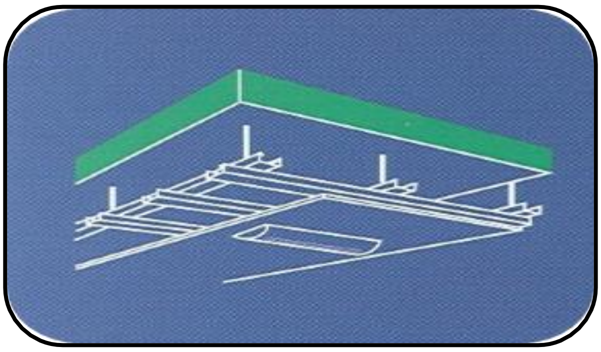


Figure 91 Suspended Ceiling in EQ Zone

Suspended ceilings should always be fastened properly in order to eliminate the risk of objects falling on individuals and causing damage to human life.

c. Recommended Construction Methodologies

i. Prefabricated Structures:

Prefabricated structures, also known as prefab buildings or modular buildings, are constructed using prefabricated components that are manufactured off-site in controlled factory environments and then transported to the construction site for assembly.

By leveraging prefabricated construction methods, communities can build more resilient structures that are better equipped to withstand and recover from disasters, ultimately saving lives and reducing the economic and social impact of catastrophes.

Figure 92 Sample of Prefabricated Structure

Advantages of prefabricated structures:

- Speedy Construction/Less time taking.
- Enhanced Resilience Against Earthquakes.
- Recoverable/ Reusable Post Disaster.

ii. Confined Block Masonry

Confined block masonry, specifically, refers to a variation of masonry where concrete blocks are used as the primary building material for the walls. The blocks are laid in a regular pattern and then surrounded by reinforced concrete elements such as columns, bond beams, or tie columns. These concrete elements are typically reinforced with steel bars to provide additional strength and ductility. It is a cost-effective and practical solution to improve the seismic performance of masonry buildings. It offers an effective way to retrofit existing buildings and construct new ones with improved seismic resilience, ultimately reducing the risk of damage and loss of life during earthquakes.

Figure 93 Steel Reinforcement in Confined Concrete Block Masonry

Advantages of Confined Masonry:

- Confinement Offers Additional Resilience against Earthquake.
- Light Weight Compared to Conventional Bricks.
- Plinth & Lintel Beams provide resistance against lateral movements.

iii. Improved Stone Construction

Improved stone construction involves incorporating specific design principles, materials, and construction techniques tailored to mitigate the risks posed by various natural disasters. This approach should only be adopted for single storied buildings. It mostly involves the use of Timber or wire mesh in stone structures to enhance their resilience and to unify the various structural elements.

Figure 94 Improved Stone Masonry Construction for Mountainous Areas

Advantages of Improved Stone Construction:

- Reinforced with Timber.
- Enhanced Resilience Against Earthquakes.
- Made of Locally Available Materials.

iv. Wooden Construction

This type of Construction employs use of timber as main construction material. Care should be taken in the adoption of this approach to avoid deforestation and adverse effects to the ecosystem. This construction technique can also be used in erecting more stories above an already standing stone structure.

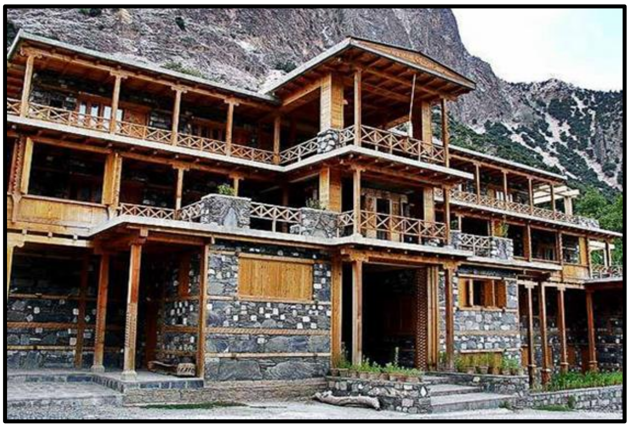


Figure 95 Wooden Construction for Mountainous Areas

Advantages of Wooden Construction:

- Timber offers higher resilience against earthquakes.
- Local manpower is skilled enough to build these structures.
- Utilization of locally available material reduces dependence upon other areas.

Figure 96 Wooden Construction for Hilly Areas

v. Steel Structures/Pre-Engineered Buildings


Figure 97 Sample of Pre-Engineered Buildings

Pre-engineered buildings (PEBs) are structures that are fabricated using standardized components and methods, typically designed, and manufactured off-site by a PEB supplier or manufacturer. These components are then transported to the construction site for assembly, where they are bolted or welded together according to predetermined engineering specifications.

Advantages of Pre-Engineered Buildings:

- Reduced material waste, shorter construction timelines, and lower labour costs.
- Consistent quality and adherence to engineering standards.
- Provide highest resilience against ground shaking due to its ductile nature.

vi. Moment Resisting Frame RCC Construction


Figure 98 Steel Reinforcement for RCC Construction of High-Rise Structure

Moment-resisting reinforced concrete (RCC) frame structures are a common type of structural system used in building construction to resist lateral loads. In moment-resisting frame structures, the columns and beams are designed to provide resistance against bending moments, which are the primary forces generated during lateral loading events.


Figure 99 Steel Reinforcement for RCC Structures High Rise Buildings

However, it is to be kept in consideration that the design of the moment resisting frame should always be in accordance with the building code of Pakistan and coupled with on ground quality control as per standard parameters.

Advantages of Moment Resisting RCC Construction:

- Moment Resisting RCC structure have an inherent stiffness and strength help maintain the structural integrity of the building, reducing the risk of collapse.
- MRFs can dissipate seismic energy through yielding of structural elements, such as beams and columns, thereby minimizing damage.
- MRFs exhibit ductile behavior under extreme loading conditions allowing occupants more time to evacuate safely during a disaster.
- MRFs are often easier and quicker to construct compared to other structural systems, which can be crucial for rapid rebuilding efforts after a disaster.

2. Zone B (Plains)

a. Site Selection

i. **Elevation**
To mitigate flood risk, prioritize areas with higher elevations while steering clear of low-lying regions susceptible to flooding. Selecting elevated sites helps safeguard against potential inundation and water damage.

ii. **Proximity to water bodies**
To minimize flood risk, refrain from constructing near rivers, streams, or other water bodies susceptible to flooding. Avoiding such areas reduces the likelihood of damage from overflow during heavy rainfall or storms.

iii. **Soil Composition**
Assess soil permeability and compaction to determine its ability to absorb water. Avoid areas with clayey or impermeable soils that can exacerbate flooding.

iv. **Infrastructure Design**
Design buildings and infrastructure with flood-resistant materials and elevation techniques. Flood-resistant materials include concrete, metal, and waterproof coatings that can withstand water exposure. Incorporate flood barriers, raised foundations, and flood-proofing measures. Flood-proofing measures involve elevating structures above flood levels, installing flood barriers, and sealing openings to prevent water intrusion, enhancing resilience against flood damage.

v. **Flood Zone Analysis**
Conduct thorough flood zone analysis using historical data and flood maps. Prioritize areas outside of flood zones or with minimal flood risk.

b. Recommended Structures

i. **Flood Plain Zoning**
This is a land management practice aimed at reducing the risk of flooding and minimizing damage to properties and infrastructure in flood-prone areas. Floodplain zoning typically involves regulations and guidelines on

what types of development are allowed in floodplains, as well as construction standards to mitigate flood risk. These measures might include restrictions on building in certain areas, requirements for elevated structures, or mandates for stormwater management systems. By implementing floodplain zoning, communities can better protect lives and property from the impacts of flooding. The advantages of floodplain zoning are as follows.

Advantages of Flood plain Zoning:

- By delineating floodplain areas and implementing zoning regulations, floodplain zoning helps reduce the risk of flood damage to buildings, infrastructure, and natural resources.
- Encourages flood-resistant building practices and land use planning strategies that mitigate the impacts of flooding, such as elevating structures above the base flood elevation, using flood-resistant materials, and preserving natural floodplain functions.
- Promotes the preservation and restoration of natural floodplain ecosystems, such as wetlands, riparian buffers, and flood storage areas. By safeguarding these natural resources, floodplain zoning helps maintain ecological balance, enhance biodiversity, improve water quality, and provide valuable ecosystem services, such as flood control, sediment retention, and habitat support.
- Implementing floodplain zoning regulations may require upfront investments in planning, enforcement, and infrastructure improvements, the long-term benefits outweigh the costs by reducing flood damage, insurance claims, and disaster recovery expenses.

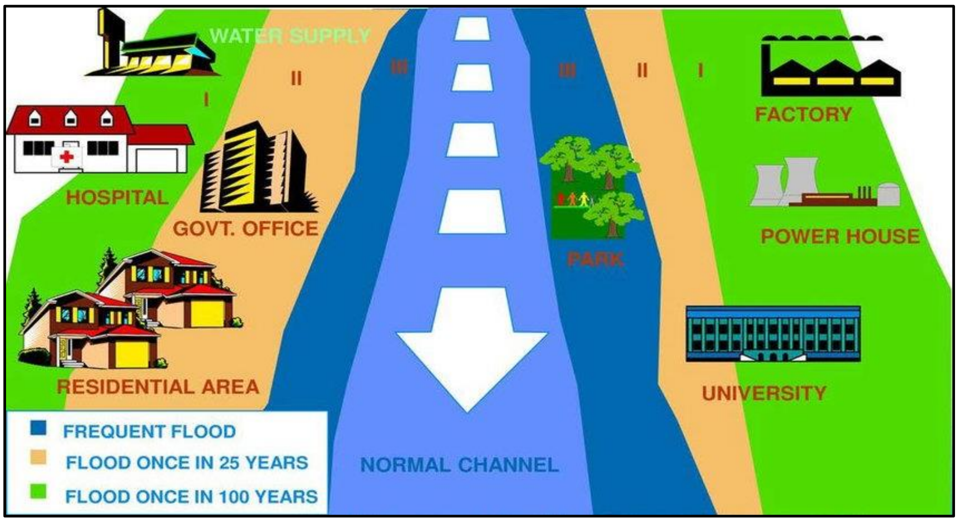


Figure 100 Flood Zoning Pattern

The Flood plain zoning is divided in three zones:
Prohibition Zone are prone to flooding, and should remain of building and encroachment, where this zone aims to safeguard against inundation and preserve natural landscapes.

Restrictive Zone is where there is moderate flood susceptibility and low-cost building with less populated areas however caution should be taken while constructing in these zones due to chances of potential inundation.
Warning Zone which is the least prone to flooding and is allowed to have all activities without any restriction, and there is low risk of inundation which allows for uninhabited development and usage of resources; however, this zone still requires monitoring, preparedness remain crucial to address any unforeseen changes in flood patterns.

ii. **Rainwater Harvesting:**

Rainwater harvesting is the process of collecting, storing, and utilizing rainwater that falls on rooftops, pavements, and other surfaces for various purposes, rather than allowing it to run off into storm drains or waterways. This ancient practice has been used for thousands of years to capture and store rainwater for domestic, agricultural, and industrial use.
Rainwater harvesting can indeed play a significant role in flood management by reducing the volume of stormwater runoff and alleviating pressure on drainage systems during heavy rainfall events.

Advantages of Rainwater Harvesting:

- This technique provides an alternative source of clean water for drinking, cooking, and sanitation, helping to meet the urgent needs of affected populations during disasters.
- Rainwater harvesting systems can provide a decentralized and resilient water supply that is less vulnerable to disruptions, ensuring continuity of water access even in challenging circumstances.

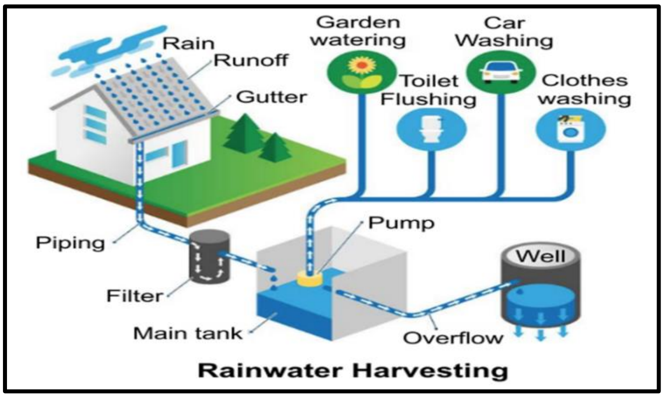


Figure 101 Pictorial view on how the rain harvesting works

- By supplementing traditional water sources with harvested rainwater, disaster-affected communities can reduce their dependence on external aid and alleviate the burden on relief organizations tasked with providing emergency water supplies.
- Rainwater harvesting systems can help mitigate the impact of heavy rainfall by capturing and storing excess water. This reduces the volume of stormwater runoff, minimizes flooding risks, and protects vulnerable communities and infrastructure.
- Rainwater harvesting infrastructure can play a crucial role in supporting recovery and reconstruction efforts. It provides a sustainable and locally available water supply for rebuilding homes,

schools, hospitals, and other essential facilities, facilitating the return to normalcy.

- Helps to reduce the strain on natural water sources and minimize the environmental impact of water extraction during emergencies. By promoting sustainable water management practices, they contribute to long-term environmental resilience and adaptation to climate change.
- Enhances overall resilience by diversifying water sources and reducing vulnerability to water-related hazards. This integrated approach strengthens community resilience and enhances preparedness for future disasters.

iii. Channel Modification:

This technique involves altering the width, depth, alignment, or other characteristics of natural or artificial water channels, such as rivers, streams, canals, or estuaries.

Figure 102 Channel Modification to regulate flow of water

Figure 103 Channel Modification in USA

Advantages of Channel Modification:

- Modifying water channels can help regulate the flow of water and reduce the risk of flooding in downstream areas.
- Channel modifications may involve restoring or creating floodplains adjacent to water channels which can reduce peak flood levels, minimize flood damage, and protect communities located at downstream areas from catastrophic flooding.
- Bank stabilization measures, such as riprap placement and vegetation planting, can help prevent erosion along water channels and protect adjacent land from erosion-related hazards thus enhancing resilience.
- This technique can help to safeguard critical infrastructure, such as roads, bridges, utilities, and buildings, from flood damage.
- Channel modification projects such as dredging and sediment removal can help maintain channel capacity and prevent

sedimentation in waterways thus ensuring efficient water flow, minimize flood risk, and protect downstream areas from sediment-related hazards.

- Waterway channel modification projects contribute to building community resilience by reducing vulnerability to floods, enhancing floodplain management practices, and protecting livelihoods and assets from water-related disasters.

iv. Levees:

Levees are structures built along riverbanks and other waterways to contain and control the flow of water, particularly during floods. Levees are typically constructed using compacted soil, sand, clay, rock, concrete, or a combination of these materials, and they vary in size, shape, and design depending on the specific requirements of the site and the intended purpose of the levee.

Levees are crucial infrastructure for flood mitigation in Pakistan, especially along major rivers like the Indus. These raised embankments act as barriers, confining river channels and preventing overflow onto surrounding land during periods of high-water levels. By containing floodwater within the river channel, levees protect densely populated areas, agricultural land, and critical infrastructure from inundation and damage. In Pakistan, where the annual monsoon season brings heavy rainfall and riverine flooding, well-maintained levees are essential for safeguarding communities and reducing the impact of floods. However, it's vital to ensure that levees are properly designed, constructed, and maintained to withstand extreme flood events and prevent breaches. Integrating levees into comprehensive flood management plans can enhance Pakistan's resilience to flooding, protect livelihoods, and promote sustainable development in flood-prone regions.

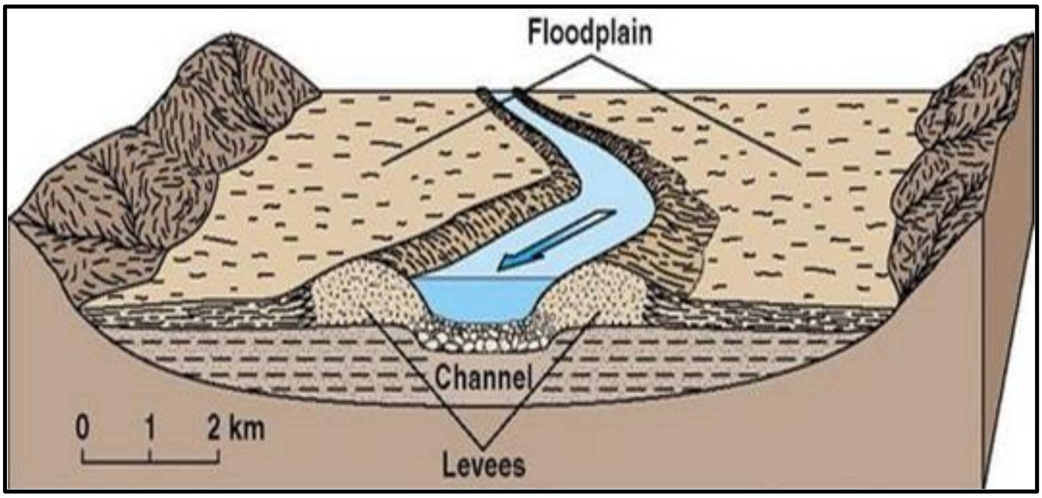


Figure 104 Graphical depiction of Levees in flood plains

v. Rain Garden:

Rain gardens offer a nature-based solution to flood mitigation in Pakistan. These gardens are designed to capture, absorb, and filter stormwater runoff from impervious surfaces like roofs and pavements. By directing rainwater into specially constructed depressions planted with native vegetation, rain gardens help prevent water from overwhelming drainage systems during heavy rains. This reduces the risk of urban flooding and erosion while replenishing groundwater supplies. Additionally, rain gardens enhance biodiversity, support pollinators, and improve air quality in urban areas. In Pakistan, where rapid urbanization and inadequate infrastructure exacerbate flood vulnerabilities, integrating rain gardens into urban planning can mitigate flood risks, enhance green spaces, and promote sustainable water management practices. Embracing rain gardens as part of a comprehensive flood mitigation strategy can bolster Pakistan's resilience to climate change and create more resilient communities.

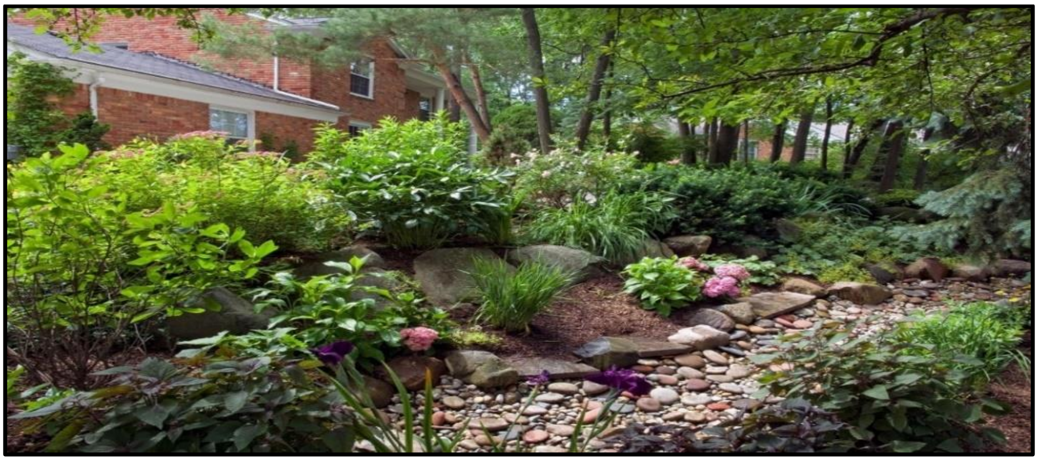


Figure 105 Local rain gardens.

vi. **Detention Basin:**

Detention basins are vital flood mitigation tools for Pakistan's flood-prone regions. These basins temporarily hold and slowly release stormwater, reducing peak flow rates downstream during heavy precipitation. By regulating the flow of water, detention basins prevent flash floods, protect infrastructure, and safeguard lives and property. They also help recharge groundwater aquifers, enhancing water availability during dry periods. In Pakistan, where monsoon rains often lead to devastating floods, strategically locating, and constructing detention basins can mitigate flood risks, particularly in urban areas. By integrating detention basins into comprehensive flood management plans, Pakistan can enhance its

Figure 106 Detention Basins to tackle flood mitigation

resilience to flooding, minimize flood-related losses, and promote sustainable development in vulnerable regions.

vii. **Green Roofs:**

Green roofs, by covering rooftops with vegetation, offer a sustainable flood mitigation solution for Pakistan. These roofs absorb and retain rainwater, reducing stormwater runoff and relieving pressure on drainage systems during heavy rains. By slowing down the flow of water, green roofs help prevent flash floods and minimize soil erosion. Additionally, they provide insulation, reducing energy consumption and urban heat island effects. In Pakistan, where rapid urbanization exacerbates flooding, implementing green roofs on buildings can significantly mitigate flood risks, enhance urban resilience, and contribute to sustainable development efforts. In densely populated cities like Rawalpindi and Lahore, integrating green roofs into urban planning can alleviate flood-related damages, enhance urban green spaces, and improve the overall quality of life for residents. With proper implementation and widespread adoption, green roofs can play a vital role in Pakistan's flood resilience strategy, fostering a more sustainable and resilient future for its cities.

Figure 107 Example of Green Roofs on building.

c. Recommended Construction Methodologies

i. **Distance:**

There should be a minimum distance of 4' between a retaining wall and any adjacent structure. Ideally the distance should be equal to the height of the wall.

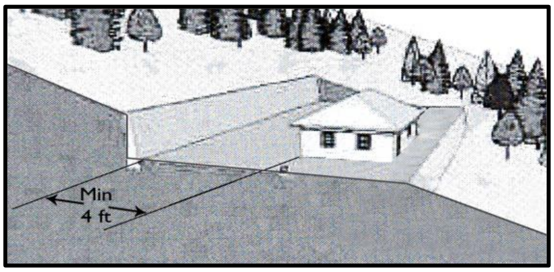


Figure 108 Minimum Distance between retaining wall and building

ii. **Coating Lower End of Bamboo:**

Molten Bitumen, Mobil or sump oil or a combination of these can be used. It extends the life of bamboo post by a couple of years or so. Bamboo column diameter should be at least 4."

Figure 109 Bitumen coating on structural element

iii. Internal Structure Frame:

If floods or precipitation damage the earth's plaster, the framework stops the house from falling. The figure shows an example of Wattle and Daub Method

Figure 110 Wattle and Daub Method

iv. Elevated Bamboo Construction:

Elevated bamboo construction refers to building structures primarily or entirely using bamboo as a construction material and elevating the structure above ground level. This construction method has several benefits, particularly in flood prone areas which includes the adoption of a sustainable approach, quick construction, light weight and flexible construction materials like bamboo which reduce the transportation time and risk and increase resilience to floods.

Figure 111 Elevated houses for flood plains

v. Elevated Plinth Level Construction:

Elevated plinth level construction involves raising the base level of a building above the anticipated flood level in flood-prone areas. It is an effective strategy for protecting buildings and communities in flood-prone areas, providing resilience against flood hazards and promoting sustainable development in vulnerable regions.

Figure 112 Elevated Plinth level helps to prevent flood water intrusion in structure

vi. Adobe Brick House:

These houses are built using bricks composed of a blend of clay, sand, water, and occasionally straw or other organic elements. Adobe bricks are energy and environmentally efficient since they are sun-dried rather than kiln fired.

Figure 113 Sample of Adobe/Mud Brick House

vii. **Modified Mud House:**

Reinforced elevated mud houses can be constructed in flood prone areas. The elevated foundation above the flood plain level minimizes the risk of water intrusion in living area of the house. Reinforcing the foundation with concrete or stone and elevating and installing proper drainage systems can prevent accumulation of water underneath the house.

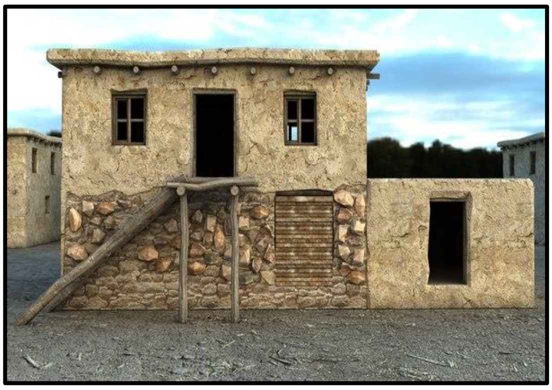


Figure 114 Modified Mud houses for Floodplains

viii. **Precast Concrete:**

Precast concrete enhances flood resilience with its heightened strength and durability, offering flexibility in design and easy installation. Its robust properties provide reliable protection against floodwaters, ensuring long-lasting infrastructure even in challenging conditions.

Figure 115 Grey Structure of Pre-cast concrete

ix. **Confined Masonry:**

Confined masonry structures excel in resisting flood loads, ensuring durability. Their robust construction withstands flood impact, safeguarding against structural damage and maintaining stability amidst inundation, ensuring long-term resilience.

Figure 116 Steel Reinforcement in confined masonry structures

x. **Reinforced Concrete:**

Reinforced Concrete is essential for critical infrastructure like schools, hospitals and government institutions, providing resilience against both earthquake and flood loads. Its sturdy construction ensures structural integrity, safeguarding life and maintaining functionality during natural disasters.

Figure 117 RCC Columns of Building

3. Zone D (Arid and Coastal)

a. Site Selection

i. Location Normalization plans

The first recommendation is to develop location normalization plans. Such plans comprise of demarcating areas as Promotion Areas and Prohibition Areas. In simple terms promotion areas are such areas where development is encouraged by the authorities, these areas are less prone to disaster effects and their infrastructure network is relatively less affected in the event of disasters. On the other hand, Restriction/ Prohibition zones are such areas where only specific type of construction is allowed and are vastly impacted in the case of a disaster event.

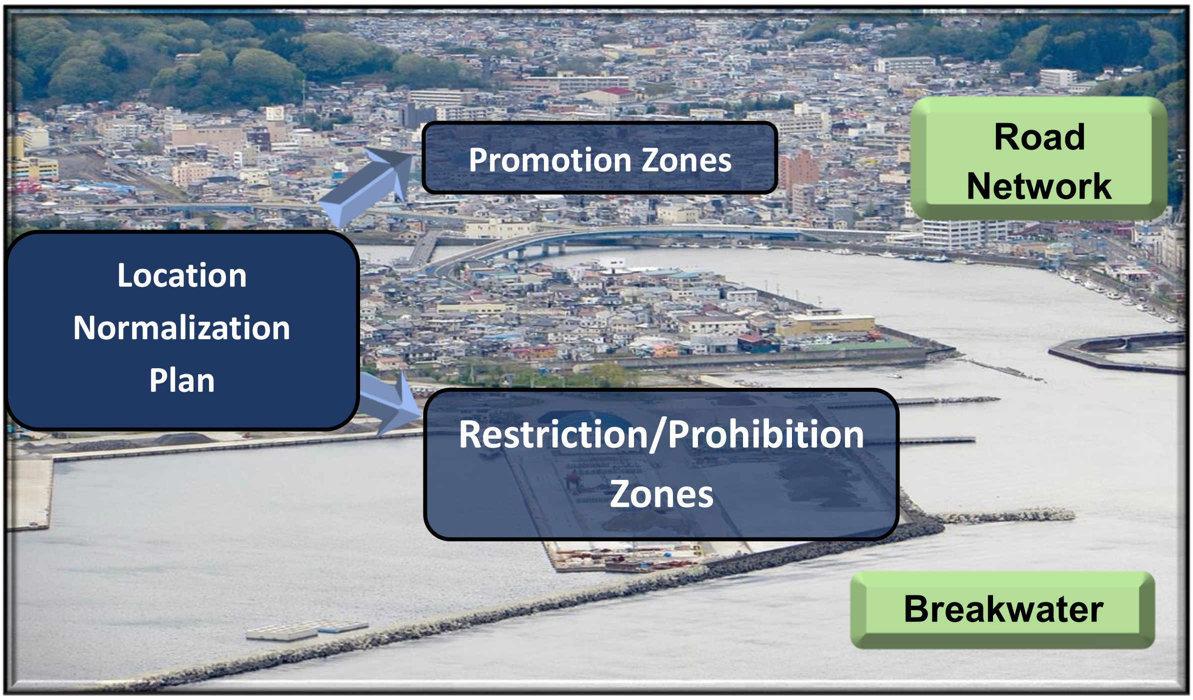


Figure 118 Location Normalization Plan of Miyako, Japan

The image shows Miyako. Japan. The location normalization plan is implemented in which the road infrastructure is raised above ground and breakwater is constructed to break the flow of coming tsunami and coastal flooding. Construction in restricted zones require approval from the higher authorities. Furthermore, the population is restricted from constructing houses here.

The promotion area has the heavy road infrastructure and services to divert the population away from the prohibition areas.

b. Recommended Structures

The following structures are recommended for coastal areas of Pakistan.

i. Upgraded Embankment

The second proposed strategy is the construction of embankments using locally available material, this technique entails certain benefits including waste reduction, sustainable use of materials and effectively catering supply chain issues related to non-local materials. Using this technique can help in tackling flooding risk effectively and prevent erosion in areas adjacent to seas and rivers effectively enhancing the resilience of infrastructure that is prone to flooding.

ii. Sea dikes and Breakwater

The third effective technique is the building of sea dikes and breakwaters that can effectively mitigate the effects of tsunami impact.

Figure 119 Sea Dikes example for defense against coastal flooding

Sea dikes, also known as coastal dikes or levees, are embankments built alongside the coastline to protect them from flooding. Typically, they are constructed using sand, soil, concrete or a combination of these materials. They can be quite effective in protecting adjacent land and infrastructure from damage and erosion. As stated above, Breakwaters are offshore structures that are either built parallel or at such an angle to the coastline which dissipated the maximum energy. They are typically constructed using large rocks, concrete blocks, or other durable materials.

iii. Sulphate Resistant Concrete

Figure 120 Cement Mixture for building

Using sulphate resistant concrete in water structures to reduce the damaging effects of sulphate ions found in soil and water is an effective strategy. These sulfate ions are partially detrimental in Marine Structures like piers, sea walls, docks and other offshore structures. The use of sulphate resistant concrete can lead to longevity, durability and enhanced resilience of Structures.

iv. Galvanized Steel

Figure 121 Galvanized Steel Structure

In such areas the environment is generally humid thus increasing the risk of corrosion in Steel components of a building. Galvanized iron has a protective zinc coating that acts as a barrier between the steel and moisture from the atmosphere. It greatly enhances the durability of steel structures and reduces the maintenance requirements.

Although the upfront cost of Galvanized Iron is greater than Untreated Iron but over the course of its lifetime, its long-term durability contributes to significant cost savings. Furthermore, the protective zinc coating is recyclable and helps in increasing sustainability.

v. Waterproofing coats and membrane

Figure 122 Bitumen coating for water proofing of structures

Another important recommendation that can be used to enhance infrastructure resilience in this zone is the application of waterproof coatings such as bitumen or waterproofing membranes to foundations, retaining walls and sump pits. This helps to eradicate water ingress in concrete structures which is one of the primary causes for damaging of such structures.

Water resistance of Structures can also be enhanced by using water stoppers and swellable bars which prevent the entry of water into structures. Conclusively, the use of such techniques can help in enhancing resilience of structures where water ingress is the primary cause of damage.

vi. Elevated Structures

Figure 123 Elevated Substructure for flood prone areas

In addition to the previously discussed techniques, the adoption of elevated structures in flood prone areas can effectively cater the risk of floods by raising the structural components at a suitable elevation above the flood level. However, it is to be kept in mind that raised structures should be designed in such a manner that they are dynamically resilient and can bear lateral displacements.

vii. Diagonal Bracing

Figure 124 Diagonal Bracing against Wind loads

Providing Diagonal bracing in structures is recommended in areas that are prone to strong winds and hurricanes. Diagonal bracing helps to bind the various components of a building as a single whole and helps in effective load transfer mechanism, increasing the load bearing capacity of structures thus reducing the risk of damages arising in case of strong winds and cyclones. It is a cost-effective solution for enhancing structural stability and its design simplicity can lead to a decrease in costs associated to manpower and materials.

c. Recommended Construction Methodologies

The following construction methodologies are recommended for the coastal areas of Pakistan.

i. Precast Concrete Construction

Precast Construction is a type of Construction in which the various structural elements of a building are produced in a factory or controlled environment. These components are afterwards transported to the site for installation.

Figure 125 Precast Concrete Structure

Advantages of Precast Construction:

- Precast Construction is less time taking as compared to in-situ construction as the ongoing works at site can be carried out parallel to the manufacturing of Precast components in factories.
- As such components are manufactured in a controlled environment it leads to better quality control and conformance to design standards.
- It reduces the costs related to labour that are incurred in the case of onsite construction.
- Precast Concrete is more durable and long lasting because of the production in a conducive environment under optimum conditions.

ii. Improve Adobe Construction

Improved adobe construction requires the addition of cement or lime to act as binding material. It leads to better bonding between the Structural Components thus leading to enhanced resilience. Improved adobe construction is a helpful technique as it only entails a minor additional cost as compared to traditional adobe construction. This type of structure can be easily made even by less skilled manpower thus it is an efficient alternative for rural areas where a shortage of highly skilled manpower persists.

Figure 126 A Mud House at Chanan peer village

Advantages of Improved Adobe Construction:

- Improved adobe Construction is financially a feasible technique as it does not incur major additional costs.
- It only includes some minor changes in the existing methodology of Traditional Adobe Construction, thus eradicating the availability issue of highly skilled workmanship.
- Such type of construction increases the resilience of structures to precipitation, floods and winds.

iii. RCC construction

A detailed discussion of RCC construction has already been done in recommended strategies of Zone A. In addition to the benefits enlisted in that section RCC construction also offers certain advantages that are highly relevant to the risks associated in the zone D which are as follows:

Figure 127 RCC High Rise Grey Structure

Advantages of RCC construction:

- RCC construction offers the benefits of increase in strength.
- High resistance to wind loading makes the structures more resilient in case of tornados and cyclones.
- Durability of structures is increased due to the high resistance to deterioration in a humid environment.
- These buildings can also serve as Evacuation buildings during the occurrence of Disasters.

iv. Block and Brick Masonry

Another important recommended methodology in this regard is the adoption of block and brick masonry in this zone. The block masonry refers to concrete block. Apart from cost effectiveness, these structures impart certain benefits, the details of which are as follows.

Figure 128 Concrete Block Masonry

Advantages of Block and brick masonry:

Figure 129 Brick Masonry Building

- Increase strength and durability.
- Reduced Water Infiltration.
- Enhanced resistance to cyclones and winds.

CHAPTER 4

Aspects for Enhancing Infrastructure Resilience

1. Role of Technology

Technology plays a vital role in enhancing the resilience of structures through various means:

a. Remote Sensing and Monitoring

Drones and other remote sensing technologies, such as satellite photography, offer real-time data on the state of infrastructure before, during and after a disaster. With the use of this information, damage may be quickly identified, impacted regions can be evaluated and prompt action can be taken to stop future degradation or collapse.

b. Predictive Analytics and Modelling

Advanced modeling and predictive analysis techniques can be utilized to identify the prioritized infrastructure retrofitting by identifying weak places or links in the infrastructure systems.

c. Structural Health Monitoring

Sensors can be installed in critical infrastructure such as bridges, dams and buildings to monitor structural health and performance. These sensors should be able to identify approaching failures such as fractures, displacement or deformation and should notify authorities to take required actions in case of such an event.

d. Resilient Materials and Construction Techniques

Research in the field of material science and efficient construction methodologies can lead to development of disaster resilient infrastructure. Techniques such as elevated construction, use of materials such as reinforced concrete and use of techniques such as base isolation can greatly enhance the structural capacity to withstand disasters.

e. Integrated Risk Management Systems

Technology makes it possible to combine several risk management techniques into a unified framework, such as hazard mapping, emergency response planning and recovery plans. Decision-makers may create efficient mitigation and reaction plans by using integrated systems, which provide them with a thorough awareness of risks and vulnerabilities.

f. Community Engagement and Resilience Building

Technology provides venues for education, training, and cooperation, which helps with community participation and resilience building initiatives. Authorities may interact with communities using interactive tools, mobile applications and social media channels. They can also spread knowledge about the hazards of disasters and encourage people to take preventative action to safeguard their property and themselves.

2. Role of Education

Education plays a crucial role in enhancing disaster resilience at individual, community and institutional levels. Education raises people's knowledge of different catastrophic scenarios, their possible effects and the value of preventative actions including assembling emergency supplies, forming family communication plans and being familiar with evacuation routes. People who possess knowledge about the likelihood of disasters are inclined to take proactive measures to get ready for calamities.

Education equips people with the information and abilities needed to react to emergencies successfully. Individuals who complete training programs in first aid, CPR and fundamental firefighting tactics are equipped to help others and themselves in an emergency. Furthermore, emergency personnel who have received specialized training are better equipped to handle complicated crisis scenarios. Social cohesiveness and community involvement are fostered by education and are crucial components of catastrophe resilience. Social networks are strengthened, and collective resilience is increased through educational programs that encourage community engagement in disaster planning, such as neighborhood preparedness groups or community emergency response teams (CERTs).

Critical thinking and problem-solving abilities are developed by education and these abilities are helpful in negotiating unpredictable and quickly evolving crisis scenarios. A higher level of education makes people more capable of identifying hazards, weighing their options and making wise choices under duress, all of which improve disaster response and recovery operations. Education facilitates efficient information exchange between stakeholders in crisis management as well as within communities. People with more education are better equipped to convey their needs and concerns during emergencies, comprehend and interpret emergency signals and warnings, and work with others to coordinate response activities. Education enables individuals, communities and institutions to develop resilience plans and strategies for adapting to changing environmental conditions and emerging disaster risks. Educational programs on climate change adaptation, sustainable development and urban planning empower communities to build resilient infrastructure, protect natural resources and mitigate the impacts of future disasters. Education raises awareness about the psychological impacts of disasters and promotes strategies for coping with stress, trauma and grief.

Individuals are also empowered to advocate for policies and practices that promote disaster resilience.

3. Self Help Practices

Self-help practices are essential for individuals and communities to effectively manage disasters and mitigate their impact. Here are some key self-help practices for disaster management:

a. Emergency Preparedness Kits

Prepare emergency kits containing essential supplies such as food, water, medications, first aid supplies, flashlights, batteries and important documents. Ensure that each household member knows the location of the kits and how to use the items inside.

b. Family Emergency Plan

Develop a family emergency plan that includes evacuation routes, meeting points and communication strategies. Discuss the plan with all household members and practice drills regularly to ensure everyone knows what to do in an emergency.

c. Stay Informed

Stay informed about potential hazards and disasters that could affect your area. Monitor weather forecasts, listen to emergency alerts and follow updates from local authorities through official channels such as radio, TV, social media and emergency notification systems.

d. Learn Basic First Aid and CPR

Take a first aid and CPR training course to learn life-saving skills that can be invaluable during emergencies. Knowing how to administer first aid and perform CPR can help stabilize injured individuals until professional help arrives.

e. Secure Your Home

Take steps to secure your home and minimize damage during disasters. Install smoke detectors, fire extinguishers and carbon monoxide alarms. Anchor heavy furniture, appliances and shelves to prevent them from falling during earthquakes or strong winds.

f. Practice Fire Safety

Implement fire safety measures such as installing smoke alarms, maintaining electrical appliances and keeping flammable materials away from heat sources. Develop a fire escape plan and conduct fire drills with your family.

g. **Build Community Connections**

Get involved in community preparedness initiatives and build connections with neighbors, local organizations, and emergency responders. Collaborate on disaster planning, share resources, and support each other during emergencies.

h. **Create a Communication Plan**

Establish a communication plan with family members, friends, and neighbors to stay in touch during emergencies. Exchange contact information, designate an out-of-area contact person, and agree on alternative communication methods in case regular channels are unavailable.

i. **Evacuation Planning**

Identify evacuation routes and shelters in your area and familiarize yourself with evacuation procedures. Plan for the needs of vulnerable family members, pets, and livestock. Keep a list of essential items to grab quickly if you need to evacuate.

j. **Stay Calm and Flexible**

During a disaster, stay calm and follow your emergency plan. Be prepared to adapt to changing circumstances and make quick decisions based on the information available. Keep a positive attitude and support those around you.

By practicing these self-help measures, individuals and communities can enhance their resilience and ability to respond effectively to disasters, ultimately reducing the impact on lives and property.

4. Multi-Use Materials

Multi-use materials play a significant role in disaster management due to their versatility, adaptability, and ability to address various needs and challenges during emergencies. Here are some key reasons for the importance of multi-use materials in disaster management: multi-use materials can serve multiple purposes, reducing the need for storing and transporting a wide range of specialized items. This enhances resource efficiency and allows for more effective utilization of limited resources, especially in resource-constrained environments or during large-scale disasters.

These materials are inherently flexible and adaptable, making them suitable for diverse applications and scenarios. They can be repurposed or modified on-site to meet specific needs as situations evolve during a disaster response or recovery operation.

They can help optimize space in storage facilities, shelters, and temporary housing arrangements. By consolidating multiple functions into a single item or material, they minimize the storage footprint and maximize the use of available space, which is particularly valuable in crowded or congested environments.

Investing in multi-use materials can yield cost savings over time compared to acquiring specialized equipment or supplies for individual tasks. By eliminating the need for redundant items and streamlining procurement processes, multi-use materials offer a cost-effective solution for disaster management agencies and organizations.

These materials can serve as backup solutions for critical functions or tasks if primary equipment or resources become unavailable or compromised during a disaster.

Examples of multi-use materials in disaster management include tarps that can serve as temporary shelters, blankets that double as emergency sleeping bags, and duct tape that can be used for repairs, medical splints, or makeshift restraints. By harnessing the potential of multi-use materials, disaster management professionals can enhance the effectiveness, efficiency and sustainability of their operations, ultimately improving outcomes for affected populations.

5. Commercial Benefits

Investing in disaster-resilient infrastructure not only enhances community safety and reduces human suffering during disasters but also brings several commercial benefits. Disaster-resilient infrastructure helps businesses maintain continuity of operations during and after disasters. By minimizing damage to critical infrastructure such as utilities, transportation networks and communication systems, businesses experience fewer disruptions and avoid revenue losses associated with downtime.

Figure 130 Pictorial representation on low cost impact

Properties located in areas with disaster-resilient infrastructure are perceived as safer and more desirable by investors, tenants and homeowners. As a result, property values tend to be higher, leading to increased returns on investment for developers, landlords and homeowners. Compliance with building codes and regulations for disaster resilience is increasingly becoming a requirement in many jurisdictions. Businesses that invest in resilient infrastructure not only mitigate risks but also ensure compliance with regulatory standards avoiding penalties and legal liabilities associated with non-compliance partnerships, enabling them to expand operations and pursue growth opportunities.

Overall, the commercial benefits of disaster-resilient infrastructure extend beyond risk reduction to encompass improved business performance, financial stability and long-term sustainability.

6. Disaster Management Infrastructure Material Hub

Pakistan, being prone to various disasters and having a large geographical footprint of 796,096 km sq. suffers from various supply chain disruption during disasters. Infrastructure networks being adversely affected during such events present a problem before us requiring an immediate solution; the supply chain cut off leads to shortage of construction materials in the affected areas and this adversely impacts the reconstruction and rehabilitation efforts and prolong the time span required for recovery of the affected community.

The IA&PD Wing of NDMA recognizing the impacts of this issue has presented a concept of establishing material hubs at different locations in Pakistan with the collaboration of Government and private entities. The various proposed locations for material hubs are shown in the figure below:

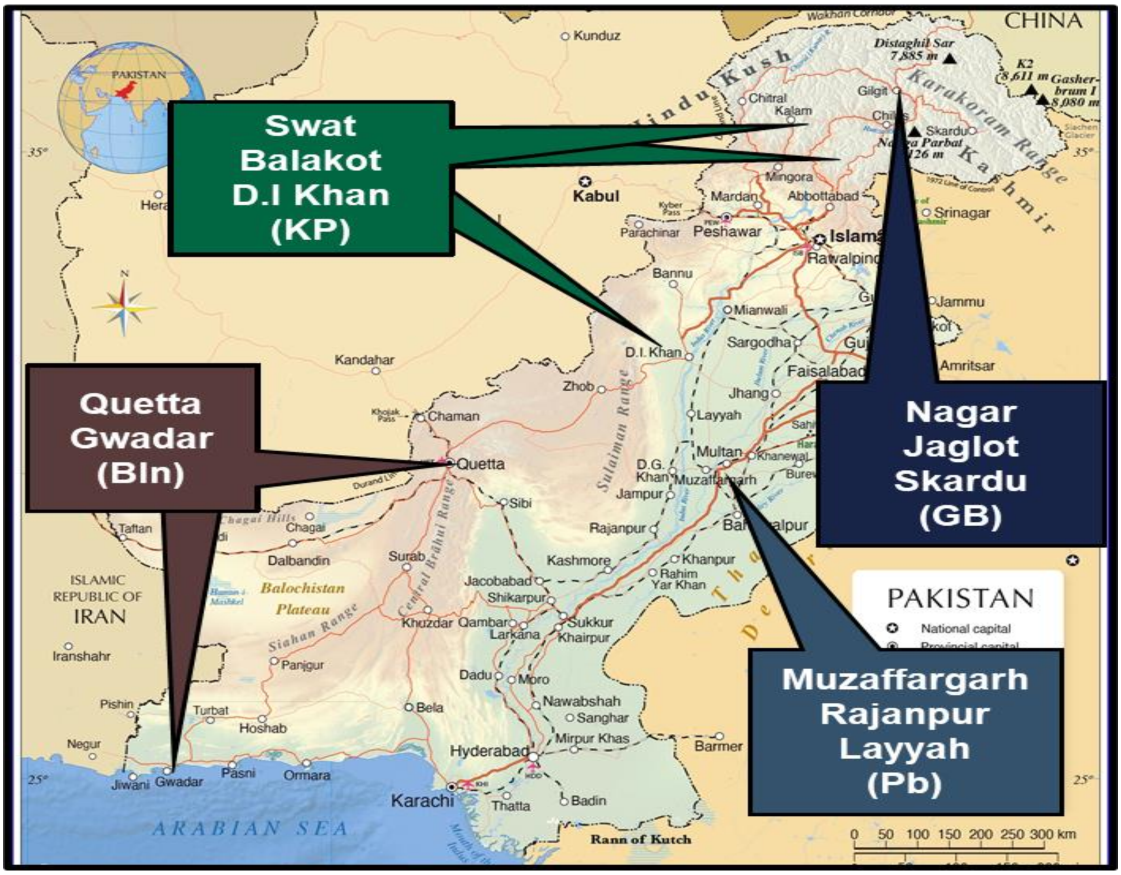


Figure 131 Location marking of tentative material hubs construction in Pakistan

The site selection has been made keeping in view their vicinity to vulnerable areas and maximum area coverage in case of disaster. The core concept is to stock building materials which can expedite the speed of reconstruction even in case of supply chain cutoffs and thus help in minimizing the adverse impacts of disasters.

Furthermore, these structures can be utilized as emergency shelters in the case of a disaster event. In addition to their use as emergency shelters, they can be utilized as training centers during disaster preparedness to train local youth and vulnerable groups about infrastructure weakness, resilience and reconstruction mechanism.

Conclusions

On a conclusive note the adoption of such zone specific strategies in the various disaster zones of Pakistan can lead to enhancement of structural resilience and can significantly reduce the social and economic impacts of disaster.

The adoption of such methodologies and construction strategies is required for the creation of a sustainable resilient infrastructure that is necessary fir the disaster risk reduction.

In addition to this, the creation of resilient infrastructure will have a significant financial impact that will ultimately help to uplift the economic conditions of the country and improve the living standards of the people living in disaster prone areas of Pakistan.

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